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# the winnie bear

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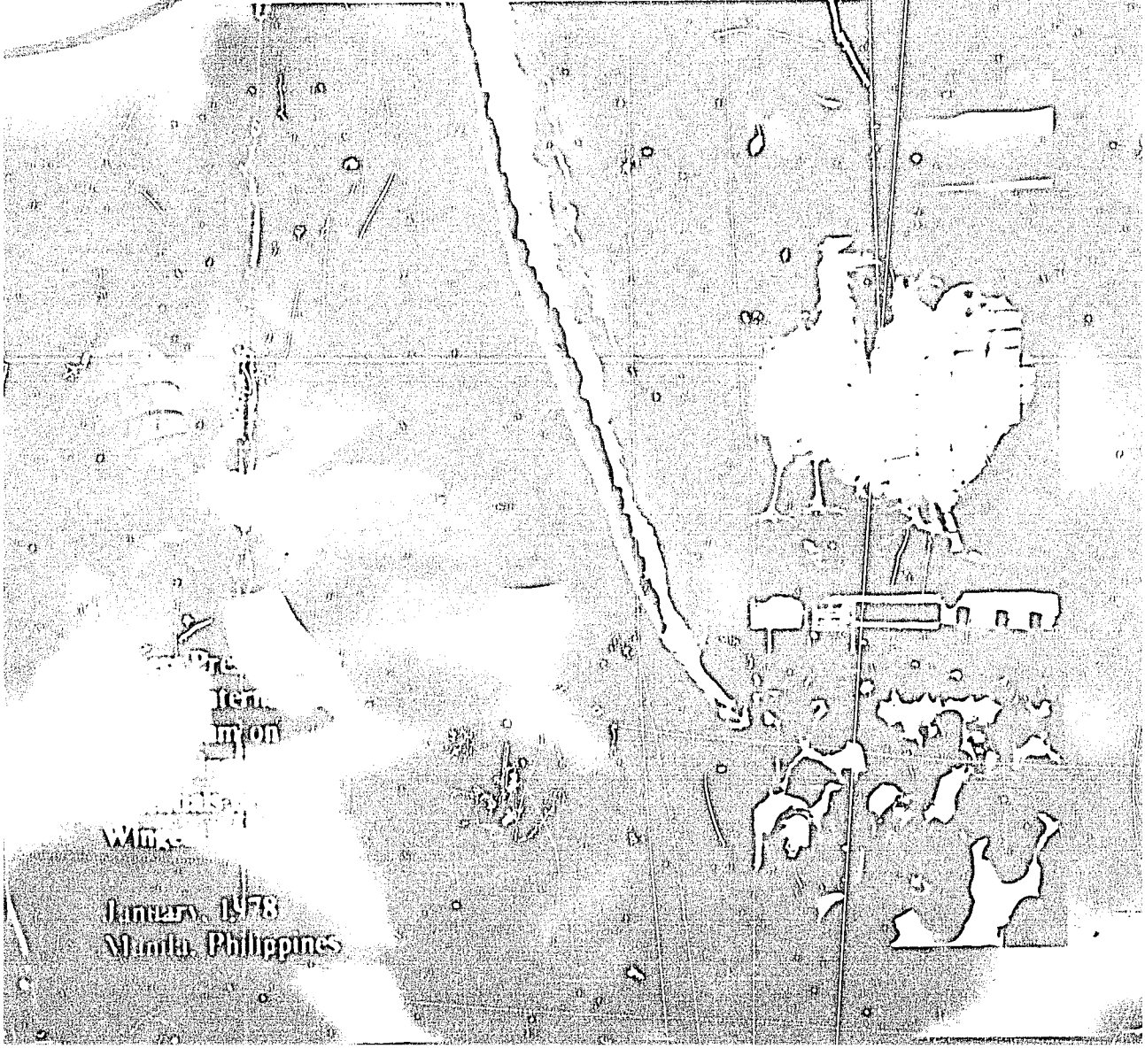

January 1978
Manila, Philippines

# the winged bean

Papers Presented in the
1st International Symposium on
Developing the Potentials
of the Winged Bean

January, 1978,
Manila, Philippines

PHILIPPINE COUNCIL FOR AGRICULTURE AND RESOURCES RESEARCH
Los Baños, Laguna, Philippines

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# Foreword

This volume records the contributions of a widely selected group of scientists who gathered at Los Baños, Laguna, Philippines, in January 1978, to discuss reports on the winged bean. The global conference was partly inspired by reports of the U.S. National Academy of Sciences on the winged bean, an underdeveloped and underutilized plant which is very high in protein.

Two major results of that conference seem noteworthy:

1. For the first time, scientists from different parts of the world compared notes on this bean which suddenly seemed to have gained attention, partly because of its potential as a source of food protein.
2. As a consequence, the process led to the conclusion that an effort of global dimensions should be launched to develop this underutilized bean.

At the end of the conference, as a logical result, a decision was reached to organize the International Council for Development of Underutilized Plants (ICDUP). The winged bean, it was decided, should be the first concern of ICDUP.

Mounting a program to promote the winged bean was going to be the objective of ICDUP.

A little over a year has passed since the first global conference on the winged bean. Mainly because of this only a few developments appear worthwhile mentioning.

New research initiatives are taking place in the Philippines, Thailand, and other countries in Asia and Africa. Commercial interests have started to look into potential markets for this bean. New productive lines of the bean have been identified. A new surge of interest in planting this crop has been triggered!

One conclusion has become apparent so far. The great potential offered by this plant seems to be matched only by the complex problems, biology-or market-related, associated with its development.

The development process has been initiated rather auspiciously for a crop that holds great promise for a hungry world.

J. D. DRILON, JR.
Director General
Philippine Council for Agriculture
and Resources Research
President, ICDUP

# Remarks

I continue to be interested in the development of the winged bean as a crop for assisting in solving world food problems. I draw a parallel between a new crop which we have been trying to develop over the past 14 years — triticale — and the development that you and your organization is undertaking in the case of the winged bean. We all know that it is impossible for any one at the present time to know what percentage of the maximum genetic yield potential has been obtained with any of the important agricultural crops upon which our world depends for food and fiber production. In all probability, in the case of such crops as maize, wheat and rice, we are much closer to the maximum genetic yield potential than in other crops which have had little benefit from intensive research in genetics and plant breeding, plant pathology, entomology and economy. It was, for this reason, that we felt justified in embarking on a research effort toward the development of triticale as a commercial crop. We have had many frustrations during the course of the development of its program and there have been many who have said that this research will probably never result in the development of an important commercial crop species. Nevertheless, we have seen tremendous improvement in grain yield and many other important characteristics such as agronomic characters that are important to farmers, e.g. plant height, straw strength, early maturity and better disease and insect resistance.

Fourteen years ago the best triticales yielded only about 40% of the best wheat varieties when they were grown under Sonora-Mexican conditions, where wheat yields are very high. During the last several years in our experimental plots in Sonora, the best triticales yielded as much or slightly more than the best wheats. There are some areas of the world, especially in problem soils such as the very acid soils of the "*campo cerrado*" in Brazil and the red soil type of Kenya, Tanzania, Ethiopia and East Africa and certain of the acid soils in the Himalayas in Asia, where triticale will outyield the best wheat varieties by at least 50%. Nevertheless, triticale is not yet an important commercial crop but I have hopes that within the next 5 years it will become an important crop in certain areas of the world, especially in problem soils or disease areas where wheat is poorly adapted.

As I reflect on what is happening to triticale and the great difficulty we have had in obtaining support when we launched this program about 15 years ago, I fully understand the difficulties that lie ahead in building the winged bean into an important crop to meet growing needs. I have in a general way, looked through the number of publications that have dealt with a number of crop species that might be useful for expanding food production. Among the species listed it would appear to me with my limited experience in tropical crops, that winged bean should be given the highest priority as a species meriting a serious research effort. I congratulate the Council for initiating this undertaking and I wish you well in your continued work.

Dr. Norman E. Borlaug
International Maize
and Wheat Center (CIMMYT)

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# Workshop Notes

*Noel D. Vietmeyer*[1]

The overwhelming message of this conference was that the winged bean is in good hands and progressing apace. It is impressive that the plant has caught the enthusiasm of so many people. It is also vastly encouraging that the early impressions as sketched in the National Academy of Sciences (NAS) book are so far largely standing up to the scrutiny of the superbly competent group of researchers assembled for this conference. Obviously, the plant has so much to offer the world that its former obscurity is baffling.

In 3 years the winged bean has gathered incredible momentum. Few crops have risen so quickly from total obscurity to the level of prominence exemplified by the papers presented at this conference. The mass of data presented was awesome; it was not the hastily contrived hash of superficial observations often given at such conferences. The larger number of tables, graphs, observations, and measurement data attests to the fact that this work is detailed, dedicated, painstaking, and professional — in short, the type needed to lay the basic science groundwork for the development of a new crop. The scientific data in these papers is of very high quality indeed. If the rate of accumulation of knowledge keeps up this pace, within a few years the winged bean will become one of the best understood of all pulses.

Virtually all of the agronomic and nutritional research needs listed in the 1975 NAS booklet on the winged bean have received at least some attention. Furthermore, the taxonomic survey of the genus *Psophocarpus* recommended in the NAS report is now being undertaken by one of the world's foremost legume taxonomists, Dr. Bernard Verdcourt of the Royal Botanic Gardens at Kew, near London. In addition, a newsletter (also recommended by the NAS panel) is already in existence. Entitled The Winged Bean Flyer, it is currently sent to about 1,000 researchers in over 60 countries. A winged bean grower's handbook for Papua New Guinea farmers has appeared.

In the Philippines, PCARR has developed a national program on the winged bean and the crop is now an officially designated target crop of the Philippine Department of Agriculture. The Government of Indonesia has also formally taken up the winged bean as a priority research crop. In Ghana, the bean is being adopted as a crop for its green pods. These fetch 45¢ per kg, a handsome price in Ghanaian markets. Winged bean pods now also appear in the markets in Western Samoa.

As a result of these activities, the winged bean is now receiving intense, impartial, and independent scrutiny. Yet no one at the conference expressed any doubt that the plant is worth the attention, effort, and funding it is receiving. Conference participants came from more than 20 nations and all had planted and grown the crop. Many of them had been the first to cultivate the plant in their country. Despite all the scrutiny, the sense of the winged bean's promise as expressed in the NAS booklet, seems to have survived and to have been enhanced.

Important advances are being made in laboratories all over the world, and the winged bean is proving a great equalizer because major developments have been reported from all continents and from countries both rich and poor. A great spirit of cooperation and shared excitement pervaded the entire conference.

## THE PLANT

Conference participants learned some new things about the winged bean itself and had some former speculations confirmed.

There is now no doubt that the plant has an extraordinary capacity to nodulate. Individual plants with hundreds of nodules have been observed in several countries. One speaker reported measuring over 20 g of nodules per plant, 777 kg of fresh nodules per ha.This is manyfold the nodulation he reported for peanuts, beans, and cowpeas. We now know that the plant is readily infected by a wide range of Rhizobium strains, and highly effective innocula are available for distribution from Malaysia, Hawaii, Papua New Guinea and Thailand.

[1]U.S. National Academy of Sciences.

The plant can produce exceptional amounts of seed even higher than the most optimistic yields reported by the NAS panel. We now have at least 7 reports of yields of over 2 tons per ha (at least 3 different varieties have topped this figure in Papua New Guinea, and it is now quite usual to exceed 2 tons of seeds per ha in experimental plots there). We have 3 reports of yields of over 3 tons per ha and one record of a yield over 4 tons per ha. (It is interesting to note that some of these — reported by Dr. Khan — were obtained with unstaked bushes, because previously staking was thought to be essential in order to get even a small yield of pods and seeds.) We have learned that tuber production can be much higher than reported by the NAS booklet. Yields of over 11,000 kg per ha have been reported by Dr. Russ Stephenson and his colleagues who measured it by digging up a traditional field in Papua New Guinea village garden. This indicates that these "stone age" farmers know how to grow winged bean for tubers better than researchers.

As a result of the germplasm collections it is clear that the winged bean has a broad and diverse genetic base. There are types with pods, leaves, and flowers of various shapes, sizes, and colors. In addition, there appear to be daylength neutral types, early and late flowering types, fungi resistant types and nonshattering types. Some lines with pods up to 70 cm (over 2 ft) have long been located in Indonesia. Also found recently are lines with light colored seeds (white, cream, or yellow), which may be important for reducing off flavors in processed food products.

From early experience with the available germplasm it seems likely that the crop may eventually be grown in a wider range of environments than the NAS booklet indicated. The world's largest individual fields of winged beans are now in Florida, a subtropical region outside the true tropics, formerly thought to be the plant's limit. Furthermore, it has been grown at altitudes well over 2,000 m. It is now known that the winged bean can be grown as a crop under much less rainfall than previously reported. Moreover, it is proving to grow well under shade and in areas with continual cloud cover.

We now have compositional analyses on many more seeds than in 1974 and they have been measured by researchers working independently in different parts of the world. It is heartening to see that all the seeds contain a high quantity of protein. Amounts ranging from 30 to 42 percent crude protein (dry weight basis) are recorded. It is also encouraging to see that the tubers are uniformly nutritious in protein, averaging 10-12 percent protein fresh weight, sometimes exceeding 20 percent protein on a dry basis. No other root yet measured can match this protein content. Various individuals, including myself, attest to the tastiness of these tubers (at least the ones grown in Papua New Guinea), and Dr. Narong provided the conference with delicious cocktail snacks made from fried and salted winged bean tuber. Although tubers had previously been reported only from Papua New Guinea and Burma, as a result of this conference we now know that they have been produced in areas as diverse as Ghana, Puerto Rico, Thailand, and Malaysia.

We learned that tuber formation is at least partly controlled by genetics, some varieties being more prone to produce tubers than others. Furthermore, we learned that pods are the dominant energy sink, so that tuber formation is enhanced if the flowers are plucked or if flowering is suppressed by genetic or environmental features, or by cultural practices.

One of the most important revelations of the conference was the high protein content of the pods themselves, coupled with high pod productivity. I heard statements referring to pods with around 30 percent protein (dry weight basis), and the production of pods was given at 10-15 tons per ha, sometimes exceeding 20 tons per ha (wet weight). From this it would seem that there is more protein in the pods than in the seeds, and the protein production per hectare is substantial.

I now suspect that the best way to introduce and to initiate winged bean production around the world is through the pods. Growing the plant for pods and getting people to eat them seems easier for the immediate future than producing and marketing seeds or tubers. Although with research slightly more delectable pods may be produced, the current lines already contain varieties that can be intensively promoted for widespread growing as a field crop and garden vegetable, especially outside of Southeast Asia. One point that didn't get much mention, but with which Mr. Karikari, Dr. Senanayake, and the Rubber Research Institute of Malaysia have had considerable success, is the use of winged bean as a cover crop. This is another purpose to which it can be put almost immediately. As Karikari pointed out, some Ghanaian plantation owners are now abandoning *Centrosema* and *Pueraria* species as cover crops for oil and cacao plantations in favor of the winged bean, which supplies the plantation owner and workers with food while producing a very thick carpet that protects and (with its exceptional nodulation) improves the soil.

Perhaps that is inevitable when the work is being done at widely disparate locations. Staking systems developed by Dr. Rachie at IITA and at Centro Internacional de Agricultura Tropical are very promising, as

is the use of other plants to support winged bean. In particular, small leguminous trees like leucaena (*Leucaena leucocephala*), that can be grown in dense stands, seem to offer a cheap, adaptable solution to the staking problem. We learned from Professor Stephenson that planting densities in the order of 125,000-150,000 plants per ha seem to be optimum.

As was predicted by the NAS panel, researchers are now beginning to note the appearance of pests and diseases. Luckily, the only organisms to seriously affect the crop seem to be a couple of fungi. Apart from these (which are so far restricted to Papua New Guinea and Indonesia), the winged bean still seems to be almost trouble-free to grow (though trouble with viruses has been serious in the Ivory Coast).

One of the remarkable disclosures of the conference is the indication that *Psophocarpus palustris* and *Psophocarpus scandens* have highly useful properties too. This opens up whole new lines of research into species that are the winged bean's close relatives.

The conference produced some discussion on the winged bean as a large-scale commercial crop. Some delegates believe that the crop is unlikely to be mass produced until erect, self-standing varieties become available. However, not all the participants were convinced of this, and it was pointed out that in Oregon pole beans are produced on farms up to 25 ha in area. With lower wage rates in most tropical countries, they argued, the winged bean can probably be commercially produced on large scale. Indeed, entrepreneurs in both Thailand and the Philippines are now attempting this and have signed contracts with European feed importers.

## NUTRITION

It is really a major measure of progress that so much detail on the nutritional value of the winged bean was presented at the conference. The plant's botany and some agronomy were known before, but the production of winged bean foodstuffs in laboratories and their use in feeding trials is very new.

I was delighted to see the foods prepared by Dr. Narong, Dr. Prateap, Dr. Ravelli, Dr. Kordylas, Mr. Shurtleff, and others. We saw slides or samples of winged bean prepared in more than 20 different ways, from the very primitive to the most sophisticated. We saw winged bean products steamed, boiled, fried, roasted, fermented, made into milk, tofu (bean curd), and, in some cases, eaten raw. Special food preferences are often a barrier to introducing a new food. Nevertheless, since protein pervades all parts of the winged bean, and since there is a wide range of edible foods into which they can be made, surely the plant can find a role in many different dietary patterns around the world.

Several authors demonstrated that the digestibility of winged bean products is high. Particularly impressive was Dr. Ekpenyong's data showing high digestibility in leaves, pods, flowers, and the other parts of the plant. Dr. Cerny showed that the leaves are extremely rich in vitamin A (over 20,000 international units); this is most important, because in many areas children are blinded through vitamin A deficiency, their productive lives destroyed. There is also tocopherol in winged bean seeds, which enhances even more the effectiveness of the vitamin A present. The rich content of iron is also nutritionally important.

We learned that the tubers have disappointingly poor protein quality, but the amount of protein present, together with the high amount of carbohydrate, make the tuber a wonderous product, nonetheless. Also, there is hope that plant geneticists can discover tuberous varieties richer in sulfur containing amino acids.

In New Ireland (Papua New Guinea), researchers have found farms growing winged bean whose immature seeds are sweet and appetizing. They might prove easier to introduce in some regions than the mature seed as a pulse.

There was considerable discussion of fermented winged bean products. To Westerners they might seem foreign, but there are a number of Americans who think that products like tempeh will soon become acceptable and common foods in the Western world.

I was intrigued by Dr. Cerny's observation that, with the exception of soybeans, none of the eight grain legumes selected for worldwide research by the United Nations Protein Advisory Group (PAG) can rival the winged bean seeds in nutritional value. Had the PAG made its selection a year or two later, the winged bean undoubtedly would have been included.

But to use winged bean seeds in foods, we still have the nagging problem of the hard seed coat. Dr. Franklin Martin of Puerto Rico described a cooking method that uses baking soda and quickly softens the cooking seeds. It may be a godsend.

As far as anti-nutrition factors are concerned, much uncertainty still remains. Actually, most legume seeds are rather nasty in their raw state, and unless first processed, soybeans, lima beans, and many other

pulses are toxic to laboratory animals. Mature winged bean seeds seem not much worse than any of the others.

Uncertainties over nutritional difficulties that might be caused by the behenic acid in winged bean oil seem to be fairly well resolved. This acid is a chemical relative of toxic erucic acid that is in rapeseed oil. But from all contacts, and from comments at the conference, behenic acid appear to be benign and its presence in the oil is not alarming.

A large area yet little explored is the question of industrial processing. An Australian paper by Gillespie and Blagrove seems a little pessimistic on this point, but Dr. Ekpenyong has been able to separate the protein in high yield, though under rather extreme conditions that may have denatured it and made it less useful, at least as human food.

From Dr. Chubb's work it is heartening to note that the winged bean shows promise as an export from the tropics to Europe and Japan as an animal feed.

## AREAS OF UNCERTAINTY

A few random points relating to future endeavors struck me during the conference.

To the best of my knowledge, "winged beaners" still have affected few actual marketplaces. In Papua New Guinea and in Asia, people are still growing the types they have grown before, using the same methods. So far, the research effort hasn't eased the farmer's burden, or increased his yield, or provided him with new winged bean products to improve his income. We have been too deeply involved in illuminating the basic features of the plant. The wealth of data, even if incomplete, must quickly be crystallized in ways that can help the needy. Perhaps the adoption of winged bean as a cover crop in Ghana and Malaysia is an example by which we have brought about an improvement in small farmer welfare. But in the other areas it is time to concentrate on extension work.

We still have not attained the dwarf type plant, although some conference members believe the search for it is unnecessary. I think there is a need for both types. The soybean now helps feed poor people more protein than any other plant species, but it wouldn't be doing so if the Chinese hadn't found the dwarf types. Similarly, there is room in the world today for both vining and self standing varieties of lima beans, tomatoes, and other crops. The discovery of dwarfed winged beans does not mean the demise of the types we have today. It will just help extend the plant's use to larger farms and new areas.

The whole field of animal feed has been ignored in all our thinking. Yet lablab bean, rice bean, moth bean, and some other grain legumes are commonly used as feeds as well as pulses.

Experiments at Kununurra using mechanical harvest reported by Tanveer Khan would have been spectacular had pod shattering not occurred. The search for non shattering types seems to be particularly important.

From all the different designators used to distinguish winged bean lines (TPt, UPS, Chimbu and others), it seems clear that we need a standardized system for organizing the winged bean germplasm so that everyone knows which line he is working with, and so that results from different regions can be more easily compared.

Professor Stern recommended a central germplasm storage facility together with a centralized breeding program to undertake fundamental breeding research. This is not to suggest that national program breeding projects designed to fit winged beans to local needs are to be excluded -- in fact, quite the contrary.

We need to develop better tuber producing types -- ones that will perform predictably, yielding edible tubers of the type I enjoyed in the Papua New Guinea Highlands.

This leads to the thought, often expressed during the conference, that the struggle to produce the all purpose winged bean is likely to end in frustration and failure. What we need are distinct selections and breeding programs for each of the plant's uses: for seeds, edible pods, tubers, edible leaves, ground cover, and forage. What makes the winged bean extraordinary is its ability to produce such wealth of products. This makes for efficient research, advances and failures made in one line of investigation may be crucial to advancing the development of the other uses of the plant.

An important research need is to overcome the abortion of the flowers in an inflorescence. Usually only one flower produces a pod. If the abortion of the others could be overcome we could get bunches of pods from each inflorescence, which possibly would increase yields.

Almost nothing is yet known of postharvest storage of winged bean products and any losses that might occur.

# The Beginnings, A Program For Action And The Future

*Louis Lazaroff*[1]

Historically, and for reasons ranging from the limited amount of nutrients in the soil, the availability of water, and the persistence of high temperatures, man has found it far more difficult to develop the food he needs in the arid and humid tropics than in the more temperate zones. During the years of independence and development following World War II, as population in the tropics and subtropics burgeoned, the threat of widespread hunger and malnutrition has become aggravated. Until recently the potential for meeting these needs within the region has barely been tapped.

Agricultural productivity in the temperate zones has been spurred on by high quality research, increasing that level as a result, ten to twenty fold over the level of a few centuries ago. Until recent decades, little comparable research had been directed to the needs of tropical agriculture.

One aspect of the current effort to increase agricultural productivity in the tropics has been the attempt to develop food and feed crops based on the use of hitherto neglected indigenous plants. A leader in this effort has been the U.S. National Academy of Sciences. In 1974, the Academy convened an ad hoc panel to examine neglected tropical plants that showed promise of being useful to man. Of some 400 promising plants suggested by scientists throughout the world, the panel selected 36 as "crop plants for the future". Of these, the winged bean, *Psophocarpus tetragonolobus* (L.) DC., because of what appeared to be its exceptional merits, was selected for more intensive examination. The results of this examination by a special international panel were brought to the attention of scientists and the international development community in a publication which attracted widespread attention: *The Winged Bean, A High-Protein Crop for the Tropics*.

The panel recommended a research and action program which it hoped would taken up by "philanthropic institutions and international development agencies concerned with the growing problems of food shortage and malnutrition."

This challenge was taken up initially by The Asia Foundation which appointed an international ad hoc steering committee to develop a program on the winged bean and composed, for the most part, of some of the members of the Academy's winged bean panel.[2] After exploring the state of research and interest in a number of countries, the ad hoc committee called for an international workshop/seminar to take stock of what was known, to determine the most important work that must be undertaken in order to expand the technical knowledge base to make firm plans for continuing this work in a coordinated manner so as to avoid duplication of effort, and to make the work done available to farmers, industry, and government so as to increase winged bean production and use.

Because of the shortage of seeds needed for research and in order to prepare for the work to come after the meeting, the steering committee secured the support of The Asia Foundation to produce winged bean seed in quantity and to collect outstanding varieties to be used, after the meeting, in conducting varietal tests in various parts of the world. Following a further recommendation of the National Academy of Sciences' panel, the steering committee also secured the support of The Asia Foundation in inaugurating a semi-annual newsletter of winged bean developments, *The Winged Bean Flyer*. The first three issues of the *Flyer* were produced by the University of Illinois under the direction of steering committee member, Prof. Hymowitz.

The first international Workshop/Seminar on the Development of the Potential of the Winged Bean was held at Los Baños, Laguna, Philippines, from January 9-12, 1978, under the joint sponsorship of the Philip-

[1]Secretary General, International Council for Development of Underutilized Plants.

[2]The members of the ad hoc steering committee on the winged bean were Dr. T. N. Khan (University of Papua New Guinea), Dr. Kenneth O. Rachie (CIAT, Colombia), Dr. Theodore Hymowitz (University of Illinois, U.S.A.), Dr. Noel Vietmeyer (National Academy of Sciences, U.S.A.), and Mr. Louis Lazaroff (The Asia Foundation).

pine Council for Agriculture and Resources (PCARR), the Southeast Asia Center for Graduate Study and Research in Agriculture (SEARCA), and The Asia Foundation. Additional support for the meeting was provided by generous contributions from the U.S. Agency for International Development, the Rockefeller Foundation, the Coca Cola Corp., Castle and Cooke, Inc., the General Foods Corp., and the San Miguel Corp.

Almost 200 researchers from 26 countries on six continents reviewed 47 scientific papers on all aspects of the plant and 18 country reports. These are reproduced in this volume. At the conclusion of the three days of scientific discussions, a Planning Group, composed of participants from each country spent a full day planning future actions. Because of the importance of these decisions to continue collaborative work on the winged bean the action taken on continuation of the program is dealt with separately, below.

At the conclusion of the workshop/seminar and the meeting of the Planning Group, a Public Forum was held in Manila on January 13 and 14 for representatives of industry, government, public and private international agencies, major academic institutions, and the general public. The forum was conducted by 40 scientists who had participated in the workshop/seminar. There were displays of photographs, slides, samples of winged bean varieties, seeds, tubers, processed products and publications, and distribution of seeds of outstanding varieties to participants.

A highlight of the meetings was a dinner at which Dr. Buckminster Fuller, the well known and imaginative engineer, inventor, humanist, and poet spoke to the participants. As a parting gesture, to honor both the winged bean and those who were now prepared to continue to help develop its potential, he presented the group with a poem he had written for the occasion. Dr. Fuller's poem is reproduced in this volume.

## THE ACTION TAKEN

The objectives of the Planning Group which met to lay out plans for continued winged bean work were to:

- Determine priority research needs and recommend sites in new areas for trials of selected winged bean varieties assembled by the steering committee with The Asia Foundation support;
- Make recommendations to national government on research needs;
- Recommend sites for assembling seeds and maintaining germplasm collections;
- Arrange for exchanges of germplasm, and
- Consider identifying a center for collecting and disseminating information on the winged bean, including continued issuance of a newsletter.

The action plan which was agreed upon is potentially one of the most far reaching achievements of the meeting. The scientists assembled, agreed to the establishment of a coordinated international research program on the winged bean. To encourage close identification of research to national needs, early practical application research results to benefit farmers, and to hold costs to a minimum, the group decided to establish a network of scientists throughout the world, prepared to work on the winged bean within their respective countries and institutions, but under an agreed upon set of research priorities. Results would be shared and fed into a small centralized research facility in SEARCA in the Philippines. The research itself, it was agreed, would focus on increasing both knowledge and use, on getting the small farmer to use this neglected legume to improve his nutrition and income, and on introducing it into commercial agriculture at the earliest possible time.

But because the winged bean is but one of a number of comparatively neglected plants with substantial promise of yielding benefit to man, and in order to formalize its proposed action program, the scientists assembled took the further step of establishing a new organization to encourage knowledge and use of underutilized plants for human use. But it was agreed further that for the next three to five years, the new organization would concentrate its efforts on the winged bean. It established the International Council for Development of Underutilized Plants and, under it, an expanded Winged Bean Steering Committee.

The program for which the new Council was to be responsible would include:

— Establishment of germplasm centers — with the primary center to be at the Institute of Plant Breeding, the University of the Philippines; a germplasm subcenter at the University of Papua New Guinea; an intermediate center at the International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria; and long term storage in the National Seed Storage Laboratory at Fort Collins, Colorado;
— A listing of priority areas of research on the winged bean to be conducted at national and international levels, including collection of local germplasm and information on habitats; biology and identification of pests and diseases; methods of cultivation, management procedures, cropping systems, etc.; nutritional preferences and cooking habits; nodulation studies; storage and post-harvest physiology, variety testing, production, economics and marketing; forage, feed and industrial utilization; food technology and human nutrition, etc.;
— A research plan for winged bean plant breeders including breeding objectives, adaptation, basic studies on cytogenetics, genetics of yield and yield related characteristics, pollination agents and isolation distances, breeding methods, etc.);
— International trials of selected varieties of winged bean, the seeds of which had been assembled for this purpose, in countries throughout the world (23 had agreed as the meeting's end), following a manual of standards and procedures which was then completed and distributed; the work to be under the general direction of the Steering Committee's research coordinator, Dr. T. N. Khan;
— Continuation of documentation and information services, including continuation of the semi-annual newsletter, *The Winged Bean Flyer*. The *Flyer* would now be produced at the University of Papua New Guinea under the direction of Dr. R. A. Stephenson, with information and documentation services linked to the Agriculture Information Bank for Asia, in SEARCA; and
— Publication of the papers presented at the workshop-seminar.

In the months following the workshop-seminar the Council has assumed responsibility for encouraging and funding the international winged bean program. It has established an international Board of Directors with representation from the Philippines, India, Ghana, Mexico, Great Britain, and the United States. It has assumed responsibility for the broader Winged Bean Steering Committee which was elected by the workshop-seminar participants and which now includes, in addition to the members of the former ad hoc committee, scientists from Philippines, Thailand, Indonesia and Ghana with additional members from Papua New Guinea and the United States. The Council has been incorporated as an independent, private, non-profit organization with headquarters in California. It has elected its officers and determined that its responsibilities with respect to the winged bean are to encourage its early domestication and commercialization; it has broadened the research strategy, enlarged the number of participants in the variety trials (to 90 trials in some 30 countries), begun to computerize its formation on the winged bean so as to provide, in time, a source of rapid and accurate information on all aspects of the winged bean, and begun to secure the necessary funding for winged bean research and action.

The quality of the presentations at the workshop-seminar, the degree to which knowledge on the winged bean had been pushed beyond the level reported on by the National Academy of Sciences, and the promise of the winged bean is amply borne out by the papers that follow. The action taken by the conference participants to continue the work gives muscle to the Academy's call for sustained effort.

What does not appear elsewhere in this volume but which should at this point is the gratitude of all who participated — to the sponsors for making the meetings possible, to our colleagues for the findings so ably presented, to The Asia Foundation whose vision and financial support in the first instance made the meetings and the action program that flowed from it possible, and to the efficient, hospitable, and generous services of the staffs of both PCARR and SEARCA who transformed the conception of these meetings on the winged bean into an expertly administered reality. We are especially grateful to the Philippine Advisory Committee, the Coordinating Committee, the Planning Committee, the Secretariat, the staff of The Asia Foundation in the Philippines, and, overall, to the assistance of Dr. Joseph C. Madamba, Director General of PCARR, Dr. I. D. Drilon, Jr., Director of SEARCA, Mr. J. Andrews, the Representative of The Asia Foundation in the Philippines, and Dr. Ponciano A. Batugal, Director, International Projects Division, PCARR, for the invaluable assistance before and during the meetings — and not the least, for assuming the responsibility for editing and publishing this volume.

# Overview

- *Variation Ecology and Cultural Practices of the Winged Bean*
- *Ethnobotany and Plant Geography of the Winged Bean*
- *The Winged Bean in the Context of other Underutilized Tropical Food Plants*

# Variation, Ecology and Cultural Practices of the Winged Bean

*T. N. Khan*[1]

**Variation in the winged bean in relation to centre of diversity and centre of origin is discussed, and it is pointed out that Indonesian Archipelago and Papua New Guinea Highlands represent the greatest diversity. The fragmentary information on ecological requirements and cultural practices is reviewed. Potential areas of research are indicated.**

## INTRODUCTION

In less than four years, the winged bean (*Psophocarpus tetragonolobus* (L.) DC) has travelled from almost complete obscurity to much talked about crop almost all over the World. Since the first press release in 1975 in the New York Times (Brody, 1975), the winged bean has appeared in hundreds of newspapers in a variety of languages all over the world. This probably is a unique example of the way in which this tropical plant has caught the imagination of the world looking for the crop resources to meet the global need for protein nutrition. The primary reason behind the potential of this species stems from its extra-ordinary capacity to fix large amounts of nitrogen (Masefield, 1973) and its distribution in a variety of edible plant parts in the form of proteins. Its dry seed compares favorably in protein content with most high protein grain legumes including soyabean; the tubers contain 5 to 8 times greater protein than most other tuber crops grown in the tropics; and the leaves are a good source of protein and Vitamin A and C (Claydon, 1975). Its potential as oil seed crop was recognized as early as 1929 in the Philippines (Agcaoili, 1929). Its green pod is widely used as vegetable in South and South East Asia and some parts of Africa. Flowers and young leaves are edible and may be used in salads. It is grown mainly for its tuberous roots in Burma and Papua New Guinea (Khan *et al.* 1977; Thomson and Sawyer, 1914). The use of dry seed appears to be limited. In Indonesia, seeds are fermented to make tempeh (Sastrapradja and Aminah-Lubis, 1975) and occasionally dry seeds may be parched or fried for consumption (Pursegolve, 1968; Khan *et al.* 1977).

At present, the winged bean appears to be widely distributed throughout South and South East Asia, including mainland China (see Pospisil *et al.* 1971), Papua New Guinea, parts of Africa, the Caribbean, and in some Pacific Islands. In most of Asia, it is considered mainly as a backyard vegetable crop. It is only in Papua New Guinea (Khan *et al.* 1977) and Burma (Thomson and Sawyer, 1914) that it is grown as a field crop for tuber production.

The origin of the winged bean is not clearly understood. Burkill (1906) believed it to have originated in Mauritius, Madagascar or the East Coast of Africa, where the other remaining members of the genus *Psophocarpus* are also found (Masefield, 1973). On linguistic grounds, Burkill (1906) believed that the species was brought to South East Asia during the 17th century and Powell (1974) suggested that it may have reached Papua New Guinea at almost the same time. On the other hand, Ryan (1972) and Hymowitz and Boyd (1977) suggested Papua New Guinea to be the center of origin in view of its antiquity and diversity in that area. The belief of Vavilov (1951) that it originated in India was discounted by Hymowitz and Boyd (1977). Khan (1976) claimed that Papua New Guinea may be the center of the greatest genetic diversity in the winged bean but did not believe that it originated there. However, he indicated the possibility of a longer history of winged bean in Papua New Guinea than that indicated by Powell (1974).

There are only two detailed reports of its cultivation in the literature (Pospisil *et al.* 1971; Khan *et al.* 1977). The report from Burma, although considerably old, appears to still hold at least in parts. Small pieces of information are scattered throughout the literature. This review attempts to synthesize the current status of the knowledge available before the workshop. The use of new information to be presented during the workshop has been intentionally avoided as far as possible.

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## ECOLOGY

It is commonly believed that the winged bean is a crop of the hot and humid tropics (Purseglove, 1968; Rachie and Roberts, 1974). Both these qualifications can,however, be argued against. Masefield (1973) suggested a minimum rainfall for growing winged bean to be 152 cm but that it thrives in 250 cm or greater rainfall conditions. This is supported by a report that it thrives in damper parts of India (Anonymous). Rachie and Roberts (1974) considered that rain in excess of 1,500 mm is necessary to perform well. Thomson and Sawyer (1914) reported that in Burma, it is grown on rich soils under wet conditions in hills. Irrigating winged bean in the plains appears to be a common practice in Burma. In the drier season of Papua, winged bean crop appears to grow normally under irrigated conditions. In the highlands of Papua New Guinea (Khan *et al.* 1977), winged bean is normally grown in the drier parts of year which is in agreement with the recommendation of Purseglove (1968) to grow it in the drier season in Nigeria and Trinidad.

Similarly, the range of temperature conditions also vary greatly. In Malaysia and Papua New Guinea, its cultivation extends from sea level to altitudes up to 1,800 m (Masefield, 1957; Khan *et al.* 1977). In Papua New Guinea, the highland areas appear to be the main winged bean areas and a limited cultivation of this crop has also been reported in areas above 2,400 m. In Asia, the winged bean appears to experience a wide variety of temperature conditions. However, very high temperatures of the sub-tropical mid-summer appear to be detrimental.

The winged bean is basically a short-day plant. Photoperiodic inhibition under long-day conditions of sub-tropical India was recorded as early as 1906 by Burkill. In England, Masefield (1961) found both long-day conditions in summer and lower levels of solar radiation in winter to be inhibitors of flowering. However, flowering in subtropical summer conditions is not altogether unknown, indicating that possibly a narrow range of variation exists in the photoperiodic response.

The winged bean appears to tolerate a variety of soil conditions. In Burma, loamy or sandy soils were considered essential (Thomson and Sawyer, 1914). In the highlands of Papua New Guinea, the range varies from peat soils of swamps in the valley to heavier soils on the mountain ridges (Khan, *et al.* 1977). However, there is almost universal agreement on the intolerance of this crop to water-logging. Free soil drainage is essential (Burkill, 1906; Thomson and Sawyer, 1914; Rachie and Roberts, 1974).

There is no report on the tight requirements, although in view of its distribution, it can be concluded that it tolerates the heavy cloud cover conditions prevalent in the wet tropics. Senanayake and Sumanasinghe (1976) have experimentally shown that shading improves the pod length and consequently the number of seeds per pod.

From the fragmentary information, it can be safely concluded that the winged bean is ideally suited to the equatorial climate. However, there is evidence of genetic variation in response to environmental factors. Greater understanding of this relationship will be needed to define the horizons for the winged bean outside the tropics.

## VARIATION

Systematic attempts on collection and study of variation have been reported from Indonesia and Papua New Guinea (Sastrapradja and Aminah-Lubis, 1975; Khan, 1975; Khan, 1976). Among qualitative characters, the basic pigmentation of the stem is purple and green with green being the most common (Khan, 1976). The two basic flower colors in the PNG material were blue and purple with considerable variations in the color intensity. White flowers on plants bearing very pale blue (Khan, 1976). White-flowered strains are, however, widely distributed throughout Southeast Asia (Cobley, 1956; Herklots, 1972; Sastrapradja and Aminah-Lubis, 1975; Thomson and Sawyer, 1914). There appears to be very little variation in flower size (Sastrapradja and Aminah-Lubis, 1975).

Variation in pod color appears to be limited in Southeast Asia, ranging mainly between pale green and green with rare purple coloration (Sastrapradja and Aminah-Lubis, 1975). On the other hand, a greater diversity of pod color has been reported in Papua New Guinea. The basic background colors are green, pink, pale yellow and purple. In addition, variously colored wing and shade combinations have enabled the identification of 9 types (Khan, 1976). Pod shape as seen in cross section has been classified into rectangular, semi-flat and flat (Sastrapradja and Aminah-Lubis, 1975; Khan, 1976). Among flat pods, the position of suture can be

on the flat faces or the sides. Pod surface was classified as rough and smooth (Khan, 1976). The wings on pods may be undulate, serrate or lobed (Sastrapradja and Aminah Lubis, 1975).

Seed color may be white, cream, yellow, brown or black (Chomchalow, 1976 *a* & *b*; Pospisil, 1971; Sastrapradja and Aminah Lubis, 1975; Thomson and Sawyer, 1914). Khan (1976) reported variations in markings on brown seeds. Chomchalow (1976a) has reported dark green seed color, which appears to be similar to the olive green recognized by the author in Papua New Guinea. However, later studies in PNG showed that olive green is a variation of light brown seed caused by certain environmental conditions. Although seed color has been found to have high heritability (Khan, 1976), environmental variation may often be seen to affect seed color (Khan, 1976; Wong Kai Choo, 1975). Sastrapradja and Aminah Lubis (1975) have reported leaf shape as deltoid, ovoid and lanceolate.

Studies in variation on quantitative characters based on wide genetic base have been reported from the Papua New Guinea (Table 1, Khan, 1976). The range in pod length, number of seeds per pod and seed weight reported from PNG appears to include variations in these characters reported from Southeast Asia (Teng Sin Wu, 1973; Thomson and Sawyer, 1914; Chomchalow, 1976a), with the exception of Indonesia where extraordinary long podded varieties measuring up to 70 cm have been reported (Sastrapradja and Aminah Lubis, 1975). The only reported study on protein content based on a wide gene pool came from Indonesia where the protein content range from 32 to 39% (Sastrapradja and Aminah Lubis, 1975).

**Table 1. Variation in quantitative characters in the original population (or germplasm collection*).**

| Characters | Original Population Number of Plants Studied | Range | Mean | Coefficient of Variation (%) |
|---|---|---|---|---|
| Single leaf area (cm²) | 637 | 19.459 | 178 ± 3.8 | 54 |
| Mean pod length (cm) | 541 | 5.8-26.4 | 15.2 ± 0.2 | 30 |
| Number of seeds/pods | | 3.6-17.3 | 9.4 ± 0.23 | 27 |
| Mean seed weight (mg) | 492 | 62-417 | 224 ± 3.0 | 30 |
| Seed yield per plant (g) | 471 | 0.6-72.0 | 15.7 ± 0.6 | 83 |
| Shelling percentage | – | 9-65 | 41.8 ± 1.0 | 25 |
| Tuber yield per plant (g)[a] | 111 | 1.3-50.3 | 15.9 ± 1.1 | 72 |

[a]Only tuber producing plants were included in estimation of statistical parameters.

*Germplasm data based on 121 pure lines.

The winged bean in Southeast Asia and Papua New Guinea (Sastrapradja and Aminah Lubis, 1975; Khan, 1976a), appears to be predominantly self-pollinated, although bee visitation is commonly seen and a limited amount of out crossing has been reported (Khan *et al.* 1978).

Khan (1976a) considered mutation to be the main source of variation in PNG, although recombination was not ruled out. Genetic studies on qualitative characters such as yield, adaptability, and genetic structure of population have been reported from the PNG (Erskine and Khan, 1977; Khan and Erskine, 1978; Khan *et al.* 1978).

It appears that Indonesia and Papua New Guinea represent the centers of genetic diversity, with the latter perhaps representing the greatest diversity. The Papua New Guinean gene pool, however appears to differ from the South Asian variation by way of having predominantly short podded varieties, unique variation in pod color and an absence of white seeded varieties. Such differences may have evolved through isolation over a considerable time span. The picture of variation presented above is far from complete and such broad conclusions may warrant reconsideration when variation in Asia becomes better known.

## GROUND PREPARATION AND PLANTING

As the plant is mainly grown as a backyard vegetable in most of Asia, little has been reported on the planting methods. In Burma, 2 to 3 plowings were practised. Cattle manure was added, and in the plains the ground was divided in ridges spaced 60 cm broad and 20 to 25 cm high (Thomson and Sawyer, 1914). In Papua New Guinea, land is divided into chocolate block patterns, each block approximately 2.5 m² in area and surrounded by drainage ditches 15 to 20 cm deep.

Seed germination is slow. Teng Sin Wu (1973) from Malaysia suggested scarifying or overnight soaking to improve germination. This practice, however, does not appear to be widely adopted. Seeds are sown at 2 to 3 cm depth in Papua New Guinea and Philippines (Khan *et al.* 1977; Anonymous, 1970), and at a greater depth of 5 cm in Burma (Thomson and Sawyer, 1914).

A variety of plant spacings are employed (Table 2). Generally, crops for tuber production appear to be planted at closer spacings than those intended to produce pods. The data of Pospisil and Cerny (1967-68) on plant spacing and yield is presented after further processing in Fig. 1. As no significance test can be applied, it is difficult to interpret the results at lower plant population. However, a general trend of an increasing yield with higher plant populations is evident. At 17,921 plants per ha with two special arrangements 0.91 x 0.61 and 0.61 x 0.91, the latter arrangement resulted in substantial yield decline. Plant populations in this report are substantially lower than those seen in farmer's field in Papua New Guinea, and further gains in yield may be anticipated at plant populations above those employed in this experiment. The rate of sowing will depend on the plant population. In the Philippines, 5 to 6 kg per ha is recommended (Anonymous, 1970).

**Table 2. Reported recommended plant spacings for the winged bean.**

| Location | Spacing (cm.) | Author |
|---|---|---|
| Burma — Hills | 7.5 15 | Thomson and Sawyer (1914) |
| Plains | 60 × 7.5 15 | Thomson and Sawyer (1914) |
| Ghana | 60 × 60 | Pospisil *et al* (1971) |
| Malaysia | 45 × 45 | Wong Kai Choo (1975) |
| Nigeria | 75 × 20 30 | Rachie (1975) |
| Papua New Guinea | 8-40 | Khan *et al* (1977) |
| Philippines | 100 × 10 | Dep. Agr. Comm., Laguna, (1970) |
| | 200 × 100 | Dep. Agr. Comm., Laguna, (1970) |
| Thailand — Young Pods | 120 × 60 | Chomchalow (1976b) |
| Seeds | 60 × 60 | Chomchalow (1976b) |
| Tubers | 7.5 15 | Chomchalow (1976b) |
| Cover Crop | 100 × 60 | Chomchalow (1976b) |
| — | 120 | Macmillan (1948) |
| — | 120 × 60 | Purseglove (1968) |
| — | 50-75 × 45-60 | Tindall (1968) |

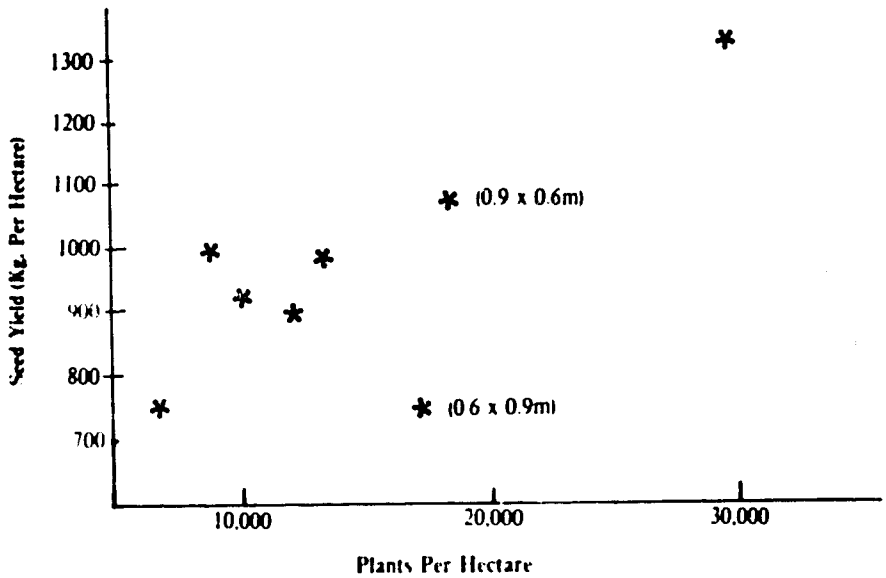


**Fig. 1. Effect of plant spacing on yield.**

In the tropics, with adequate rainfall, the winged bean can be sown any time of the year. More commonly, it is sown at the beginning of the rainy season (Herklots, Thomson and Sawyer, 1914; Sastrapradja and Aminah Lubis, 1975; Chomchalow, 1976a). In Nigeria, in Burmese plains, and in the Papua New Guinea highlands, sowing is done in July (Rachie, 1974; Thomson and Sawyer, 1914; Khan *et al.* 1977). In the Papua New Guinea highlands, drier season but with adequate rainfall is preferred (Khan *et al.* 1977). However, if the crop is to be grown for dry seeds, time of planting will be of critical concern to allow drier conditions during maturity.

## INTERCROPPING AND CROP ROTATION

In Burma and Papua New Guinea, a good proportion of the winged bean is grown in pure stand (Thomson and Sawyer, 1914; Khan *et al.* 1977). However, interplanting of winged bean with maize and a variety of other crops is common in the highlands of Papua New Guinea. In Ghana (Pospisil *et al.* 1971), it is rarely grown in pure stand and intercropping with cereals is commonly practised. There is little available information on rotation. In Papua New Guinea, sweet potato (wet season) — winged bean (dry season) rotation is common. In Burma, paddy winged bean-sugarcane rotation was reported (Thomson and Sawyer, 1914).

## NODULATION AND PLANT NUTRITION

The common belief that winged bean can successfully tolerate poor plant nutritional conditions is likely to have little truth in it. In Burma, rich soils are preferred and cattle manure is added (Thomson and Sawyer, 1914). In the Papua New Guinea highlands, winged bean is often grown on recently cleared land (Khan *et al.* 1977). In Southeast Asia, as a backyard plant it may experience a variety of soil nutrition status. Plant nutritional problems were commonly seen by the author under heavily leached conditions in Port Moresby.

The problem of nitrogen nutrition may, however, be of uncommon occurrence as excellent nodulation appears to occur under a variety of conditions in the tropics (Thomson and Sawyer, 1914; Wong Kai Choo, 1975; Khan *et al.* 1977; Elms, 1976). It appears to be capable of nodulation by strains of *Rhizobium* from many tropical legumes of the cowpea cross-inoculation miscellany. Poor nodulation has, however, been reported from Southern Nigeria (Rachie and Roberts, 1974). Masefield (1957) demonstrated under Malaysian conditions that winged bean excelled all other grain legumes in both weight of nodules and nodule numbers (Table 3). Nodules of the winged bean may range in diameter to 12 mm (Masefield, 1961). Yield of fresh nodules per hectare was estimated to be 770 kg (Masefield, 1973). Thomson and Sawyer (1914) reported an increase of 50% in the yield of sugarcane, following a crop of winged bean in Burma, presumably, as a result of nitrogen enrichment of the soil. No such data is available to show if there is any effect of the winged bean on succeeding sweet potato crop in the PNG highlands.

**Table 3. Nodulation in various legumes of Malaysia (Data from Masefield, 1957).**

| | Mean fresh[1] weight of nodules per plant (g) | Mean number of nodules per plant | Mean plant weight (g) |
|---|---|---|---|
| *Vigna unguiculata* | 3.69 | 60.00 | — |
| *Phaseolus vulgaris* | 0.93 | 113.00 | — |
| *Arachis hypogaea* | 1.03 | 396.0 | 132.9 |
| *Psophocarpus tetragonolobus* | 21.65 | 441.2 | — |
| *Glycine max* | 3.29 | 256.3 | 146.7 |
| *Pachyrhizus erosus* | 0.23 | 1.0 | 42.6 |
| *Pisum sativum* | 0.03 | 16.1 | 7.3 |
| *Phaseolus aureus* | 0.42 | 29.8 | 24.3 |
| *Canvalia gladiata*[2] | 0.01 | 7.2 | 32.9 |
| *Dolichos lablab*[2] | 0.15 | 6.6 | — |
| *Voandzeia subterranea* | 0.13 | 14.17 | 87.6 |

[1]Results of the best sample.
[2]One sample only.

## PLANT SUPPORT

Plant support is normally provided due to the twining habit of the plant. This practice is supported by experimental evidence where a 2.3 to 2.5-fold increase in seed yield was reported as a result of trellising in Nigeria (Rachie, 1974). In the dry lowlands of the PNG under irrigated conditions, an even greater increase of 4.6-fold ($P < 0.001$) was obtained (Khan and Blackburn, unpublished results). This increase in yield was associated with a greater number of pods in the supported treatment. Significantly, both the above reports suggest an increasing response to plant support with decreasing yield levels. Similar studies are not available on tuber yield but the report from Burma (Thomson and Sawyer, 1914) suggests that the harmful effect of not supporting the tuber crop in the plains either didn't occur or was not recognized.

A variety of plant supports are provided in the backyard gardening and often, the winged bean is allowed to trail against the wall (Herklots, 1972; Anonymous). Stakes made of local available materials are commonly used (Khan, *et al.* 1977; Thomson and Sawyer, 1914). In the hills in Burma, seeds are often planted around tree stumps (Thomson and Sawyer, 1914). In the PNG, stakes of "pit pit" stems (*Saccharum* spp.) 2 to 3 m high are used on plants intended to produce beans. In tuber crops, smaller stakes 1 to 1.5 m are employed (Khan *et al.* 1977).

## PRUNING

Pruning of reproductive parts to encourage tuber formation has only been reported from the PNG (Khan *et al.* 1977). Flowers, young shoots, and pods are periodically removed from plants cultivated for tubers. A few pods are left to provide seed for the next planting. Some Southeast Asian and West African varieties produce abundant tubers without any pruning (Rachie, 1974; Wong Kai Choo, 1975; Thomson and Sawyer, 1914; NAS, 1975). However, high tuber yields similar to those in the PNG highlands have not been reported anywhere. The data of Wong Kai Choo (1975) from Malaysia shows a more than two-fold increase in tuber yield from crops grown for green pods over crops grown for dry seed. In view of this, response to pruning in Southeast Asian varieties warrants closer examination.

## PESTS AND DISEASES

Pospisil *et al.* (1971) reported that caterpillars, grasshoppers, and spider mites are the main pests in Ghana. In addition, *Maruca testulalis*, ladybird (*Henosepilachna signatispennis*), *Aphis craccivora* and an unidentified leaf miner have been reported from the PNG (Khan, 1975). The root-knot nematode (*Meloidogyne incognita* Chitwood) may cause severe damage in the PNG (Khan *et al.* 1977). Among diseases, false rust (*Synchytrium psophocarpi* (Rae) Gaumann) appears to be the most widespread and potentially damaging (Pospisil *et al.* 1971; Sastrapradja and Aminah Lubis, 1975; Khan *et al.* 1977). Leaf spot caused by *Cercospora psophocarpi* (*Pseudocospora psophocarpi* = *Cercospora aranaetae*) appears to be the other most widely distributed disease (Borlaza and Roldan, 1964; Khan, unpublished). Other disease problems identified in the PNG are powdery mildew caused by *Erysiphe* spp. (Price, 1977), collar rots, wilts and little-leaf disease.

## HARVESTING

The time of harvesting will depend on the edible plant part desired. Green pods are normally produced at 10 to 13 weeks after planting (Wong Kai Choo, 1975; Khan *et al.* 1977; Tindall, 1968; Chomchalow, 1976b). On the other hand, Teng Sin Wu (1973) from Malaysia reports that under favorable conditions, pods may be ready as early as 6 weeks. Maximum length of pod is reached in 14 to 20 days (Senanayake and Sumansinghe, 1976; Pospisil *et al.* 1971). Wong Kai Choo (1975) found that 98% pods are produced within 10 weeks after the commencement of flowering. In Southeast Asia, pods are picked when 1/2 to 2/3 grown (Herklots, 1972), (Anonymous, 1970) to avoid stringiness and to obtain best flavor. In the PNG, pods may be allowed to reach their full length, and as the flesh inside the pod and green seeds are consumed, stringiness is tolerated.

In the PNG highlands, tuber crops are ready for harvest in 4 to 5 months (Khan *et al.* 1977), whereas in Burma and Malaysia, it may take 7 to 8 months (Thomson and Sawyer, 1914; Wong Kai Choo, 1975).

Pospisil *et al* (1971) reported that tuber crop is ready 2 months after fertilization. In Burma on hard soils, water was let on to facilitate the digging of tubers (Thomson and Sawyer, 1914). It is the belief that root tubers can be partially stored in the ground (Rachie and Roberts, 1974).

Pod-splitting and seed-shattering is common in the winged bean and therefore, dry pods have to be picked regularly. Wong Kai Choo (1975) reported that harvesting of dry pods was started after 19 weeks and continued for 5 weeks to recover 98% seeds. In the PNG, earlier maturing varieties occur but periodic picking over 3 to 4 weeks is still required.

## YIELD

Yield of green pods from a six month crop was reported to be 4,980 kg/ha (Wong Kai Choo, 1975). Burkill (1906) reported tuber yields in Burma ranging from 4,805 to 6,037 kg/ha and higher, depending upon the districts. In the PNG highlands, a comparable, though a higher range of 5,533 to 11,754 kg/ha has been reported. In Malaysia, experimental root tuber yields varied at 2,246 kg/ha and 4,980 kg/ha from crops grown for dry seed and green pod production, respectively.

From a modest experimental seed yield of 570 kg/ha reported by Pospisil *et al* (1971), yield figures from widely different situations in the world are now available at 2,426 kg/ha from Nigeria (Rachie, 1974), 2,200 kg/ha from PNG (Khan and Erskine, 1978), and 4,590 kg/ha from Malaysia (Wong Kai Choo, 1975). Genotype x environment studies in the PNG showed environment to be the predominant factor influencing yield, and selection of site and management may be crucial in achieving high yields.

No yield figures are available on flower and young shoots and as these yields are likely to be antagonistic to seed production, it is difficult to assess the total value of the crop. Perhaps the most impressive figures on overall production are those from Malaysia (Wong Kai Choo, 1975). From the same crop 4,590 kg seed of dry seed and 2,246 kg of fresh tubers per hectare were obtained. Assuming 35% protein in seed and 8% in the fresh tubers, this represents a per hectare protein yield of 1,786 kg. Protein yield from the winged bean tuber crop of the PNG highlands has been reported to excel in several folds the protein yield from the traditional staple crop, the sweet potato (Khan *et al.* 1977).

## ECONOMICS AND MARKETING

It is safe to assume that this crop does not enter into active economy anywhere in the world. In Burma, there is a lively demand for roots and it is a trade commodity at the rural level (Thomson and Sawyer, 1914). In the PNG, cooked roots and green parts are sold in the local market (Khan *et al.* 1977).

The gross value of a one hectare tuber crop in the PNG highlands has been reported to vary between US$1,300 to 4,000 (Khan *et al.* 1977). On the other hand, "net" profit from a similar crop in Burma was reported to be US$6 (approximately) by Thomson and Sawyer (1914). In view of the time difference between these two reports, it is not proper to make comparisons. Good seeds for planting appear to be in much demand in most places and may fetch a handsome price.

## CONCLUSION

The information reviewed here should provide the basis for planning a future strategy. However, it is hastily pointed out that at this stage of rapid extension and development of this species, it is necessary to take urgent steps to record the existing practices and beliefs of the people who traditionally grow winged bean even as a backyard or minor crop. This kind of information is lacking from most of Asia. The report of Thomson and Sawyer (1914) from Burma needs reviewing to include modern developments. Such work may be of considerable value in strengthening our understanding of the research needs for the future.

It is apparent that genotypes x spacing is an area for immediate investigation. These experiments may also be extended to study the interaction of genotype x spacing x trellising vs not trellising, with a view of further exploring the possibility of growing the winged bean without support, at least as tuber crop. There is an urgent need to study the soil nutritional requirements and these experiments may possibly be integrated with the long term rotation trials and with the field studies in nodulation and nitrogen fixation. These studies will need to be done in several environments, and treatments in each location may therefore vary. The area of considerable significance is the establishment and early growth. There is a need to know more about the

growth and development of a range of varieties both tuber and non tuber forming. Studies in variation in flowering are necessary to extend its horizon to the subtropics and mediterranean summer conditions. Also, relationships between photoperiod sensitivity and tuber yield is of considerable interest.

Agronomic studies in the winged bean may be complicated by the multiplicity of the edible plant parts, and the antagonism between various products such as dry seed and tuber. The aim of the experiment may therefore need careful definition, and in view of the work done by Wong Kai Choo (1975), perhaps the winged bean may be looked upon either as vegetble crop or dry seed crop. As a vegetable it offers the compatibility of half grown green pod removal with the tuber growth.

The winged bean has often been described as being relatively free of pests (Rachie and Roberts, 1974). However, the experience of handling it experimentally on a large scale suggests that the potential threat of pest and disease damage is indeed very great. At this stage with limited variability at hand, it may not be feasible to control these calamities through breeding. However, greater research into epidemiology in relation to cultural practices including rotation, intercropping and selecting the growing season may be of immediate application.

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# Ethnobotany and Plant Geography of the Winged Bean

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**The paper considers some aspects of the cultivation of the winged bean in two separate areas of the highland region of Papua New Guinea, Mount Hagen in the Western Highlands Province and Pangia in the Southern Highlands. It draws on information from an earlier paper by the author (1976) and adds additional field data. The main point of the paper is to draw attention to differences in the importance of the winged bean in the two areas and to seek an explanation for the differences. In Pangia, growth of the winged bean is on the decline, whereas in Mount Hagen it continues to be a very popular luxury and cash crop. Access to market outlets, cultural beliefs and practices and the actual utilization of the winged bean plant are all reviewed. The ethnoclassifications of winged bean varieties in the two areas are also considered. Finally, the paper points briefly to the fact that available evidence suggests that the Pangia area is most likely to have nutritional problems and encourages extension officers to grow winged beans.**

## INTRODUCTION

Agricultural scientists working at the University of Papua New Guinea during the 1970s realized the significance, for future nutritional policies, of the established indigenous crop known as winged bean, *Psophocarpus tetragonolobus*. Anthropologists, in their turn, had often written briefly about this crop in the course of describing general horticultural practices in their fieldwork areas, but without, perhaps realizing its nutritional importance as a supplier of protein for populations among whom the consumption of meat is a luxury rather than an everyday expectation. The author's observations and discussions of the crop have been made in two different parts of the Highlands region of Papua New Guinea; and the point of this paper, in addition to presenting some information on ethnoclassification and cultivation practices, is to note the different degree of elaboration in the use of the plant in these two areas, correlating this difference with the extent to which cultivation of the plant is still popular or otherwise. The implications for agricultural extension work are then briefly outlined.

The two areas are Mount Hagen in the Western Highlands Province and Pangia in the Southern Highlands. Fieldwork in these areas has been carried out, from time to time, since 1964, continuing up to 1978. The most intensive work has been done in Mount Hagen. Observations on the winged bean have regrettably formed only a very minor part of the research, which has today been concerned mostly with the analysis of social structure, leadership, and political and economic change. An earlier article (A. J. Strathern 1976) summarized information about the winged bean then available. The present article repeats a part of that information, but draws also on investigations made during December 1977. For general publications on the two areas see A. J. Strathern (1971, 1972). The most relevant points concerning society in these two areas are that the people are in general skilled horticulturalists, growing a wide variety of vegetable crops with an accent on the sweet potato as a staple and raising considerable herds of pigs for slaughter on festive occasions; that the division of labor is primarily sexual and a great deal of the daily mundane labor-input into gardening and the preparation of food for consumption falls upon women in their capacity as wives and mothers; and that the people are divided into a complex series of groups, ideologically patrilineal, within which men act as the primary landholders and between which exchanges of goods and resources, activated through intermarriage, are of prime importance.

## MOUNT HAGEN AREA

The Mount Hagen area has a population of 100,000, the majority of whom speak Melpa, or the related Temboka language which predominates south of Mount Hagen township, lying at the western end of the Wahgi Valley. The two languages are closely similar, and may indeed be classified as divergent dialects of a single language, and those who speak one are readily understood by the other. The modern township is at

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an altitude of c. 5,600' a.s.l., situated on the Ogelbeng Plain, which has expanses of rich brown soil, partially covered by growths of fallow trees and small remnants of primary forest. Swampier, low lying parts are also found, obscured by dense stands of canegrass. The Nebilyer Valley, which opens out to the south-west of the township, contains rolling stretches of woods and grassland descending to c 4,500' a.s.l. at its southern end, where it meets the flow of the Kaugel river. The Kaugel rises to the west, at the much higher altitude of 7,000' a.s.l., within the Tambul district. Winged beans are grown most extensively in the Nebilyer and immediately around the township throughout the Ogelbeng Plain, but one also finds patches of them right up to 7,000', the highest altitude of regular cultivation. It is recognized by people in more mountainous territories that the home of the winged bean is the flatter valley, where soils are easily worked and the climate is warmer. Production of winged bean has also undoubtedly been stimulated in recent years by the establishment of a town based market for the immediate sale of vegetables. Mount Hagen, as an administrative and minor industrial centre, has grown rapidly to accommodate a population of 10,000 people, mostly indigenous Papua New Guineans, and sales of food are brisk, the market operating every day and visited by passenger carrying trucks from a radius of 20 or 30 miles around. Winged beans and their tubers are regarded as luxuries by fellow Highlanders and are a very popular item at the main market, as well as at the subsidiary markets which have also sprung up at places near to government stations, churches, and commercial plantations. The knowledge that the crop can conveniently be marketed is undoubtedly a stimulus to its continued cultivation. It is interesting to note that its sale, like the sale of the vast bulk of vegetables at these markets, is conducted by women, who thereby gain a minor income, which they may either retain for purchases of store goods or contribute towards men's enterprises in ceremonial exchange or in vehicle purchases.

Mount Hagen was first discovered and explored by Europeans in the early 1930s. It therefore has now a reasonably long history of contact, has experienced considerable economic development in terms of wage employment on plantations and of indigenous-based cultivation of coffee for cash, and possesses a network of roads linked to the main highways.

## PANGIA AREA

In the Pangia area, which lies south of Mount Ialibu some 90 miles from Mount Hagen, the history of contact is much shorter. The Pangia station was opened only in 1962, and remains small, housing only those who work for the government. There is a prison nearby, and stations of the Catholic, Lutheran, Bible and Wesleyan missions. On Saturdays a small market is held near the local government buildings at the end of the station with most of the produce being carried in on foot. Coffee growing and cattle schemes were begun in 1967 and now bring in income. Rainfall here is much higher than in Hagen (up to 250" p.a. as against c. 100" p.a.), so that both transport and garden work present more problems. Since 1974 subsidiary markets have grown up, as in Hagen, at sub-centres of government activity, and people mostly sell to others of their own area however, the numbers of external buyers are very small. It is evident that cash incomes in Pangia are smaller per annum than in Hagen, and there is therefore less cash to spend on luxury foods in the market. Winged beans are, however, an important traditional crop, utilized in exchanges, between in-laws, and since such exchanges continue and are normally upheld nowadays, one might have expected that winged bean cultivation would continue to flourish, but it does not. A closer examination of cultivation practices in the two areas will be necessary before it can be said whether this pattern of decline in Pangia, as against the crop's popularity in Hagen, is simply a result of the less favourable economic situation in the former area.

## CULTIVATION PRACTICES

The outstanding feature of the winged bean plant is that it produces edible leaves, flowers, pods, and tubers, each part high in protein value. However, if cultivators desire the tubers to form, they must pluck the flowers early so as to prevent the pods from forming. This is a standard practice with certain varieties in Hagen. As one informant (Ongka, a big-man or leader) put it:

> "When they wish to obtain the bean pods (*aklmongi*) they take the dried bean seeds and plant them in the mixed vegetable gardens cut from woody fallow (*pana*). When they want the tubers to develop, they plant the seeds in the ground used for sweet potatoes before digging up the ground and turning it continuously until it is soft (*noropul ropa morom*) to enable tubers grow in it. If they have planted it to obtain the pods, then they allow the flowers and the leaves

to remain; if they want to get the tubers, they pluck off the flowers and leaves at the top, allowing the leaves to remain in the middle only. It is only if we take off the flowers (*tkombo*) regularly that the roots will grow larger, for if not, all the juice goes into the pods and forms the *aklmong*. The roots we call the *at* or *ate*, that is the *pat* tuber itself. We plant when the fruit *pandanus* is about to form and harvest it when we eat the *pandanus* (in December and January). When we plant in the *panz*, we put the bean seeds in first, then the other foods, and in December we eat the greens and cucumbers and the *pat* are ready following that."

A middle-aged woman, Rambe, gave a parallel description. Her mother, was from an area nearer to Hagen town, where the winged bean is grown frequently, so that she had a good knowledge of it:

"We call the garden for these tubers the *pat raka*. We make it when a sweet potato garden is finished. Then we shake out the earth and make it very crumbly and fine. The women do this work, and the men dig trenches so as to form the seed beds [in the same way as is done for sweet potato cultivation]. The women then make the holes and place in these seeds. When the plants begin to grow, women again ask the men to cut stakes (*kwipai*) for them and they do so, placing one stake in between two plants, so that each reaches for the stake and grows up on it, turning round the other, as we say *op kan pat kan*, 'twined round like yam or winged bean tendrils,' or a husband and wife pair who argue but stay together. We wait until the leaves are dry and they are withered, then we know that the tubers are ready underneath the ground. So the women dig them up and we steam cook them in the earth ovens, and we distribute them among ourselves and also take them to the market to get money. We make the *pat raka* when the cicada (*kint walwa*) comes out into the sweet potato gardens in the mornings to make his cries, and we plant it when the cicada retires into the forest and sings further away from home."

Ongka's account makes explicit the management of the plot itself to obtain its produce; Rambe's is more explicit about the division of labour between men and women. It is apparent that it is a women's crop in a sense, because they actually plant and harvest it. But men are associated with the work and with cooking tubers or the beans in the steam ovens, and when a distribution is made they are the ones who tend formally to hand out the bundles of tubers for each person. Nevertheless, one frequently hears of a woman that "she is cooking *pat*", implying that the crop is in a sense hers. It will be noted that the tubers are grown in soft ground also for sweet potatoes, for which women have the prime responsibility. As noted in an earlier article, if a man other than a woman's husband helps her by staking up her plants, he expects to receive a special portion of the crop later (A. J. Strathern 1976:146). More work of this kind is involved in valley areas, where the proportion of winged beans to other crops may approach the 1/5 figure suggested by Khan, Bohn and Stephenson (1977). At higher altitudes the proportion is likely to be 1/10 or less, and the crop takes longer to mature, as does the sweet potato itself.

Practically every woman in *Kawelka Kundmbo*, where the author lives had planted *pat* in 1977, although Rambe complained that hers had not grown well. Nine women, married to a father, two of his grown-up sons, and a brother's son, had all planted together in a single sweet-potato garden site by a river about half a mile away from their home settlements. Rambe herself had planted (and already by December 25th harvested) along with five other women at another well-known garden site. At a further settlement nine women, again married either to a senior man or to his sons, had also planted together in a single garden near to their consolidated settlements. The practice of grouping plots together in this way therefore appears to be standard, and is not doubt related to perception of soil quality, and possibly also to the practice of growing a strong smelling plant around the edges of plots in order to keep away 'snakes' (wireworm/caterpillars?) which may attack and spoil the winged bean itself. This pest is more prevalent in hilly areas such *Kundmbo* occupy.

## SUPERSTITIONS AND TABOOS

The value of the winged bean is highlighted by the realization that it can be affected by disease or by pests and also by the belief that taboos must be observed towards it. Thus, no menstruating woman should go near it when it is growing, (nor, indeed, should they enter a sweet potato or other vegetable garden), nor should anyone who has recently had sexual intercourse be in contact with the plant. In both cases the 'smell' is said to disturb the plant's growth. In Pangia there are parallel ideas, viz. that no-one wearing the ornaments or smelling of a particular kind of decorating oil (*walo*) should touch or go near the plant; and that an adverse effect also results

from the smell of soap and kerosine which people handle nowadays. The current use of these was in fact cited as a reason why either people do not cultivate winged bean in Pangia nowadays, or why if they do, it does not flourish. Formerly, the rule against menstruating women applied in Pangia as it does in Hagen; and people were careful not to wear *walo* oil except on very special occasions, for fear of upsetting the bean plant. Take note that, while the basic logic of ideas here is exactly the same in the two areas, in Hagen nevertheless, where kerosine and soap are in more common use than in Pangia, the logic has not been extended to these substances and also the cultivation of the plant has increased rather than declined.

Phrases in Melpa expressing failure of the crop in one way or another are: *pat kawa romba, pat mukl poklma ropa pin pan etepa pororom* = "the tubers will become lumpy, they will fork out in different directions and then they rot." This is said to be the effect which results from the presence of menstruating women, the 'rotting' being seen as a result of the 'smell' involved. *Ndip kamb pem* is another phrase, referring to a die-back effect in the leaves before the plant reaches maturity. *Kint wount nom* is the term for a disease which eats the leaves, comparing it to leprosy. *Koemb kit amb amborom* is applied to a very large swollen tuber with a knobbly skin; this they do not harvest, but cover it up and leave it, hoping that other tubers will grow large like this but not be deformed. *Nde kan pana pem* is used when the crop is good. In addition to the taboos already mentioned, we may note that no one who has been to a funeral should go into a bean garden, for if they did the plant would die also (possibly some notion of a bad smell is also subliminally involved). There is even a moral point in one taboo, i.e. that if a thief steals the seeds (which are kept in sections of bamboo or wrapped in cloth and stored in the thatch of house roofs), and plants them, they will not grow for him. Conversely, a man who has stolen a pig and wishes to cook it will remove his own seeds and put them safely out of the way, for his act of theft would otherwise offend the beans (again, by the smell of stolen pork?) and they would not germinate later. These last observations were not as elaborate in Pangia as it is in Hagen.

It is the same also with customs at the cooking of the tubers. In Hagen such a cooking tends always to be ceremonious and communal, with much emphasis on proper distribution, and it is clear that producing the tubers rather than just the beans is a matter of some pride and concern. There are customs of setting up a little arrow to ward off evil influence from the tubers while they cook, and of making sure to laugh and be merry when the oven is opened, so that the skin will easily split away from the white flesh beneath when people eat them. Ongka confirmed that the purpose is to keep off spirits: "It is done against *kum, kint kopakl,* or whatever other 'rubbish thing' (*mel korpa*) might come and smell the fragrance of the tubers cooking and so prevent them from steaming well. People used to say also they were keeping away the sky-man *Nggukunggakla.*" *Kum* is a malevolent substance akin to witchcraft which can fly through the air and attack people; *kint kopakl* appears to be a disease bearing substance, which can cause leprosy. In general, these taboos, just like those surrounding the planting, management, and harvesting of the crop, seem to stress its value. No such taboos are attached to the cultivation of the staple sweet potato, other than the universal rule concerning menstruating women. In Pangia also, as noted in the 1976 article (p. 149) a special ritual *ipe ture,* was done to propitiate the ghosts of previous gardeners and ask them to bless the crop so that it would grow well.

## POPULARITY AND DECLINE IN CULTIVATION

In attempting to pinpoint differences in the generally similar complexes of ideas and practices relating to winged beans in Hagen and Pangia, one difference appears to be significant. That is, in Pangia consumption of the tubers is not so important as it is in Hagen. There is a term for the tubers, *kalo pere,* and they are certainly eaten, but there is more emphasis on the bean pods, which are harvested in bundles and given to kinsfolk and in-laws. A woman who could produce bundles of this kind regularly to give to her brother was known as 'big woman' (*kamo aroa*). Such a gift would be reciprocated later by durable wealth objects such as shells, pigs, axes, and bundles of ash salt. It would belong to the category known as *langi,* ceremonial gifts of vegetable food. The lesser emphasis on the tubers goes, as would be expected, with a lesser need to prepare the soil to a fine consistency. The *Wiru,* make fine garden beds for their sweet potato cultivation, constructing mounds of worked over soil in the fashion found also in Hagen and westwards among the *Enga.* They do not, however, appear to alternate these beds with winged bean plantings as Hageners regularly do (*toka wulya penditimin,* as the phrase is in Melpa). Instead, the beans are planted with mixed vegetables in the *lama ipe* (= *pana* in Melpa). In one such garden inspected in 1974 the beans had not been systematically staked as they invariably are in Hagen, and they had fallen and were trailing on the ground. Nor was the garden kept

weeded. Other plots were similarly small and not particularly well cared for. How could this be when the crop originally had quite an honorable place?

First, the lack of emphasis on tuber cultivation means that the crop does not have so many uses as in Hagen. Instead of communal cookings and distribution of the tubers, there is simply a process, at the end of the time when the plant bears its ripe bean pods, of pulling up the roots and roasting casually what small tubers have developed. Similarly, there is no systematic collection of leaves and flowers for consumption, so the plant is left to grow much by itself. Altogether, its cultivation is not so intensive or regimented as in Hagen. The *Wiru* nowadays say they cannot undergo the bother of staking it.

Statements of this latter kind should not immediately be taken at face value, however. In fact, there are other important crops which the *Wiru* have also given up within the last fifteen years, since the government station was opened, and they themselves advance three reasons for this. First, they say, the crops — varieties of taro and yams in the main — were produced partly for religious festivals, and as these have been forbidden by the missions,there is no point in continuing to grow the crops themselves. Second, they say, they have in any case had too much compulsory work for the government on road-construction, house-building, and field clearing for cattle schemes to concentrate properly on their gardens. This situation has eased somewhat since 1975. Prior to that, the *Wiru* in fact seem to have experienced an increasing recurrence of times of minor food shortage *ttaim hangri* in Melanesian Pidgin), especially in 1972, when severe frosts hit many parts of the Highlands and destroyed many gardens of sweet potatoes. Third, they add that when the missionaries came they preached against the cultivation of numerous varieties of food crops, arguing that if people's minds were on these they would not think properly of God. Such an absurd extension of the ethics of religious abstinence into an area which is subject to periodic overall food shortage and whose people need vegetable proteins to supplement the small amounts of meat they tend to obtain can scarcely be credited. However, that this is indeed what evangelists, in rather misguided enthusiasm, did say, and that the people, interpreting their remarks as directions for new ritual taboos, literally did give up cultivation of many of their valued plants; and that the decline of winged bean cultivation is to be traced partly to this cause also. The report of what evangelists apparently said in fact supplies the needed link between luxury crops and religious rituals previously established among *Wiru*. These rituals did not specifically and exclusively require the cultivation of the crops. For example, the latter could be cooked with pork at the cyclical pig-killing festivals which still survive in the area, stripped of most of their pagan religious ritual. Indeed, yams and taro *are* steam-cooked for pig-killings, as I have observed. But what is meant by the *Wiru* in their association of crops and ritual is many things: that they were stimulated into production of fine crops by ritual needs; that essentially the ghosts had blessed their labour and the 'high spirits' such as *Timbu* and *Aroa Ipono* had concurred in this; and that if these blessings were removed and God were presented as an alternative source of power it was a matter of prudence to follow God, since his messengers appeared to be so powerful.

## REINTRODUCING THE WINGED BEAN IN WIRU

Clearly, the complex of suppositions needs to be unravelled now, to the extent that it has led the *Wiru* mistakenly to abandon cultivation of valuable crops and to suffer a loss of pride in themselves as well. It may be, of course, with the advent of coffee as a cash crop and the chance that some of the cattle schemes may be profitable, that the *Wiru* could not now be persuaded in any case to take up cultivation of the winged bean again. However, this cannot be known until the suggestion has been made to them, and at a time when the Department of Primary Industry is at last becoming aware of the need to improve and strengthen subsistence agriculture throughout Papua New Guinea it would seem very opportune to have extension workers engaged on such a project. There will definitely be resistance to overcome, since the *Wiru* see the earlier command to give up cultivation of their luxury crops as having emanated from the authorities and the idea of such authorities changing their minds will be troublesome to them. Further, they already associate the agricultural officers with cash-cropping schemes, and so are likely to ask if some plan for marketing the beans or their tubers will be forthcoming; and to be puzzled if told this is not so. Extension officers should therefore be aware of these likely problems and be versed in ways of urging the people to take note of their own nutritional needs. A good way would be to begin by establishing what proportions of young children in the area are malnourished and to lead on in discussion from observations about how to improve the children's food intake. In Hagen, the dark leaves of the winged bean are often mixed in and steam-cooked with other greens

and small pieces of meat. They could be cooked also in the bamboo containers which the *Wiru* use for the same purpose. Indeed, one young *Wiru* woman, who learned the Hagen practices, said she would know how to pluck the leaves and eat them when she was hungry, for they were so tasty (they resemble, in fact, vine leaves in their consistency and tang). Small pieces of advice such as this could help people to appreciate again the value of the plant, and there is no reason why they should not use it once more in their *lanei* exchanges, although nowadays there is a preference for introducing store brought foods, such as fish and rice, into exchanges of this kind. The point here is that while such introduced foods remain fairly cheap they do nevertheless cost money and so involve the *Wiru* in a growing dependency on the outside world, whereas cultivation and consumption of their own resources would make them more truly independent.

## ETHNOBOTANY

That there is an indigenous basis of knowledge on which cultivation can proceed is shown quite clearly by the elaboration of ethnobotanical terms for the winged bean in both areas. The primary reference for the people's classification of the winged bean in Hagen is Powell *et al.* (1975). Powell was assisted in gathering materials for this publication by her co-authors, who were University students from Ndika, Moker and Yamka tribes among which the plant's cultivation is most prevalent. This would help to explain the proliferation of terms collected (48 in all) for the 'types' of winged bean, and shows the advantage of having a collaboration of this sort. Some problems, however, remain. What, for example, is the social distribution of the knowledge? Do men know more types than women? Which types are planted most often? Are some types 'fashionable' and others 'outmoded'? In terms of detailed description of each type, Powell's information is excellent, and indeed provides a full basis for practical appreciation of which varieties to grow for what purpose. It does not however answer the question of the existing distribution of knowledge.

The above remarks have been prompted by the fact that in the hilly area where I work, in Dei Council north of the Ogelbeng Plain, at altitudes above 6,000' a.s.l., the number of types recognized falls considerably short of 48. An informant, Rambe, gave the following list: *keep, mokl, wakl, mbonong, porpa, mbalkele, kekl, munt*. She added a brief exegesis on these:

> *Keep, mbonong,* and *mokl* used to be planted by the old people. Now *mbalkele* and *munt* are the popular ones. Seeds were obtained from the people near Hagen town (*wi Kuma wambi*). The people in the lower valleys used *keep* only for its bean and pods. We use it for tubers also, but they are long and thin (*rokkworlu*). *Mbalkele* grows like sweet potatoes do; it is a good type, and *munt, porpa* and *wakl* resemble it. *Mokl* has smallish tubers, but it puts out many bean pods."

When Rambe had finished, her husband, Rongnda, added a further set of names: *murlki, ropokli, kaema, kuri* and *mbuin*, and another middle aged man, Pangk, of the same settlement area, gave *popoi* as an extra. On another occasion, the names of types actually growing together in a single kitchen garden were gathered: *wanunga, rakop, popoi, peng rakop, mokl kopana, mbalkele, mom,* and *mokl*. This list, collected in a valley area some 5 miles to the east of Kundmbo territory, contains further some names and also illustrates the second level of sub-classification. In another plot nearby there were further types grown just for their beans: *Enga munt, kuma,* and *kurumbukl*. The pattern here of several types all growing together conforms to that for other crops such as taro, sweet potatoes, and sugarcane. There is no attempt made to separate the types out on individual plots.

Powell et al. (1975) agree that there are seven main terms for commonly recognized varieties, including most of those given above. They translate the two-tier or three-tier forms of classification used by the Melpa into English terms such as 'species' and 'variety'. Assuming that the procedure here is correct, and that levels of classification in Melpa do correspond exactly to the English botanical classification, the existence of varieties and sub-varieties may be recognized. Powell's scheme could thus be represented as follows:

| | |
|---|---|
| Species: | *Aklmong* (bean)/*Pat* (tuber) |
| Variety: | *Koip, Boron, Popai, Wanenga, Bonong, Kaipa, Kuri.* |
| Sub-variety | For *Koip*, e.g., there are eleven subterms; for *Boron* two; for *Popai* two; for *Wanenga* four; for *Bonong* six; for *Kaipa* two; for *Kuri* three. |

*Boron* did not appear in the author's list (although perhaps it is another rendering of *Bonong* in fact). Others, do not appear in this list. *Mbalkele* may be very recent, which would explain its absence from Powell's lists. *Koip* = *koep*, and the name is appropriate, for *koep* also means 'eel'. The tubers of this variety are long and thin. *Koip kung* may refer to a dark purple colour of the bean similar to the plant dye known as *kung* which is grown to produce the colour for staining women's netbags and men's aprons. *Koip kund* means 'red *Koip*'. *Koip pakan* appears to compare the bean's pod to the pakan plant which has stiff, spiky leaves. *Koip kel* means 'small *koip*' simly. *Wanenga uiya* may refer to the bean having a taste similar to that of the *uiya* or *uya* nut which is gathered in the Jimi Valley north of Dei Council. *Bonong* is also a term of classification for types of yam and introduced Irish potatoes, and refers again to purple skin or purple flesh. *Kungrui*, a sub-variety term, may mean 'very large', with a reference to the Harpyopsis eagle, which is so big it is said to be able to attack and kill pigs (*koi ndoa kungrui*). Again, such metaphorical and connotational ways of identifying sub-varieties are common in Melpa ethnobotany.

For Pangia, R. Paia (ms. 1976:2) gives a rather shorter list of types recognized: *kailanga, tipu, kongoipo, kaire, akene, mbelere, tomiyo, yako, awaparo, pero* and *youwa*. Four of these, *mbelere, tipu, kailanga* and *kongoipo*, are, he says, the most commonly grown today. *Akene*, like Melpa *koep*, is also the *Wiru* term for 'eel', so presumably it is a long variety; *yako*, which has white seeds, is also the name of the white cockatoo bird; *pero*, with black and brown seeds, seems to be named after a similarly dark-coloured decorating oil which is found in places seeping from the ground; and *youwa*, with greenish seeds, is likened to a kind of large snake (python?) with greenish-yellow markings. Another term is *niripo*, which is also the name of a kind of vine which grows wild; and a further *tumaparo*. Both of these terms, are used in appreciation when one sees a bundle of fine bean pods presented as *langi* to a relative. Mr. Paia does not list sub-variety terms, nor can be added at the moment though this does not mean they are not in existence or did not exist.

## CONCLUSION

More intensive work would be needed to judge the true copiousness of *Wiru* classifications, but it is apparent that the salient terms in *Wiru* are not so well-known or so further subdivided as in Melpa, a conclusion which fits also with present information on cultivation and harvesting practices. Paradoxically, it is the Pangia area which could most benefit from a revival of cultivation of winged beans, since food-shortages, including a shortage of vegetable proteins along with a general shortage of calories, are more prevalent in Pangia than in Hagen, and the people are not likely to have as good acces to markets or to store goods as they do in Hagen, at least for some years to come.

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# The Winged Bean in the Context of Other Underutilized Tropical Food Plants

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## INTRODUCTION

The narrow band of tropics spanning about 45° of latitude and centered on the equator represents an exceptionally broad range of agricultural ecologies formed by an infinite combination of soil types, moisture availabilities and distributions, temperatures, elevations, humidities, air movement, proximity to physical land masses of bodies of water, topography, prevalence of pests and diseases and many other factors. These conditions are further complicated by human needs, preferences and sheer numbers in the torrid zones estimated at 1.57 billion people or about 39% of the world total and growing at the rate of 2 to 3.5%/annum. A recent report (December 1977) on the world food situation shows the collective food deficit of developing market economies (DME's) — the majority of which are situated in the tropics or sub-tropics — to be worsening at a fast rate. At projected rates of population growth rate and national production increases, the food deficit for DME's will rise from 37 million metric tons in 1975 (a comparatively good year) to 120 to 145 million tons by 1990.

In many areas multiple cropping is essential to provide enough food for the heavy population pressures. In such situations even a partial crop failure becomes a human disaster. Most obvious, and perhaps the major limiting factors, are heavy constant pressures by diseases and pests. These hazards are frequently aggravated by unreliable rainfall or floods; lack of improved technology; unavailability of agricultural chemicals and fertilizers; and generally poor management. Increasingly limited energy supplies impose even greater restraints on agricultural productivity in the tropics, especially in drastically limiting the use of chemical fertilizers and plant protectants.

On a world-wide basis plants contribute 70% of human protein needs while animals furnish about 30% (Tahir, 1970). The primary sources of caloric energy and protein in developing tropical countries are cereals such as rice, maize, millet and sorghum and starchy staples such as cassava, yams and plantain. The people in regions with semi-arid to subhumid climate (e.g. northern Nigeria and India) rely primarily on cereals, with two-thirds of dietary calories derived from these sources. In contrast, populations located in the more humid tropics (e.g. Uganda and eastern Nigeria) obtain 44 to 68% of their calories from starchy roots, tubers and plantains (Stabursvik, 1971; FAO, 1966).

### Indigenous Farming Systems

Despite overwhelming odds, peasant agriculture in the tropics has survived and even thrived but the cropping systems used are unfamiliar to temperate zone concepts of crop production. The farmer often utilizes extensive areas of land in slash and burn systems which recycle nutrients and aid in weed and pest control. Several annual and perennial species are usually intermingled in the field and the farmer makes multiple uses of each, harvesting seeds, fruits, vegetables (green seeds, pods and leaves), starchy roots or tubers, vegetable oil, herbs and spices, fuel, and structural materials from a single area. In many systems the perennial component such as oil palm, cacao, coffee, or coconut remain in place, with food crops shifted or rotated to new areas.

Subsistence farm operations in the tropics are usually highly labor intensive — the heaviest demand is for weeding — and are characterized by low levels of external inputs due to lack of credit, low profitability, unavailability of inputs and ignorance of improvements. Harvesting is done by hand, one product at a time. Yields are generally low. In many situations the cultivator is less concerned about crop yields per unit area than he is about productivity per man-year, since manpower, not land, is generally his first production con-

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straint. However, such intensive cropping is more productive per unit of land when all produce is considered than are many highly mechanized monocrop systems, so that it makes "good sense" when arable land is scarce.

This kind of agriculture is often highly complex and sophisticated depending on the accumulated wisdom of several lifetimes of careful observation handed down from father to son. While many remain open to the thoughtful and perceptive tropical agronomist, the heedless tampering with any part of these systems can cause serious repercussions. Encouraging a crop monoculture may increase soil erosion, nutrient loss, and pest and disease incidence, all of which may be effectively buffered in complex associations.

Normal peasant cultivation practices are changing with increasing population pressures on the land. The immediate result is to bring more secondary lands into cultivation. This reduces agricultural productivity per farmer since more effort is required to produce the same amount of food when the bush fallow period is shortened and less productive lands are cultivated. Since secondary lands are generally more fragile in terms of their susceptibility to erosion and loss of fertility, their use implies an accelerating "desertification" in a broad sense, leading to poverty for the farmer and disruption of his society. Eventually most peasants caught in this situation migrate to metropolis slums (about half of Latin America's population is already urbanized), creating grave, if not insurmountable, social and political problems.

## POSSIBLE STRATEGIES

At this time the strategy for optimizing productivity should be to study and advocate crops and cropping practices less dependent on externally purchased inputs. Essentially this means reducing monoculture, de-emphasizing cereal production, diversifying crops and increasing the use of nitrogen-fixing species, especially the grain and forage legumes. Although several species have been developed and are in extensive use in the subhumid to semi arid tropics, virtually no attention has been given to identifying, evaluating and improving those species best adapted to the lowland tropics. In the past, attempts have been made to introduce and adapt crops like soybeans, groundnuts, cowpeas and *Phaseolus* beans to the soil conditions and high humidities of lowland tropical environments. These effforts have met with some success, especially when the level of management is high and there are no restrictions on the use of soil amendments (lime), plant nutrients and plant protection chemicals. However, in the absence of any of these inputs, productivity is often reduced below the level of economic incentive.

This strategy is not without problems. It implies major changes in crops and cropping practices, learning new methods of food preparation and changing dietary habits. A critical aspect of the shift to starchy staples is the need for greater care in nutritional supplementation, i.e. providing higher intakes of high protein foods together with richer sources of vitamins and minerals. Food habits can be changed, but only slowly.

### Need for Crop Research

Increasing and stabilizing food production under the high stress conditions of the lowland tropics are paramount research problems. It is suggested that solutions may be found through greater emphasis on crop diversification, the utilization of more rustic cereals (like the millers *Pennisetum typhoides*, *Setaria italica* *Eleusine coracana* and others), greater reliance on more efficient root and tuber crops, and more intensive use of tropical legumes for food, forage, cover and *in situ* soil enrichment. Perhaps the most urgent and potentially rewarding activity is the immediate focusing of attention on food legumes.

### More Efficient Energy Sources

The production of starchy root and tuber crops is inherently more efficient than the production of cereals, especially on marginal lands and/or with minimal external inputs. It is estimated that, with roots and tubers, at least two to three times more caloric energy can be produced per unit of land and time -- and with only one third to one half the production cost of cereals. It is therefore suggested that an increasing proportion of human energy needs will be derived from starchy roots and tubers and a cereal-based diet will be regarded as a luxury. Although it is most unlikely, if India and Bangladesh were to convert from cereal based to root and tuber based diets, these countries could solve their food energy deficit problems into the 21st century.

If 1,680 calories, or four fifths of daily requirements, are derived from cassava, a ton of fresh material would sustain 2.3 persons for one year. One ton of sweet potatoes would sustain 2.0 persons for one year under similar conditions, while one ton each of yams and (*Colocasia* spp.) will feed 2.1 and 1.6 persons for one

year, respectively. Table 1 summarizes the ability of some tropical crops to provide calories, by listing the number of adults whose energy needs would be met for one year by the production (near optimum yields utilized) from one hectare over one crop season.

**Table 1. Summary of the ability of tropical crops to provide calories.**

| Crop | Yield (Tons/ha) | Period (mo.) | Persons sustained. |
|---|---|---|---|
| Cassava | 60 | 11 | 138 |
| Sweet potatoes | 55 | 5 | 110 |
| Maize | 10 | 4.5 | 59 |
| Rice | 7 | 5 | 41 |

All tropical roots and tubers grown in 1974 (except Irish potatoes) would have provided calories to 80% of dietary demand for approximately 590 million people, or 37% of the total population of the tropics (FAO, 1975). Global production of roots and tubers has increased sufficiently over the past dozen years to provide primary sustenance for more than half the annual population increase in the tropics.

### Supplementing Starchy Energy Foods

A 10 to 20% addition of pulses is usually adequate to balance the protein level of diets based on cereals. However, to balance proteins, vitamins and minerals in diets based on starchy root and tuber crops is more complex, requiring from 20 to 35% pulses if they are used as the major protein source. However, legume protein is generally deficient in both the sulfur amino acids and in lysine. Such starchy staple/legume diets should thus include green leaves, fruits, vegetables and nuts to make up the deficiency in amino acids as well as vitamins and minerals. This has indeed been observed to occur in the more humid regions of West Africa, where diets are rich in green leaves and vegetables gathered from the fields and forests (Luse and Okwuraiwe, 1976).

## LEGUMES IN THE TROPICS

Legumes — both annuals and perennials — form a major component of cropping systems in the lowland tropics of Asia, Africa and the America. Several species have unexplored potential for contributing both protein and calories to the diets of humans and domestic animals. Dry legume seeds are frequently the most practical source of storable and transportable protein in regions lacking refrigeration facilities. Their ability to grow vigorously in diverse environments and especially on poor, nitrogen deficient soils is particularly advantageous in subsistence agriculture. The consistently high yields of peanuts, the rapid vegetative growth of cowpeas and dry beans, the extended reproductive period of viny species (yam, lima and velvet beans) forage cover potential of herbaceous species (*Stylosanthes*, *Desmodium*, *Centrosema* and *Pueraria*) and the persistence of woody perennials (such as pigeon peas, *Leucaena* and *Acacia*) offer complementary uses in complex farming systems.

### Food Legumes

Food legumes often have a distinct advantage over many other crops in the simplicity of their preparation and in the multiplicity of their edible forms. Tender green shoots and leaves, unripe whole pods, green peas, and dry seeds are commonly eaten. Some species produce edible tubers as well. The nutritional value of most food legumes is particularly important in supplementing the non-cereal, low protein, starchy staples of many tropical diets. Grain legume proteins are usually the least expensive protein source for both rural and urban populations in developing areas of the tropics (Rachie and Roberts, 1974).

Six edible legume species are of primary importance in the lowland tropics and are currently receiving attention in several national programs and at one or more of the International Agricultural Research Centers. They include the two industrial oil seed crops, soybeans and peanuts, as well as cowpeas, pigeon peas, *Phaseolus* beans and mung beans (IITA, 1974; 1975).

Several of the 16 species of edible legumes have exceptional potential for contributing to basic food needs in the tropics. Unfortunately, they are hardly known outside of their presumed zones of adaptation, there is very little information on their production and use and they have been almost totally neglected in improvement. Some of these, besides winged beans, are very interesting and are briefly described below (Rachie and Roberts, 1974; IITA, 1974; 1975):

1. **Velvet bean** (*Mucuna pruriens* var. *utilis*) is grown for food, forage and cover from the Western Hemisphere to Africa and Southern Asia. It may have the greatest immediate potential in respect to producing dry seeds and vegetable matter. The greatest range of genetic diversity has been observed in Indonesia, where it is used for food in certain area; — the dry seeds can be fermented with *Aspergillus* sp. to prepare "tempeh" (as in soybeans).

   Investigations at IITA, Nigeria (IITA, 1974) demonstrate the exceptional seed yielding potential and absence of serious pests and diseases. Apparently the flowering process results in a lower level of abortion than many other grain legumes. Absence of pod borers in Nigeria may be due in part to the hairy (velvety) pod surfaces. The presence of L-DOPA in the seeds has been shown to provide good protection against storage pests, a major constraint of grain crops in the lowland tropics. Investigations in Bogor have also demonstrated that some genotypes can be exceptionally high in methionine (exceeding 1.5% of protein).
2. **African Yam Bean.** This species (*Sphenostylis stenocarpa*) should not be confused with the Mexican yam bean or "jicama" (*Pachyrrhizus erosus*), an unrelated species. It is commonly grown in association with yams (*Dioscorea* spp.) utilizing the same poles, trellises or supports. It is grown for its dry seeds and edible tubers (13 to 15% protein). The seeds are reputed to be especially delicious, preferred by experienced consumers over most other food legumes including cowpeas.

   The pods are long, brittle and hard, possibly rendering them less vulnerable to pod-boring and stored grain pests both in the field and storage. The pods are normally picked, bundled together and stored in the ceilings of native huts where smoke from cooking fires helps preserve their quality. The seeds are similar in size and shape to cowpeas, except for being somewhat more cylindrical and having a shiny, waxy testa. Protein evaluations by Prof. D. Boulter at the University of Durham indicate that some cultivars may have usually high levels of methionine, exceeding 2% of crude protein.
3. **Jack bean.** There are two closely related species of jack/sword bean, *C. ensiformis* and *C. gladiata*, which are sometimes grown for vegetable (green pods), dry seeds, forage or cover over a broad range of environments. The bush forms of *C. ensiformis* have exceptional yielding potential, producing up to 4,500 kg of dry seeds per ha in five months at IITA. However, many types of this large seeded crop lack palatability and require long cooking times with multiple changes of water. Methods of preparation should help reduce or eliminate certain undesirable substances including urease and the lectin, Concavalin A. The jack bean is very broadly adapted and has an exceptionally high level of "rusticity". A related species *C. maritima*, is sometimes planted on coastal regions to stabilize sand dunes and where it is subjected to brackish water and a salt spray. It requires improvement especially in seed quality and resistance to viruses which sometimes occur in southern Nigeria.
4. **Lima beans.** Tropically adapted lima beans (*Phaseoulus lunatus*) may have been overlooked in so far as its potential for the lowland tropics is concerned. It is widely grown, although not extensively, in the more humid tropics of West Africa and Latin America. It also has undergone some improvement, although this is almost entirely confined to temperate regions. The lima bean can be used both as a green vegetable and as a dry seed (pulse), but the latter is more important in the developing tropics of Africa and the Americas. Both viny and bush forms occur and yields of dry seeds can be exceptionally high, frequently exceeding 2,000 kg/ha, with some strains reaching 4,000 kg/ha under certain conditions in small observation plots at IITA and at CIAT (Colombia). Commercially usable agronomic types are reasonably well advanced. The crop is less susceptible to pests and diseases than cowpeas, pigeon peas or soybeans in Africa. The major constraints appear to be improving the edible characteristics of the dry seeds, and controlling viruses and nematodes. Nevertheless, it may be one of the dominant species of pulse in the lowland humid tropics at present.
5. **Other species.** There are other species of grain legumes having potential equalling or even exceeding the ones mentioned above. Three possibilities may be mentioned:

   (a) Rice bean (*Vigna umbellata*) — a small seeded, quick growing, semi viny to erect annual that is sometimes used in rotation with rice.

   (b) Mexican yam bean (*Pachyrrhizus erosus*) — used primarily if not exclusively for tuber production (22 ton fresh tubers per ha produced at IITA in 1973, and up to 60 ton/ha in 6 mo. when appropriately managed in Mexico) and can be used fresh, in salads or in Chinese dishes. It contains 5 to 10% protein on a dry weight basis.

(c) Bambarra groundbean (*Voandzeia subterranea*) — is a sub-humid to semi-arid crop, but may sometimes be planted toward the end of the rainy season in the more humid regions where it flowers and ripens during the dry season. It has few disease problems and, with the ability to ripen its highly nutritious and palatable seeds underground, escapes flower and fruit pests so important in other grain legumes.

(d) Cluster bean (*Cyamopsis tetragonolobus*) — a robust bushy herb, to 2 to 3 m tall, matures in 3 to 4 months, and is exceptionally well adapted to high temperatures and limited water supply. It is a high yielder and can be used as vegetable, pulse, mucillage, forage and green manure.

**Non-Food Legumes**

Several non-food legumes, both annuals and perennials, have important roles in tropical farming systems such as industrial products, vegetable oils, lumber and byproducts, construction materials, fuel, pasture and forage, cover and mulching and nutrient recycling and green manure.

**Tolerance to Stress.** Some species have unusual features of adaptation to drought, alkalinity/salinity, acidity, aluminum toxicity, highly depleted soils and extremes of moisture and temperatures. Among the most recent findings are genotypes of several species and genera with exceptional tolerance to low pH/high aluminum saturation like certain species of *Stylosanthes*, *Zornia*, *Desmodium*, *Centrosema* and *Galactia* (CIAT, 1978). Other species like *Aeschenomene* and perennial *Arachis* can tolerate high water tables or flooding for comparatively extended periods.

**Dry Season Forage.** A major problem for grazing animals in the tropics is adequate balanced nutrition during the dry season. Grassy herbage, the major component of pastures, dries down and the protein level drops from 7 to 9 percent to 2 to 3 percent or considerably below the maintenance level resulting in animal weight losses — sometimes 50 kg or more in a season. One solution is to grow separate paddocks of woody forage legumes like *Leucaena leucocephala* to provide needed protein and allow ruminants to digest the high cellulose grasses. Other wood species presently used in this way include: *Acacia*, *Prosopis*, *Gliricidia*, *Cajanus* and *Sesbania*. Incidentally, some recent surveys in the Cerrado (Savannahs) of Brazil indicate that as much as 60 percent of cattle grazing in the dry season is done on shrubs and trees.

**Nutrient recycling.** An interesting possibility is utilizing legumes to "recycle" plant nutrients — nitrogen from the air and other elements from deeper soil layers — and make them available to associated and sequential crops. Of course green manuring is widely practiced in some areas, but other applications have not been widely studied. For example, the use of perennial legume cover and as associated crops may deserve further study — particularly in remote areas, in "fragile" and for small holders where other options and externally-purchased inputs are not available.

Some preliminary observations on associations of annual food crops with two contrasting perennial legumes have been started at CIAT in 1976. These include experiments on associations of maize and *Leucaena* and maize with perennial peanuts (*Arachis glabrata*), and representing two prototype legumes a shrub-by tree and an herbaceous low growing "turf former". In both combinations the legume was established first, and then it was either slashed back or controlled with cultivation and chemicals to reduce competition with the young maize. The idea would be to leave the legume down "permanently" to protect the soil, increases in-filtration, lower surface temperatures, reduce weed growth and recycle nutrients. During the maize season the slashed foliage (coppice) would be left on the ground allowing leaching to carry nutrients to the maize. In other seasons the legumes could be utilized for forage, support for climbing crops (woody perennials), con-struction materials and fuel (CIAT, 1977, 1978).

Establishing the legumes required 4 to 6 months, but other species may be quicker than perennial peanuts. Sampling of the slashed *Leucaena* foliage (2 m high) four months after planting indicated that up to 172, 13, and 99 kg/ha of N P K could be recycled at the highest seeding rate of 40,000 plants/ha. In the case of perennial peanut, the nutrient levels were lower at about 22, 3, and 17 kg/ha of N P K, but about 2 to 3 cuttings could be obtained during the active growing period for maize. The competitive effects of the two legumes (reasonably controlled) on maize in the highly fertile soils of CIAT-Palmira appeared to run 10 to 15 percent. However, these studies need to be run on deplated soils over a reasonable period of time.

## CONCLUSIONS

The human needs, broad range of growing conditions and major hazards prevalent in the lowland tropics preclude the possibility of relying on any single species of food crop for extensive cultivation. Not only will it be essential to have many variants of the same species, it will be equally important to offer a broad diversity of widely-adapted, hazard-resistant, and multipurpose species for these regions. Moreover, future research must show how several different species can be intercropped in various combinations of pulses, cereals, oilseeds, fibers and industrial crops to maximize productivity while minimizing the devastation of pests, diseases, and other hazards.

Selection of some promising tropical legumes for intensified improvement should receive a higher level of priority than at present. However, the inclusion of additional species need not multiply proportionately teams of scientists for each crop. Experience in tropical Africa and the Americas suggests that several pests and diseases are either very similar or identical for this group of crops. Therefore, institutions with teams of scientists having competence in plant pathology, entomology, genetics/breeding, physiology, agronomy, microbiology and biochemistry can often cope with several species simultaneously. Even the initial assembly of germplasm and mounting of plant exploration projects would be wasteful if only a single species is considered. This does not imply that responsibility for several additional species can be added directly to existing programs without augmentation of support, but that future investment in broadening of research activities would be more efficient in building on strength. Nevertheless, crop improvement must be diversified with multiple centers involved in regions of greatest potential and interest — particularly in the lowland tropics of the Americas, Africa and Asia.

It is both surprising and encouraging that "secondary" pulses like lima, velvet, winged, rice, cluster, jack and ground beans have been shown to have reasonably high productivities, without need for substantial management inputs. This suggests that comparatively modest investments on improvement could pay off handsomely and quickly. Some local and regional agencies may well decide that mounting improvement efforts on some of these promising species is relevant to national interests. Since minor species tend to be quickly lost with the adoption and expansion of more sophisticated farming systems, there is an urgent need to systematically collect and maintain indigenous germplasm, an activity requiring international support and coordination.

The second and largely neglected research area requiring immediate attention is that of designing productive and convenient cropping associations and sequences which can be utilized as components of individualized farming systems. This research requires integration of several agricultural disciplines to assure consideration of the several factors involved in genetic improvement for mixed cropping. It also requires recognizing the validity of cropping systems comprise of complex communities of plants, each occupying a specific microecology and serving an important purpose for the farmer and his family. This approach may be the only practical means of stabilizing productivity under the high hazard conditions of subsistence peasant agriculture.

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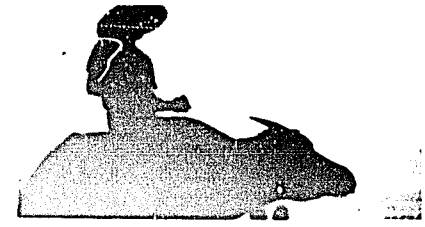
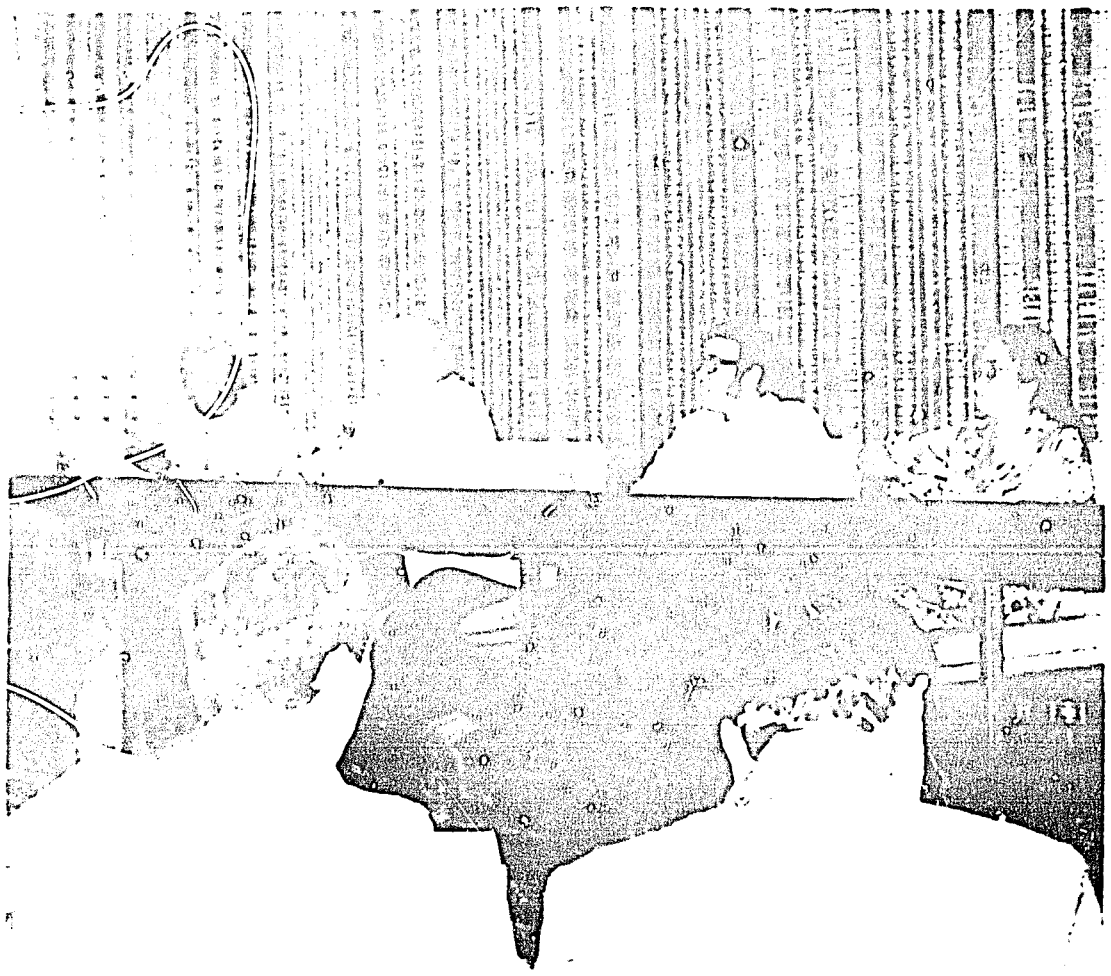
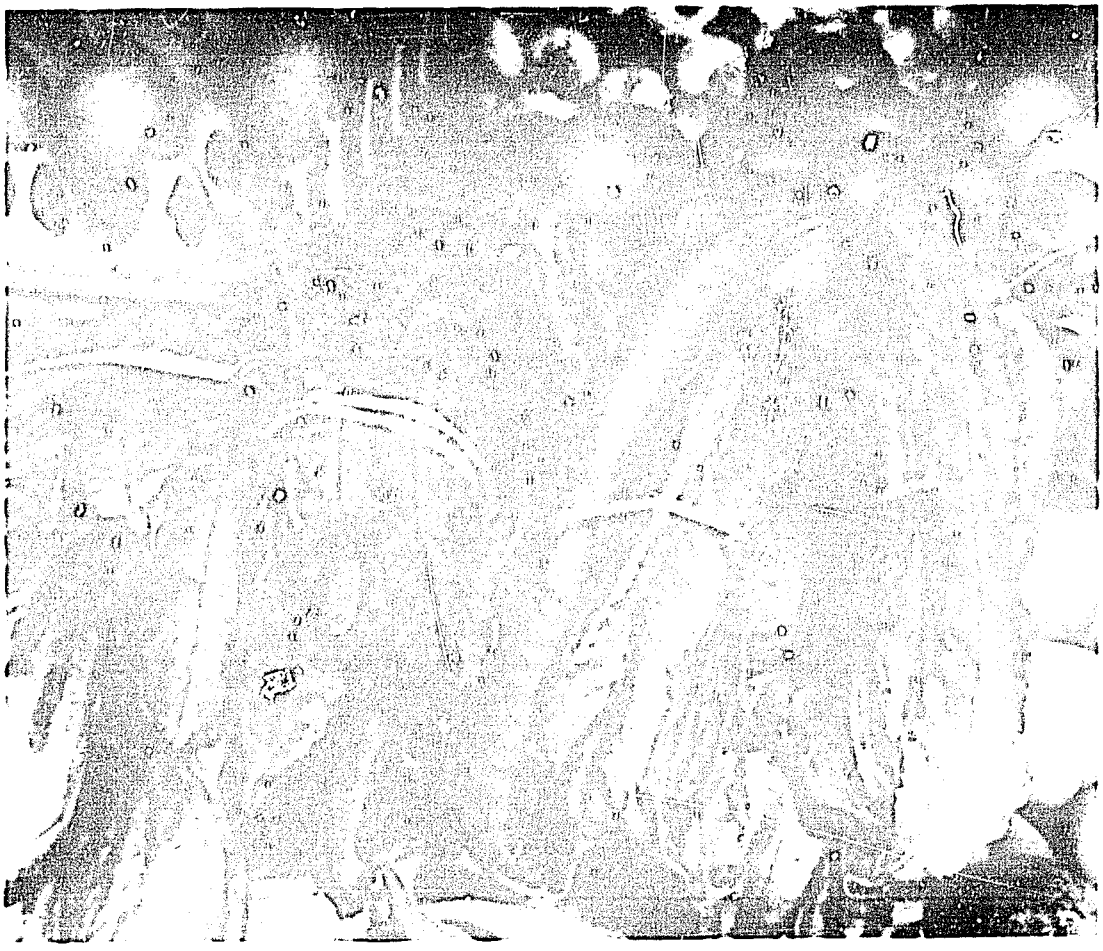




*1 Once an obscure tropical legume crop, the winged bean is now the subject of animated research in at least thirty countries most of them in the third world. 2 The winged bean holds promise in the countryside of many developing countries in the tropics. 3 Developing the potentials of the winged bean was the topic of the 1978 International Forum held in Manila which was attended by over 100 invited scientists from 26 countries.*

1.



2.

*1 Young winged bean pods are sold as vegetables in the Philippines. 2 A Papua New Guinea family with their winged bean crop in the background*

# Germplasm Resources, Genetics

- *The Genetics of Winged Bean*
- *Indonesian Cultivars of the Winged Bean*
- *Collection, Evaluation and Selection of Winged Bean in Central Java*
- *Genetic Diversity of Winged Bean in Thailand - A Preliminary Report*
- *Collection, Evaluation and Conservation of Winged Bean Germplasm in the Philippines*
- *The Genetics and Physiology of Tuber Production in Winged Bean*
- *Some Investigations on the Indigenous and Exotic Collection of Winged Bean in India*
- *Some Growth Characteristics of Indigenous and Introduced Selections of Winged Bean*
- *The Evolution of the Winged Bean Flyer*
- *Cytology of Psophocarpus spp*
- *Correlation and Path Coefficient Analysis of Components of Green Pod Yield in Winged Bean*

# The Genetics of Winged Bean

*W. Erskine*[1]

**The inheritance and use of qualitative characters in elucidating both the population structure and the breeding system of winged bean are described. An analysis of adaptation of thirty genotypes grown in five diverse environments within Papua New Guinea is then reported. This is followed by studies on the inheritance of grain yield in a seven parent diallel cross. The results of the above experiments are then discussed in relation to future winged bean improvement through plant breeding.**

## INTRODUCTION

The winged bean (*Psophocarpus tetragonolobus* (L.) D.C.) is a climbing perennial legume in the sub-family Papilionoideae of Leguminosae. It has considerable potential in the humid tropics to combat protein malnutrition owing to the high protein content of its edible parts (leaves, flowers, green pods and seeds, ripe seeds and tubers). A review of the nutritional value of the winged bean can be found in Claydon (1975).

An understanding of the breeding system and the inheritance of yield and related characters of winged bean is essential for the planning of a successful plant breeding programme to improve yields. There is, however, a lack of published information on winged bean genetics because of the crop's previous obscurity. Hence this paper attempts to summarize relevant work currently underway at the University of Papua New Guinea. After a brief taxonomic survey, a description is given on the inheritance and use of qualitative characters in elucidating both the population structure and breeding system of the crop. An analysis of adaptation of thirty genotypes grown in five diverse environments is then described. This is followed by studies on the inheritance of grain yield in an eight parent diallel cross. The results of these experiments are then discussed in relation to future winged bean improvement through plant breeding.

The cultivated winged bean is grown throughout South-East Asia, the Indian sub-continent, parts of Oceania and Africa, and now also in the New World. It is not known in the wild state, but garden escapes have been reported in the Philippines, Burma and Indonesia (Agcaoili, 1929; Burkill, 1906; Claydon Pers. comm.). Synonyms for *P. tetragonolobus* include *Dolichos tetragonolobus* L., *Botor tetragonolobus* Kuntze and *Lotus quadrangularis* Rumph. Recent cytological investigations quoted in Khan (1976) have confirmed Trixier's (1965) result that the chromosome number of winged bean is n = 9, in preference to n = 13 as described by Ramirez (1960). No further cytological work has been reported on the winged bean. A karyotype analysis should be the next step in this area of study.

The genus *Psophocarpus* Necker has been variously said to contain four (Masefield, 1973), five (Purseglove, 1968), about six (Hymowitz and Boyd, 1977) and ten species (Gillett *et al.*, 1971). However Dr. B. Verdcourt of the Royal Botanic Gardens at Kew, who is currently revising the genus, believes there are actually nine species of *Psophocarpus*.

The two species of *Psophocarpus* most similar to winged bean are *P. palustris* Desv. and *P. scandens* (Erzl.) Verdc. The former name was until recently used as a blanket description for both species. However *P. palustris* with short bracteoles is restricted to the North and West part of Africa, while *P. scandens* is found throughout tropical Africa and Madagascar (Verdcourt, 1968). *P. scandens* has been used as a cover crop under rubber in Indonesia (Saleh, 1975) and is also found in South America. Some African investigations into the cultivated winged bean also erroneously referred to *P. tetragonolobus* as *P. palustris* (Cerny *et al.*, 1971; Cerny and Addy, 1973). Thus it is not clear to which current species the chromosome counts for *P. palustris* (n = 10, Frahm-Leliveld, 1960, n = 11, Miege, 1960) refer. Chromosome counts on the new species should be undertaken to clarify the situation. Both *P. palustris* and *P. scandens* have edible pods and appear resistant to both *Synchytrium psophocarpi* (Rac.) Gaumann and *Cercospora psophocarpi* Yen., two of the major fungal diseases of winged bean in Papua New Guinea. If field resistance to these two diseases is not found within the cultivated winged bean it may be necessary to attempt to transfer resistance from the wild species to *P. tetragonolobus*.

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To this end crossing between *P. tetragonolobus* and *P. scandens* has been attempted at the University of Papua New Guinea, but so far without success. Using *P. tetragonolobus* as the female parent, 142 flowers were emasculated by the technique of Erskine and Bala (1976) and pollinated by *P. scandens*. All of these aborted later.

The other species in the genus have only been found in Africa. *Psophocarpus grandiflorus* Wilczek is found in Uganda, Zaire and Ethiopia in upland bushland, forest and grassland at 1800-2100 m. above sea level (Gillet *et al.*, 1971). *Psophocarpus lancifolius* Harms. grows in swampy grasslands and forest edges at 1,100-2,500 m above sea level and has been reported from Uganda, Kenya, Tanzania, Nigeria, Zaire, Zambia and Malawi (Gillett *et al.*, 1971). *P. luka fuensis* (De Wild.) Wilczek (Syn. *Vignopsis lukafuensis* De Wild) is known in Zaire (Wilczek, 1954) and in wet grasslands in Zambia (Masefield, 1961). *P. lecomtei* Tisserant and *P. obvalis* Tisserant are both found in Central African Republic, with the former also found in Zaire and the latter in S. Sudan (Verdcourt, pers. comm.). The ninth member of the genus, *P. monophyllus* Harms., has also been reported from Sudan and the Ivory Coast (Verdcourt, pers. comm.).

## GENETICS OF QUALITATIVE CHARACTERS

Extensive variation among both qualitative and quantitative characters has been observed in Papua New Guinean collections of winged bean showing that Papua New Guinea is a center of diversity for the crop (Khan, 1976). Qualitative variation was reported for characters like stem, flower and pod color and also pod shape. The genetic basis of five of these character differences was then investigated in two crosses.

The five character pairs for stem, calyx and pod colour, and pod shape and specking were all found to be controlled by single gene differences. There was complete dominance of purple over green for all the colour characters, and complete dominance of rectangular over flat pods (Erskine and Khan, 1977).

Among these characters, stem color is particularly important as a genetic marker since it is visible at the seedling stage and also controlled by a single gene. Marker genes such as stem color are useful in the identification of varieties and inadvertent self pollinations following hybridization. They can be used to monitor the extent of natural cross pollination and variation within winged been populations. In addition, if seedling markers are found closely linked to other desirable adult qualitative traits like male sterility or resistance to some pest, screening could be done at the seedling stage and thus be greatly facilitated.

Significant linkage between stem and calyx color was found in the coupling phase (P = 0.13, S.D. = 0.6), and between pod wing color and pod specking in the repulsion phase (P = 0.27, S.D. = 0.03). The presence of this linkage shows that an increased number of progeny will have to be raised to break the linkage and find desirable recombinant plants if selection for a particular pod color is mooted.

## PERCENTAGE OF LOCI POLYMORPHIC IN LAND RACE COLLECTIONS

With this information on the inheritance of qualitative characters, it was then possible to examine the variation within land race collections of winged bean to shed light on land race population structure. Analysis of data on 14 samples of winged bean kindly supplied by Dr. Khan showed that the mean percentage of loci polymorphic for the four loci viz., stem color, pod wing color, pod specking and pod shape was 80.4% (Table 1). This variation was between families collected in a sample and due to differences between lines that later bred true for the characters examined. Only 5.05% of single plants showed segregation in the progeny and hence any evidence of heterozygosity. Thus an individual land race consisted largely of different true breeding lines, although a low but significant level of heterozygosity was observed firstly from progeny segregation and secondly by the isoenzymic variation mentioned in Khan (1976).

Further information on winged bean land race population structure can be gained from the analysis of quantitative characters, and a partition of variation between and within land races has been made for the three characters: time to flower, pod length and average seed size. This analysis showed that land races collected less than a mile apart often differ considerably. There was also significant variation between families within land race collections. Additionally some land races, particularly samples 1 and 3, contained more variability than others (Table 1). This partition of between and within land races variation is useful in planning the collection of winged bean germplasm for conservation. Since a quantitative estimate of variation between collecting sites and within sites is available, it is possible to calculate the optimum allocation of resources for collection between and within sites. Winged bean collections in Papua New Guinea should be

made at as many sites as possible collecting a single pod from 30 to 40 different plants within a site. A clustered sampling system should be used to decide on sites for sampling within the target area (Khan, Erskine and Kesavan, in preparation).

**Table 1. Presence of allelic polymorphism and percentage of loci polymorphic in fourteen land race collections.**

| Collection number | Stem colour | Pod specking | Pod wing colour | Pod shape | % loci polymorphic |
|---|---|---|---|---|---|
| 1 | • | • | • | • | 100 |
| 2 | • | • | • | • | 100 |
| 3 | • | • | • | • | 100 |
| 4 | • | • | • | • | 100 |
| 5 | • | • | • | • | 100 |
| 6 | • | | • | • | 75 |
| 7 | • | | • | | 50 |
| 8 | • | | • | • | 75 |
| 9 | • | • | • | | 75 |
| 10 | • | | • | • | 75 |
| 11 | • | • | • | | 75 |
| 12 | • | • | • | • | 100 |
| 13 | | • | • | | 50 |
| 14 | • | • | | | 50 |
| | | | | Mean % | 80.4 |

*Presence of allelic polymorphism

## THE MEASUREMENT OF NATURAL CROSS POLLINATION

The winged bean is cleistogamous and largely self pollinating since anthesis occurs prior to flower opening (Erskine and Bala, 1976). Self pollination, the most intensive form of inbreeding, rapidly leads to homozygosity. However, evidence from the previous section of a low level of heterozygosity suggested that some cross pollination must be occuring. It was then necessary to quantify the extent of this cross pollination. Accordingly, experiments using the seedling marker-stem color to measure cross pollination were grown in four environments. The progeny from green stemmed plants, grown in alternate rows to purple stemmed plants, were scored for cross pollination.

Results from the experiment show that cross pollination varied from 0 to 7.6% (Table 2). Carpenter bees (*Xylocopa aruana* Rits.) were observed visiting flowers and were responsible for the considerable rate of outcrossing at the Crop Garden in the wet season of 1977.

The values for cross pollination may be under estimates because the experiments measured crossing between rows and not between single adjacent plants. In addition, the two genotypes utilized had different flower colors (blue and purple) and bee flower color preference may possibly have led to a bias of cross pollination toward one color.

This level of natural cross pollination has implications for the maintenance of varietal purity. Continual roguing of off types must be practised in pure lines. Also, wherever necessary, cross pollination between breeding lines can be avoided by the use of either isolation or insecticides to discourage bee pollination.

## GENETICS OF QUANTITATIVE CHARACTERS

Quantitative characters show continuous variation. And, unlike qualitative characters, phenotypes can not be classified into discrete classes. Additionally, the differences between any two genotypes for a quantitative character is not always the same in different environments. This problem is particularly acute in winged bean, which is cultivated in Papua New Guinea from sea level up to 2200 m (Khan *et al.*, 1977). The importance of genotype environment interaction in this broad area of adaptation was then investigated to enable the formulation of an efficient breeding plan (Khan and Erskine, 1978).

Briefly, the genotypic, environmental and genotype environment variances of grain yield and yield com-

**Table 2. Natural cross pollination in four environments.**

| Environment and location | Altitude above sea level (m.) | Natural cross pollination between genotypes (%) |
|---|---|---|
| Port Moresby (dry season, 1976) 9°25'S., 148°8'E. | 50 | 0.3 + 0.2[a] |
| Port Moresby (wet season, 1977) | 50 | 7.6 + 0.9 |
| Kuk + beehive (1976) 5°47'S., 144°20'E | 1500 | 0.3 + 0.3 |
| Kuk without beehive | 1500 | 0 |

[a]Standard error indicates the variation in cross pollination between rows.

ponents were calculated for 30 genotypes in five diverse environments. A maximum grain yield of 2200 kg/ha was recorded. Genotypic variance contributed only 0.3% to overall variation, while environmental variance contributed 69.9%. A significant genotype-environment interaction variance for grain yield was adequately explained by joint regression analysis. Correlation studies emphasized the importance of testing in both highland and lowland environments in Papua New Guinea. Variation in grain yield was largely due to fluctuations in pod number. Also, both grain yield and pod number showed strong negative genetic correlations with seed number per pod, seed weight and pod length.

A wide range of genotypic variation for quantitative characters has now been reported for winged bean (Khan, 1976). This genetic variation can now be exploited through plant breeding. Accordingly, a crossing program was initiated to complete a 7 x 7 diallel cross without reciprocals. The parent comprised 5 high yielding lines from within Papua New Guinea, one line from Indonesia (UPS 133) and a single plant selection (UPS 132) for a Nigerian accession (Tpt1). Diallel $F_1$ seeds together with parents were grown out in wet season 1976-1977 in a randomized block design with three replications. For each population, there were five individually staked and randomized plants per replicate. Plant means within replicates were used for diallel analysis as in Mather and Jinks (1971). Although measurements were made on many characters, grain yield alone will be discussed in detail.

There were highly significant differences between populations for grain yield, which averaged 61.5 g per plant. The highest yielding parent (UPS 122) gave 69 g per plant, while the best $F_1$ family (UPS 132 x 133) yielded 108 g per plant. The experiment has planted at 20,000 plants/ha and the highest recorded mean yield is thus equivalent to 2,016 kg/ha.

There was evidence of considerable positive heterosis over the mid-parent mean in $F_1$ families, and heterosis averaged 36.2 ± 5.7%. Among yield components, only pod number exhibited significant heterosis, thus causing the heterosis for yield. It is expected that much of this heterosis will disappear in succeeding generations.

Both additive and dominance effects were highly significant for grain yield. Among dominance effects unidirectional dominance was significant and manifested as positive heterosis, while specific combining ability was also significant.

## GENERAL DISCUSSION

A sound knowledge of the breeding system and population structure of winged bean is a prerequisite to crop improvement through plant breeding. The results of the partition of quantitative characters between and within collection sites showed striking geographic differences between winged bean land races. This mosaic pattern of variation between land races is apparent often over distances of less than a kilometer, indicating the low level or lack of gene interchange between adjacent populations.

Within populations there was significant variation between families for both quantitative and qualitative characters. The latter was characterized as percentage of polymorphic loci. There was also evidence of varia-

tion within families resulting from cross pollination. Measurements of cross pollination varied from 0 to 7.6% while progeny segregation and enzymic variation (see Khan 1976) indicated the presence of heterozygosity within families. The population structure and breeding system of winged bean are thus typical of inbreeding plants with a low level of cross pollination (Allard *et al.* 1968).

With this information we can now rationally choose the most appropriate breeding method for winged bean. Classical breeding methods that have proved successful for similar self pollinated species include pure line selection, mass selection, and hybridization with the segregating generations handled by either pedigree, bulk or backcross methods. However, recent advances in the breeding of cowpea, a legume with a similar breeding system, have resulted from the use of male sterility in population breeding (Anonymous, 1975). This population approach allows greatly increased reassortment and transfer of genes over the classical methods. Male sterility was discovered by screening in excess of a million plants at the late podding stage of growth, when normally fertile plants have yellow senescent leaves. At this time, however, male sterile or infertile plants are easily recognizable by their lush green leaves (Rachie *et al.* 1975). A similar search should be mounted in winged bean, although the need for plant support through staking will limit the number of plants screened.

Another unexplored use of male sterility or complete sterility is in the area of tuber production. Recent work has shown that tuberization is enhanced in winged bean by reproductive pruning — the periodic removal of flowers and pods (Bala, pers. comm.). It may be possible to utilize some genetic mechanism, either male sterility or complete sterility, to prune the plant automatically, thus encouraging tuberization. The use of complete sterility will need to be combined with vegetative propagation of the crop either through stem or root cuttings.

From a discussion of possible breeding methods and strategies applicable to winged bean, let us turn attention to the tactics of yield improvement within Papua New Guinea. Out of the six experiments measuring yields quoted herein two have yielded in excess of 2 tons/ha of dry seed. The problem is thus not only one of increasing yields but also consistently reaching the 2 ton/ha mark. There are two ways of tackling this problem of yield stabilization in winged bean. The first concerns the growing environment. The environmental variance of grain yield accounted for 70% of overall variance and was the major factor influencing grain yield. This suggests that we lack adequate knowledge of the adaptation of the crop — which environmental and climatic conditions best suit the crop in terms of moisture, temperature and soil type. Thus, a more critical appraisal of growing sites is needed.

The second approach to yield stabilization involves the selection of varieties which are both high yielding and stable in their performance. The adaptation experiments showed a genotypic variance of less than 1% emphasizing the limited scope for selecting among the 30 genotypes. In addition, the correlation analysis showed the response of genotypes to be totally different in highland and lowland environments, since there was complete absence of significant correlation between performance in the two groups of environments. It is thus apparent that two breeding programmes — one for low altitude levels and another for high altitudes (above 100 m) might decrease environmental variance and conversely increase genotypic variance thus aiding selection. However, with available resources it is only feasible to run one program incorporating yield trials under both highland and lowland conditions. In early generations after hybridization when little seed is available for yield trials, the best allocation of resources would include testing in two environments one lowland and one highland rather than either two highland or two lowland sites.

Prior to the results described in this paper there had been no attempt to exploit the genetic diversity of winged bean through recombination and selection. The parents used in the crossing program are necessarily only a very small, non random sample of genotypes. Thus because of the fragmentary nature of the evidence extrapolation beyond this parental set is unwise. However, grain yield was found to be controlled by a combination of additive and dominant gene effects, and some response to selection between families may be expected.

Although discussion has centered on the genetics of grain yield, recent work has shown the yield of green pods of the crop is also controlled by a combination of additive and dominant gene effects. The correlation between vegetable and dry seed yield will be of interest since it will determine whether selection for grain yield will also increase green pod yields.

The effects of dominance for grain yield are apparent as heterosis in $F_1$ above the higher yielding parent. Such heterosis is currently being exploited in many other crops. However, in winged bean the exploitation of heterosis will not be feasible until methods facilitating cross pollination such as male sterility are available.

An alternative approach to breeding for increased grain yield is indirect selection via yield components. The success of this method requires the yield component to be strongly and positively correlated to yield, without negative correlations to other yield components, and to have a higher heritability. The only yield component which is consistently correlated to grain yield is pod number, however it has a lower heritability and is more time consuming to measure than yield. It is also negatively correlated to other yield components. Hence indirect selection for yield via its components is not appropriate to winged bean improvement in Papua New Guinea.

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# Indonesian Cultivars of the Winged Bean

*S. Sastrapradja*[1]

## INTRODUCTION

The food legumes available in Indonesia are of several species. Among those species, peanuts, soybeans and green gram represent the major food legumes because they are cultivated in a much larger scale than the rest of the species. Winged bean, on the contrary, is classified as one of the minor food legumes due to the fact that it is less important economically.

In terms of subsistence agriculture, the winged bean has a better role. It is often planted in home garden in the villages, among other economic plants such as fruit trees, tuber crop and medicinal plants. Sometimes it is grown along the rice field borders.

Variation of characters were observed in the Javanese samples of the winged bean (Sastrapardja et al, 1977). In this paper, the data on the variation of Indonesian samples collected is presented.

## PROGRESS IN FIELD COLLECTION

The National Biological Institute (Bogor) started its project on food legumes in 1970. The collection was confined to the minor legumes such as lima beans *(Phaseolus lunatus)*, hyacinth beans *(Dolichos lablab)*, cowitch *(Mucuna pruriens)*, string beans *(Vigna unguiculata)*, sword beans *(Canavalia* groups), etc. In the beginning, attention was concentrated on string bean and cowitch. Several paper on these groups have been published (Aminah Lubis et al, 1972, 1974, 1976; Sastrapradja et al., 1972, 1974, 1975). Later research on food legumes was extended to sword bean *(Canavalia)* (Sastrapradja et al, 1973, 1976), rice bean *(Vigna umbellata)* (Sastrapradja and Soetarno, 1977) and the winged bean (Sastrapradja and Lubis, 1975; Sastrapradja et al., 1977).

With regard to the winged bean, samples have been collected from Java (165 accessions), Madura (8), Bali (15), Sulawesi (1), Lombok (11), Timor (2), and Flores (8). These samples were generally purchased from the local markets. Attempts to do the same in West Sumatra, Halmahera, Maluku and Irian Jaya gave no result. Occasionally samples were obtained from areas where Javanese are resettled.

## AREAS RICH IN THE WINGED BEAN TYPES

It has been mentioned above that the winged bean is commonly grown in Indonesia in a mixed garden culture. Usually not more than one or two plants are grown in a yard for the use of the family. A rather large number of plants are occasionally grown in rice field borders.

Though the winged bean can be grown in an altitude of more than 1,000 m, it is found to be more abundant in the lowlands. Its distribution pattern follows the decrease of the annual rainfall. It is much easier to find the plants in the eastern part of Indonesia than in the western part.

The greatest variation in seeds was detected in the materials collected from Java. This can be attributed to two factors: the variation of the ecological niches which is present in Java, and the ways the people use it.

With regard to the ecological factors, areas in Java may differ from one another in terms of soil type, the annual rainfall, altitude, etc. The combination of these factors offers an array of ecological niches to the growth of the plants.

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As to the ways the people use the winged bean, they employ both the pods and the seeds. The green pods are consumed either cooked or raw. For this purpose, crispy pods producing cultivars are selected. Usually long pods are less fibrous than the short ones. The latter are good as seed producers. The matured seeds are valued for food as well as for medicinal purposes. When used for food, they need the same treatment as that done in soya beans. They may also be fermented into bean cake though this practice is done only when the soya beans and other grain legumes are not available. For medicinal purpose, the seeds are roasted and pounded before mixing them with the rest of the medicinal components. The other legumes usually used in such a preparation are *Parkia roxburghii* and *Adenanthera pavonina*. Because of these uses, people always grow the winged bean. The cultivation enables any ecotype that developed in the area to survive leading to the maintenance of variation in characters.

## EVALUATION

For a preliminary evaluation, 12 samples collected from Java were used. The 12 samples differ from one another in either seed coat color, leaf shape, flower color or pod length. The seeds were then grown in Bogor Botanical Garden and the characters were compared (Sastrapradja et al. 1977).

### Seeds

There are five groups of seed coat color in the samples investigated, i.e. brown, creamy white, greyish brown, black and violet. Among these, brown predominates. When the seeds were grown in the garden, some of the samples produced seeds of different color from the ones originally planted, indicating that the samples were not of pure lines.

Variation was also noted on the size of the seeds. The smallest size weighed 29.70 g/100 seeds and the largest was 53.50 g/100 seeds. Both samples belong to the group with brown seed coat color.

### Seedlings

In comparing the character of the first leaf, it was noted that the difference among the samples investigated was not prominent. The terminal leaflet of the first trifoliate leaf, however, varied from sample to sample. Some samples possessed deltoid terminal leaflets, while the others showed lanceolate or ovate terminal leaflets. The majority of the samples however were of the deltoid type.

### Mature plants

The number of days to flowering varied from sample to sample, the shortest being 71 days after planting while the longest was 149 days.

As to the flower itself, there are four colors shown by the samples investigated. These colors are white, blue, violetish blue, and deep violet. In general, blue color is predominating. Those samples having violet color, violetish blue and some of those with blue flowers produced the same flower color in the following generation. The rest of the samples with the blue flower and the white one produced other flower colors in addition to their own color. Again this evidence shows that some samples are not of pure lines.

It has been mentioned that pod length in the winged bean can be classified into three groups, i.e. short, medium and long (Sastrapradja and Lubis, 1975). Again from the 12 samples investigated one falls into the first group, 9 to the second and 2 to the last one. One sample of the two longest pods produced seeds with brown color and the other with violet color.

Twenty new additional samples were investigated for the above characters. In view of seed coat color and flower color, there was no new color detected. It was noted that some samples produced seeds and flowers which differed in color with the original ones.

From the above data it was shown that cross fertilization commonly happen among the samples of the winged bean. The flowers, however, are protogynous in type (Lubis, 1977). This condition may secure maximum self fertilization to occur. There is high percentage of cross fertilization since the winged bean flowers open for several hours during the day. During this time bumble bees visitation is high. This may also contribute to the development of new types.

### Indonesia and the Winged Bean

The winged bean is only one of the food legumes grown in Indonesia. In an area where subsistence agriculture is in existence, such as in Gunung Kidul or Banyumas, minor grain legumes such as lima beans, sword beans and cowitch substitute the role of soya beans as a source of vegetable protein. These species are

generally consumed in the form of fermented bean cake. In the same areas, hyacinth beans and winged beans are grown mainly for their green pods.

In dry places like Madura and Lombok, the winged bean is more valued for its dry seeds. People in these places do not appreciate fermented bean cake the way the Javanese people do. Therefore, the grain legumes are cooked together with rice or taken separately as a side dish, but never fermented. Lombok Island is a good producer of winged bean seeds. The seeds are even exported to Bali. Although the winged beans are mainly grown only in rice field borders in that island it apparently offers a substantial income to the farmers.

From the point of view of seed protein content, the samples of the winged bean seed collected from Indonesia show variation between 27.06% to 36.56% (Lubis, 1977), with the greater number of them having more than 32%. Compared to the other minor legumes which are used as grain, it contains more protein. Sword bean seeds for example contain 22% to 25% protein, whereas cowitch, 22% to 28% and lima beans 20 to 22%. However, as a seed producing plant, the winged bean is less desired.

There are reasons why people prefer other seed legumes than the winged bean. The winged bean seeds imbibe water much slowly than the rest of the food legumes. Furthermore they require longer cooking and the beany smell as well as the beany taste is much stronger. Thus an extra effort is needed to treat the bean seeds before they are served.

In comparison to the other grain legumes, the yield per plant is low. Moreover, the disease infestation when grown in monoculture is quite high as shown in the Bogor experiment. However, it was noted that in Lombok Island, where the plants are grown in a larger number than in the other areas in Indonesia, disease infestation was not detected (Lubis, 1977). It is most likely that the survival of the fungus in Lombok is suppressed due to the fact that the area is dry. Whereas in Bogor which is considered the wettest part in Indonesia, the environment may stimulate the growth of the fungus.

Like the rest of the species which are classified as minor legumes the winged bean has not been studied extensively. Only recently several groups in Indonesia started to pay their attention to this bean. Among these groups are the Gajah Mada University, the Hasanudin University and the Institute of Nutrition of the Department of Health.

While potentially the winged bean is better than the rest of the minor legumes as a source of protein, its development needs a serious consideration. In a country like Indonesia, where a number of plants can serve the same purpose, people have a wide range of choice. Unless the winged bean therefore outstands the ordinary beans in more ways, one will tend to ignore it.

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# Collection, Evaluation and Selection of Winged Beans in Central Java

*Sri Kuntjijati Haryono, Joedoro Soedarsono* and *A. F. Thompson*[1]

**Early in 1977 a project on the "Evaluation and Improvement of Production Potential of Winged Beans" was conducted in the Faculty of Agriculture of the University of Gadjah Mada.**

**A total of 99 accessions were assembled and evaluated for genetic variability, 59 from Indonesia, 16 from Papua New Guinea, 14 from Nigeria, 6 from Malaysia, 3 from India and 1 from Ghana. Four plantings were made; in March, April, June and August-Sept. 1977. Considerable variation was observed between accessions as well as within numerous unselected lines. Date to first flower ranged from 40 to 125 days. Some lines planted in June failed to produce flowers. The number of flowers node ranged from 2-20. Tuberous root formation was observed in all 10 of the Indonesian accessions in the first planting. The *Chimbu* variety failed to form tubers under these conditions. No other significant variation was observed exceeding that previously reported in the literature.**

**A replicated preliminary plant population-spacing experiment was planted on Sept. 10, 1977. Seeds of one variety (UGM Acc. 1) were planted in paired rows spaced one meter apart. Spacing within rows were 12.5, 25, 50 and 75 cm, with either 1 or 3 seeds per hill. One of the paired rows was harvested to measure green pod yield and the other row for dry seed yield. Germination was good and plant stands adequate despite the effects of a prolonged dry period and inadequate irrigation water. Preliminary yields indicated considerable sensitivity to soil moisture stress in combination with high population density.**

## INTRODUCTION

In Central Java, Indonesia, winged bean pods are commonly used as green vegetables. Relatively little usage is made out of the dry seeds, and usage of the tubers as food in this area is unknown although usage of cassava and other root crops is rather extensive. Early in 1977, research was started on the winged bean within the Faculty of Agriculture of the University of Gadjah Mada in the Special District of Yogyakarta in Central Java. Research is being conducted under a project entitled "Evaluation and Improvement of Production Potential of Winged Beans", which is funded in part and stimulated by the Rockefeller Foundation.

Yogyakarta is located in the central part of Java about 110° East longitude and 8° South latitude. The city is 30 km from the South coast at an elevation from 100 to 140 meters above sea level. The elevation of the area is around 135 meters with a temperature range of 23 to 31°C and a daily mean of 26.5°C. Soils are regosols of volcanic origin and are generally sandy loams.

The project initially consists of three major activities including:

1. **Varietal evaluation and plant breeding.** This activity aims to collect seeds and establish plantings for evaluation and determination of the extent of variation in economically important characters, and to develop adapted varieties through breeding and selection.
2. **Adaptation and cultural practices.** This activity aims to study the various factors affecting adaptation, germination, growth and development, and yielding capacity of the winged bean, and to develop systems of culture to optimize and maximize its production under various environmental conditions.
3. **Assessment of nodulation and nitrogen fixation of the rhizobium-winged bean association.** To obtain quantative and qualitative information on the nodulation and nitrogen fixation of *Psophocarpus sp.* in Indonesia. To obtain effective, selected strains for the winged bean, and to determine the necessity for developing a program involving artificial inoculation.

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## VARIETAL EVALUATION

Initial activities of the project sources, both from various areas within Indonesia as well as internationally. The National Biological Institute (Lembaga Biologi Nasional) at Bogot maintains a list of over 170 accessions of winged beans collected in Indonesia. It seemed that this large collection does not contain all or even a fully representative sampling of the genetic variability available in Indonesia, which is considered a center of genetic diversity for the species. Continued wide scale collection of Indonesian germplasm is of high priority. Contacts was therefore made with various research and extension workers throughout Indonesia to enlist their support in the collection by sending supplies of seed of varieties and strains utilized in their areas. To date, 27 accessions have been obtained from cooperators in Java, Sumatra, Kalimantan, Sulawesi and Lombok. The additional 32 accessions received from the National Biological Institute brings the total number of Indonesian accessions to 59. Accessions have also been obtained from Papua New Guinea — 16, IITA in Nigeria — 14, Malaysia — 6, India — 3 and one from Ghana. All taken there are now 99 accessions assembled and 77 are currently undergoing evaluation for genetic variability and selection for economically important characters. The balance of the newly received accessions will be planted early in 1978 along with larger populations of previously observed materials.

As accessions were received, plantings were made for observation, evaluation and increase in seed supply. In most instances the number of seeds received were very limited, while germination was very low, resulting in uneven stands. Under these circumstances it has not been possible to conduct replicated yield trials during the early phase of the project.

### First Planting

The first planting was made on March 9, 1977 using UGM Acc. 1 from the Horticulture Research Institute in Pasar Minggu, Jakarta. This accession was somewhat heterogeneous for various plant characters such as leaf and pod type, but was relatively early in flowering and reasonably productive. Variation was observed for pod and seed yield and selections are being made within the population. A total of 2.4 kg of seed was harvested in May and June 1977. These seeds were used to plant a population-spacing experiment in September 1977.

### Second Planting

The second planting of 12 accessions was made on April 7, at the Agronomy Department Plots adjacent to the University Campus. Eleven of the accessions were from Indonesia, but one failed to germinate. The other variety was *Chimbu* from Papua New Guinea, but the seed source was Dr. T. Hymowitz, University of Illinois, Urbana, Illinois. Data on days to first flower, days to maturity of seed and seed yield are presented in Table 1. Root tubers developed on all of the Indonesian accessions, but *Chimbu* did not develop tubers under these conditions.

**Table 1. Performance of 11 winged bean accessions, agronomy plots, University of Gadjah Mada, Yogyakarta, Indonesia April 7, 1977.**

| UGM Acc. No. | Source of Accessions | Plants Evaluated (No.) | Days to 1st Flower | Mean No. Flowers Node | Days To Mature Seeds | Mean No. Pods Plant | Mean Pod Length (cm) | Mean No. Seeds Plant | Mean No. Seeds Pod | Seed Wt. g 100 Seeds |
|---|---|---|---|---|---|---|---|---|---|---|
| 14 | Chimbu, Papua New Guinea | 4 | 67 | 3 | 105 | 4 | 17 | 36 | 10 | 30 |
| 15 | Palembang, Sumatra | 19 | 125 | 7 | 145 | 17 | 20 | 204 | 12 | 29 |
| 17 | Purwokerto, Central Java | 60 | 90 | 7 | 120 | 12 | 18 | 102 | 7 | 27 |
| 18 | " | 40 | 105 | 7 | 141 | 13 | 14 | 83 | 6 | 25 |
| 19 | Garut, West Java | 30 | 70 | 8 | 105 | 18 | 22 | 203 | 11 | 40 |
| 21 | Mataram, Lombok | 4 | 68 | 4 | 110 | 10 | 20 | 93 | 9 | 32 |
| 22 | " | 24 | 82 | 7 | 120 | 31 | 15 | 220 | 8 | 35 |
| 23 | " | 24 | 90 | 9 | 135 | 15 | 17 | 144 | 9 | 26 |
| 24 | " | 4 | 90 | 5 | 130 | 12 | 17 | 92 | 8 | 30 |
| 25 | " | 3 | 90 | 5 | 120 | 10 | 18 | 97 | 10 | 26 |
| 26 | " | 14 | 90 | 8 | 130 | 9 | 18 | 65 | 8 | 32 |

## Third Planting

The third planting was made on June 2, and July 26 1977, at the new Agricultural Training Research and Development (ATRD) Station, Kaliurto, which is about 15 kilometers southeast of the University Campus in Yogyakarta. The elevation of this area is around 45 meters, which is 90 meters lower than the Agronomy Plots where the previous planting were made. These plots generally suffered from the lack of adequate irrigation water and the prolonged dry season. A total of 31 accessions were planted, but 9 failed to germinate. Many of the lines did not germinate well, and some replanting was attempted in July with limited success. Many of the small plants were severely damaged by chickens from a neighboring village, and had to be protected with woven baskets. As yet no resistance to this type of damage has been detected. Some difficulty was also experienced with infestations of aphids and two species of caterpillars which attacked the developing flowers and small pods. The dry soil moisture conditions contributed to blossom drop in many lines. Variation appears to exist both within and between accessions in the ability to retain blossoms and young pods under stress conditions. The ability to set pods under adverse conditions will be an important characteristic for adaptation to year round production in areas with long dry season such as Central and East Java, Bali and the Eastern islands including Lombok, Sumba, Sumbawa, Flores and Timor which comprise the regions of Nusa Tenggara Barat and Nusa Tenggara Timur. Pod set, retention and development is considered a major objective in our breeding and selection program.

Seven of the accessions planted on July 26 have failed to produce flowers until the 22nd of December. This response is likely to be conditioned by daylight. The vegetative growth of these plants appears to coincide with the slightly increasing daylength from June to December. Continued observations are being made on these plants to see if the decreasing daylength from December to June will have any influence on their flowering response. Plants have not yet been dugged so no data have been collected on root tuberization in this planting. Data on the performance of the third planting are presented in Table 2.

**Table 2. Performance of 22 winged bean accessions, ATRD Station, Kaliurto, University of Gadjah Mada, Yogyakarta, Indonesia, June 2 and July 26, 1977.**

| UGM Acc. No. | Source of Accessions | Plants Evaluated (No.) | Days to 1st Flower | Mean No. Flowers/ Node | Days to Mature Seeds | Mean No. Pods/ Plant | Mean Pod Length (cm) | Mean No. Seeds/ Plant | Mean No. Seeds/ Pod | Seed Wt. g/100 Seeds |
|---|---|---|---|---|---|---|---|---|---|---|
| **Indonesian Accessions:** | | | | | | | | | | |
| 1 | Pasar Minggu, West Java | 7 | 40 | 8 | 83 | 5 | 18 | 47 | 9 | 29 |
| 43 | Samarinda, East Kalimantan | 4 | 54 | 10 | 85 | 15 | 19 | 138 | 9 | 20 |
| 27[1] | Payakumbuh, West Sumatra | 2 | — | — | — | — | — | — | — | — |
| 28[1] | Bukittinggi, West Sumatra | 4 | — | — | — | — | — | — | — | — |
| 59[1] | Minahasa, North Sulawesi | 4 | — | — | — | — | — | — | — | — |
| 61[1] | Minahasa, North Sulawesi | 4 | — | — | — | — | — | — | — | — |
| 63[1] | Mojokerto, East Java | 8 | — | — | — | — | — | — | — | — |
| 64[1] | Mojokerto, East Java | 8 | — | — | — | — | — | — | — | — |
| 65[1] | Mojokerto, East Java | 6 | — | — | — | — | — | — | — | — |
| **Papua New Guinea Accessions:** | | | | | | | | | | |
| 9 | UPS 99 Univ. P.N.G. | 2 | 40 | 8 | 75 | 12 | 21 | 172 | 14 | 26 |
| 11 | UPS 102 Univ. P.N.G. | 1 | 43 | 6 | —[2] | 3 | 6 | 17 | 6 | 20 |
| 12 | UPS 121 Univ. P.N.G. | 2 | 47 | 6 | 78 | 5 | 20 | 44 | 9 | 30 |
| 47 | PNG 2, Univ. West Australia | 4 | 40 | 6 | 75 | 9 | 21 | 99 | 11 | 41 |
| **Nigeria Accessions:** | | | | | | | | | | |
| 29 | IITA TPT 1 | 7 | 54 | 8 | 86 | 10 | 21 | 110 | 11 | 24 |
| 30 | IITA TPT 2 | 9 | 42 | 12 | 87 | 20 | 19 | 252 | 13 | 31 |
| 32 | IITA TPT 6 | 7 | 54 | 10 | 95 | 13 | 21 | 104 | 8 | 22 |
| 33 | IITA TPT 7 | 1 | 67 | 8 | 109 | 3 | 5 | 15 | 5 | 9 |
| 37 | IITA TPT 10.2 | 1 | 42 | 11 | 9[illegible] | 10 | 20 | 110 | 11 | 3[illegible] |
| 40 | IITA TPT 14 | 2 | 47 | 8 | 8[illegible] | 10 | 20 | 110 | 11 | 2[illegible] |
| 41 | IITA TPT 15 | 3 | 54 | 10 | 99 | 15 | 18 | 201 | 13 | 42 |
| 42 | IITA TPT 16 | 6 | 54 | 12 | 7[illegible] | 20 | 20 | 236 | 12 | 4[illegible] |
| **Malaysia Accessions:** | | | | | | | | | | |
| 55 | MARDI, Univ. West Australia | 5 | 54 | 5 | 94 | 7 | 20 | 74 | [illegible] | 2[illegible] |

[1]Accessions planted on July 26, 1977 and have not flowered up to December 22, 1977.
[2]Top of plant cut off before seeds fully matured.

**Fourth Planting**

The fourth planting was made from August 5 to September 10, 1977 at the Agronomy Plots of the University Campus. A total of 53 accessions were planted. Eleven accessions failed to germinate and poor germination of many of the other accessions gave rise to uneven stands. Some replanting was attempted with limited success. Although initial soil moisture was adequate for early plant growth, irrigation water became inadequate during the prolonged dry season. Blossom drop was again noted in many lines. Infestation of armyworms caused some damage to seedlings and small plants. Infestation of aphids on certain lines became a problem, and some lines appeared to be either attractive or susceptible. At least two different types of caterpillars again caused damage to developing flowers and pods with some minor leaf damage. Symptoms of at least two types of virus diseases were observed throughout the planting. One caused curling and mottling of the leaves, while the other severely reduced leaf size to one to two centimeters in length and width.

Table 3 presents a summary of the incomplete data from the fourth planting. A total of 22 lines remained vegetative and are being observed for evidence of flowering. It would appear that the failure to flower in certain lines may be due to photoperiodic effect. A total of seven accessions were sufficiently late in maturity to prevent complete collection of mature seed yields by December 15. Some lines flowered very early and set fruit even though many blossoms dropped as an apparent response to moisture stress. It would appear that these lines may be photoperiodically insensitive. Plans are being made for the investigation of the photoperiodic effect with selected lines. Year-round, monthly plantings are planned to determine their seasonal response.

**Table 3. Performance of 42 winged bean accessions, agronomy plots, University of Gadjah Mada, Yogyakarta, Indonesia, August 5 to September 10, 1977.**

| UGM Acc. No. | Source of Accessions | Plants Evaluated (No.) | Days to 1st Flower | Mean No. Flowers/ Node | Days to Mature Seeds | Mean Pod Length (cm) | Mean No. Seeds/ Pod | Seed g/100 Seeds |
|---|---|---|---|---|---|---|---|---|
| **Indonesian Accessions:** | | | | | | | | |
| 1 | Pasar Minggu, West Java | 31 | 49 | 12 | 86 | 16 | 9 | 27 |
| 100 | Ambon | 24 | 52 | 8 | 85 | 13 | 6 | 29 |
| 27 | Payakumbuh, West Sumatra | 7 | — | — | — | — | — | — |
| 28 | Bukittinggi, West Sumatra | 21 | — | — | — | — | — | — |
| 45 | Sumarinda, East Kalimantan | 12 | — | — | — | — | — | — |
| 57 | Banyuwangi, East Java | 33 | — | — | — | — | — | — |
| 58 | Banyuwangi, East Java | 14 | — | — | — | — | — | — |
| 59 | Minahasa, North Sulawesi | 29 | — | — | — | — | — | — |
| 61 | Minahasa, North Sulawesi | 20 | — | — | — | — | — | — |
| 64 | Mojokerto, East Java | 30 | — | — | — | — | — | — |
| 65 | Mojokerto, East Java | 36 | — | — | — | — | — | — |
| 66 | 799 B-II-I; LBN, Bogor | 1 | — | — | — | — | — | — |
| 67 | 902(3) 1; LBN, Bogor | 3 | — | — | — | — | — | — |
| 68 | 902(1) 6; LBN Bogor | 1 | — | — | — | — | — | — |
| 71 | 1000 ; LBN, Bogor | 1 | — | — | — | — | — | — |
| 72 | 1102 d-7 ; LBN, Bogor | 1 | — | — | — | — | — | — |
| **Papua New Guinea Accessions:** | | | | | | | | |
| 2 | UPS 31 Univ. P.N.G. | 5 | 55 | 6 | 92 | 19 | 6 | 12 |
| 3 | UPS 32 " | 2 | — | — | — | — | — | — |
| 4 | UPS 47 " | 1 | — | — | — | — | — | — |
| 5 | UPS 53 " | 2 | 60 | 6 | 92 | 10 | 8 | 23 |
| 6 | UPS 62 " | 1 | 74 | 6 | — | — | — | — |
| 10 | UPS 78 " | 7 | 63 | 3 | 94 | 8 | 4 | 12 |
| 12 | UPS 121 " | 5 | 81 | 4 | 120 | — | 4 | 12 |
| 13 | UPS 122 " | 8 | 69 | 5 | 92 | 26 | 15 | 32 |
| 46 | PNG 1, Univ. Western Australia | 1 | 64 | 7 | — | — | — | — |
| 47 | PNG 2, Univ. Western Australia | 1 | 74 | 3 | — | — | — | — |

Table 3. continued...

| UGM ACC | Source of Accessions | Plants Evaluated No. | Days to First Flower | Mean No. Flowers Per Node | Days to Mature Seeds | Mean Pod Length (cm.) | Mean No. Seeds/ Pod | Seed g/100 Seeds |
|---|---|---|---|---|---|---|---|---|
| **Nigeria Accessions:** | | | | | | | | |
| 29 | IITA TPT 1 | 10 | — | — | — | — | — | — |
| 30 | IITA TPT 2 | 10 | — | — | — | — | — | — |
| 31 | IITA TPT 3 | 6 | 60 | 6 | 104 | 22 | 13 | 38 |
| 32 | IITA TPT 6 | 15 | 57 | 8 | 104 | 18 | 11 | 31 |
| 33 | IITA TPT 7 | 10 | 67 | 10 | — | — | — | — |
| 34 | IITA TPT 8 | 17 | 53 | 6 | 92 | 9 | 8 | 17 |
| 35 | IITA TPT 9 | 6 | 60 | 7 | 97 | 8 | 5 | 21 |
| 36 | IITA TPT 10/1 | 2 | 72 | 6 | 106 | 11 | 6 | 21 |
| 37 | IITA TPT 10/2 | 7 | 64 | 7 | 97 | 18 | 10 | 38 |
| 38 | IITA TPT 11 | 1 | — | — | — | — | — | — |
| 39 | IITA TPT 12 | 1 | 83 | 6 | — | — | — | — |
| 40 | IITA TPT 14 | 7 | 61 | 11 | — | — | — | — |
| 41 | IITA TPT 15 | 3 | 62 | 8 | — | — | — | — |
| **Malaysia Accessions:** | | | | | | | | |
| 53 | M 11/5, Univ. West. Australia | 2 | — | — | — | — | — | — |
| 54 | M 12/7, Univ. West. Australia | 1 | — | — | — | — | — | — |
| **India Accessions:** | | | | | | | | |
| 50 | India E.C. 27884, Univ. West. Australia | 1 | — | — | — | — | — | — |

## PLANT POPULATION EXPERIMENT

A preliminary plant population-spacing experiment with three replications was planted on September 10, 1977. Seeds of one variety (UGM Acc. 1) from the Horticultural Research Institute (Lembaga Penelitian Hortikultur), Pasar Minggu, Jakarta, w[illegible] planted in paired rows spaced one meter apart. Plant populations ranging from 13,333 to 240,000 per hectare were sought with spacings within the rows at 12.5, 25, 50 and 75 cm and either 1 or 3 seeds per hill. Row lengths of plots were 9 meters. Plants were supported by bamboo arched together between paired rows of each plot. Germination was very good and overall plant stand for the experiment at time of first green pod harvest was 93.4% despite the effect of prolonged dry period, and inadequate water. Green pod yields were measured from one of the paired rows and dry seed yields from the other. Tuber yields was measured from both rows at the conclusion of the experiment.

The first harvest of green pods was made on December 13, 1977, or 93 days after planting. Some of the pods were slightly overmature at this time. A few pods would have been at marketable stage approximately 70 days after planting. Early production was definitely delayed by the heavy soil moisture stress, which was relieved by the onset of the rainy season around the middle of November. Marked vegetative growth accompanied by abundant flowering and fruit set was obtained shortly after adequate soil moisture was received. Additional harvests are being made at approximately 10 day intervals. The data from the first harvests have not been statistically analyzed, but have been summarized for presentation in Table 4.

**Table 4. Effects of plant population on yield of green pods of winged beans in Central Java (Preliminary data from three harvests)[a].**

| Treatments | | Plant Population per Hectare | | Yield of Green Pods | | |
|---|---|---|---|---|---|---|
| Within row spacing (cm) | Plants per hill | Theoretical | Actual | Mean pod (g) | Kg/ha | Pods/ha (#) |
| 75 | 1 | 13,333 | 12,415 | 17.0 | 1,968 | 115,905 |
| 50 | 1 | 20,000 | 18,520 | 15.0 | 1,048 | 69,987 |
| 75 | 3 | 40,000 | 37,400 | 14.8 | 1,257 | 84,799 |
| 25 | 1 | 40,000 | 37,040 | 13.7 | 1,009 | 73,690 |
| 50 | 3 | 60,000 | 56,100 | 13.8 | 920 | 66,654 |
| 12.5 | 1 | 80,000 | 75,280 | 12.6 | 1,257 | 99,611 |
| 25 | 3 | 120,000 | 105,900 | 11.5 | 480 | 41,844 |
| 12.5 | 3 | 240,000 | 211,650 | 12.3 | 409 | 33,327 |
| **Within Row Spacing:** | | | | | | |
| 75 | | | | 16.1 | 1,613 | 100,362 |
| 50 | | | | 14.4 | 984 | 68,328 |
| 25 | | | | 12.9 | 744 | 57,773 |
| 12.5 | | | | 12.5 | 833 | 66,476 |
| **Plants Per Hill:** | | | | | | |
| | 1 | | | 14.7 | 1,321 | 89,803 |
| | 3 | | | 13.5 | 767 | 56,600 |
| **Overall Mean Yields:** | | | | | | |
| 1st Harvest | | | | 15.1 | 510 | 33,838 |
| 2nd Harvest | | | | 15.0 | 142 | 9,443 |
| 3rd Harvest | | | | 13.1 | 391 | 29,950 |
| Total | | | | 14.2 | 1,043 | 73,231 |

[a]UGM Acc. 1 planted Sept. 10, 1977. First harvest 1977; Second harvest December 24, 1977; and Third harvest January 4, 1978.

The preliminary green pod yields clearly indicate the rather extreme sensitivity of this variety to increased population density. Much of this sensitivity appears to be related to the severe soil moisture stress imposed by the prolonged dry period and inadequate irrigation. Prior to the onset of the rainy season considerable blossom drop was experienced, especially in high density plots. Mean pod weight decreased markedly with increasing plant population density, and sensitivity was related to spacing within rows and plants per hill. Yield of green pods in kg/ha and number of pods/ha were quite closely related to population density as modified by both spacing with rows and plants per hill.

# Genetic Diversity of Winged Bean in Thailand: A Preliminary Report

*Narong Chomchalow*[1], *Saowanee Suputtitada and Surin Pevachoknagul*[2]

**Collection of the winged bean seeds in Thailand was made through correspondence with agricultural extension officers. Altogether, 167 acession coming from 26 changwads (provinces) representing 4 parts of the country were studied. Considerable variation was found in several morphological characters, namely, seed color, leaf shape, flower color, pod shape, pod color, and pod surface. The basis for such a great genetic diversity and its practical value in the breeding program and in commercial production are discussed.**

## INTRODUCTION

The winged bean is one of the most common crops in Thailand. It has been grown as backyard crop for such a long time. The Thai people use the young pod as vegetable in several methods of culinary preparations (Chomchalow, 1976 a,b). In some regions, the tuber has been used as food as well as for medical remedy but no study has been made in any of these respects. After world-wide interest in the winged bean was initiated in 1973 (Masefield 1973), followed by a campaign to promote research on winged bean by the U.S. National Academy of Sciences (NAS 1975), the senior author has taken great interest in pursuing research on winged bean since the crop appears to have a potential as a new economic crop for the oil and protein industries of Thailand.

Among the priority research areas was the exploration and conservation of the available variation. Due to the limited funds and personnel, work had to start small at first by collecting seeds through correspondence and planting them for observation. There was considerable variation observed in the color and shape of the seeds collected. Morphological differences were also observed. This paper reports the results of the study on the genetic diversity of 167 accessions of the winged bean in Thailand, together with a discussion on the basis for such a diversity and its practical value in the breeding program and in commercial production

## MATERIALS AND METHODS

### Collection of Seeds

Collection of the winged bean seeds was made through correspondence. The first attempt was made in April 1976 by sending out requests for seeds to 72 changwad (provincial) agricultural extension officers throughout the country. These officers then went out to collect seeds from the villages who grew them in the backyard of their homes, or, rarely, in their farms. Most of the seeds received were already separated from the pods. No varietal designation was attached to the seed package. A serial entry number was given to each package received. There may be several packages coming from one changwad. For each entry, the seeds were separated into lines on the basis of seed color. Thus, a code for each accession was derived from the combination of an entry number and a line number, separated by a dash. For example, accession 12-03 means an entry number 12 (from Nakhon Sawan), line number 3 (with reddish purple seeds). Weight of 20 seeds was determined, either directly by weighing 20 seeds if 20 or more seeds were received, or indirectly by calculating from the weight of any amount of seeds if less than 20 seeds were received. Altogether, 52 entries with a total of 75 surviving accessions were received from 9 changwads.

[1]Deputy Governor, Research I, Applied Scientific Research Corporation of Thailand (ASRCT).
[2]Graduate Students, University Development Council Fellows in Genetics, Kasetsart University.

The second attempt of seed collection was made in February 1977 by sending out requests to 537 amphoe (district) agricultural extension officers in 72 changwads throughout the country. The same procedure as in the first attempt was practiced. Altogether, 42 entries with a total of 92 surviving accessions were received from 20 changwads.

**Planting**

Upon receiving the seeds from the extension officers, planting was made as soon as possible. The first planting was performed during May-September 1976, the collection plots of the Applied Scientific Research Corporation of Thailand (ASRCT) at Bang Khen, Bangkok. The second planting was performed during May-October 1977 also at Bang Khen and ASCRT's Experimental Farm at Tung Song Hong, Bangkok.

Germination in some lines was very poor, which may have been due to prolonged storage before they came to us. A simple technique was developed by first soaking the seeds in water overnight which resulted in the swelling of certain amount of seeds. The seeds which did not swell were then injured one by one with the use of a razor blade. Upon further soaking for six hours, swelling was observed in most of the seeds. To reduce the damage in the field, the swollen seeds were allowed to germinate between layers of moist tissue paper for one or two days. The practice yielded almost a 100% plant population in the field, using one seed per hill. A number of plants were, however, lost during the seeding stage due to an unidentified root disease, or insect damage.

Planting was made on 1 × 5 m raised bed with a spacing of 1 m between plants and 75 cm between rows, or a total of 10 plants per bed. At the time of planting about 5 g of *Rhizobium* inoculum* was added to the seed to insure nodulation since the soils used for this purpose were either riversand or rice field soils. Six, 2 m long bamboo poles per bed were staked at six hills; two poles opposite each other to form a triangle (see diagram). Another 2m long bamboo rod was used to connect two pairs of triangles at the top. Altogether, 8 rods were used for each bed. A nylon string was used to tie the rods together and to extend the climbing areas for the vines (Fig. 1).

Normal cultivation practices were given during the entire growing season, including watering, disease and insect control, and fertilizer application.

**Collection of Data**

Since it was realized that at this early stage of investigation, (1) there was a large number of accessions to be studied, (2) many of the lines may be duplicated, and (3) the growing environment was variable, no quantitative parameters, except for the weight of 20 seeds were recorded before planting. Therefore, only qualitative characters were recorded for the present study. However, certain quantitative characters were observed, viz. growth vigor, pod size, pod length, number of pod per plant, number of seeds per pod, seed yield per plant, tuber yield per plant, and shelling percentage. These characters were not statistically analyzed as the population size of each line was too small and the effect of environmental factors was too large.

As far as the morphological characters are concerned, the following were studied: seed color, leaf shape, flower color, pod shape, pod color, and pod surface. Attempts to record seed shape failed due to the lack of proper descriptive terms and their variable appearance even when they came from the same pod.

## RESULTS

At the time of writing this manuscript (January 3, 1978), many of the accessions did not mature; some did not even flower. Therefore, the results reported herein are incomplete. The distribution of the sources of winged bean seeds by parts and changwads of Thailand is shown in Table 1, Fig. 2. The characteristics of all 167 accessions resulting from two planting attempts are shown in App. 1. Variation observed in qualitative characters is shown in Table 2 and Fig. 3.

As seen from Table 1, the Northern Part submitted the largest number of accessions (107 accessions, or 64.07% of the total number submitted). The Central and Southern Parts submitted 17.6 and 14.37%, respectively. The Northeastern Part, with its vast area of dry land, sent only 6 accessions or 3.59%.

It is interesting to note that considerable variation in the morphological characters was observed among the 167 accessions of winged bean in Thailand. Among the characters under investigation, seed color exhibited the greatest variation. Thirteen colors were observed, with brown being the most dominant (24.43%).

***Isolated and prepared by Mrs. Srinan Chomchalow; Head, Process Research Division Agricultural Research Department, ASRCT.**

**Table 1. Sources of winged bean seeds in Thailand by parts and changwads.**

| Changwad | No. of Entry | No. of Line | | No. of Entry | No. of Line |
|---|---|---|---|---|---|
| **Central** | | | **North** | | |
| Chainat | 2 | 8 | Chiang Mai | 5 | 5 |
| Chon Buri | 1 | 1 | Chiang Rai | 9 | 30 |
| Petchaburi | 5 | 10 | Lamphun | 1 | 1 |
| Phra Nakhon | 3 | 3 | Lampang | 1 | 3 |
| Ratchaburi | 1 | 4 | Mae Hong Son | 2 | 5 |
| Sing Buri | 1 | 3 | Nakhon Sawan | 17 | 50 |
| Trat | 1 | 1 | Nan | 1 | 3 |
| Total | 14 | 30 | Phitsanulok | 1 | 2 |
| | | | Phrae | 4 | 6 |
| | | | Sukhothai | 1 | 2 |
| | | | Total | 42 | 107 |
| **South** | | | **Northeast** | | |
| Krabi | 1 | 2 | Kalasin | 4 | 5 |
| Nakhon Si Thammarat | 1 | 1 | Nakhon Ratchasima | 1 | 1 |
| Phuket | 2 | 2 | Total | 5 | 6 |
| Phattalung | 4 | 7 | | | |
| Pattani | 2 | 4 | | | |
| Songkhla | 1 | 2 | | | |
| Surat Thani | 2 | 6 | | | |
| Total | 13 | 24 | Grand Total | 74 | 167 |

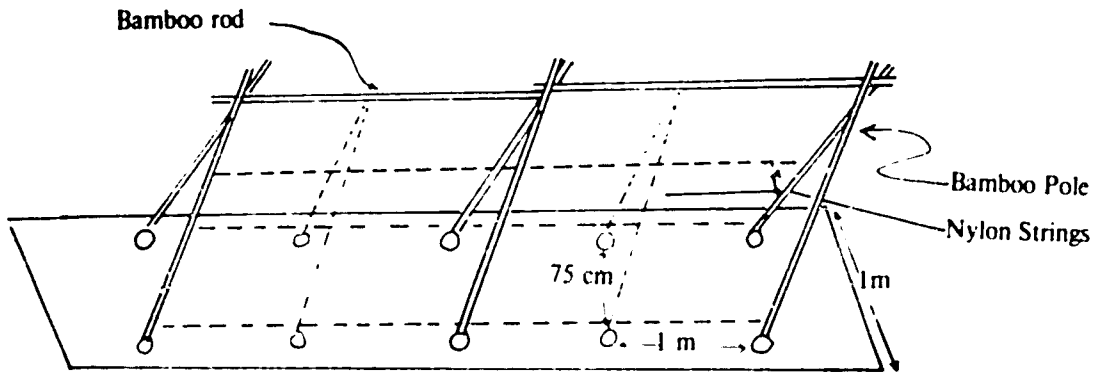



**Fig. 1. Winged bean trellis.**

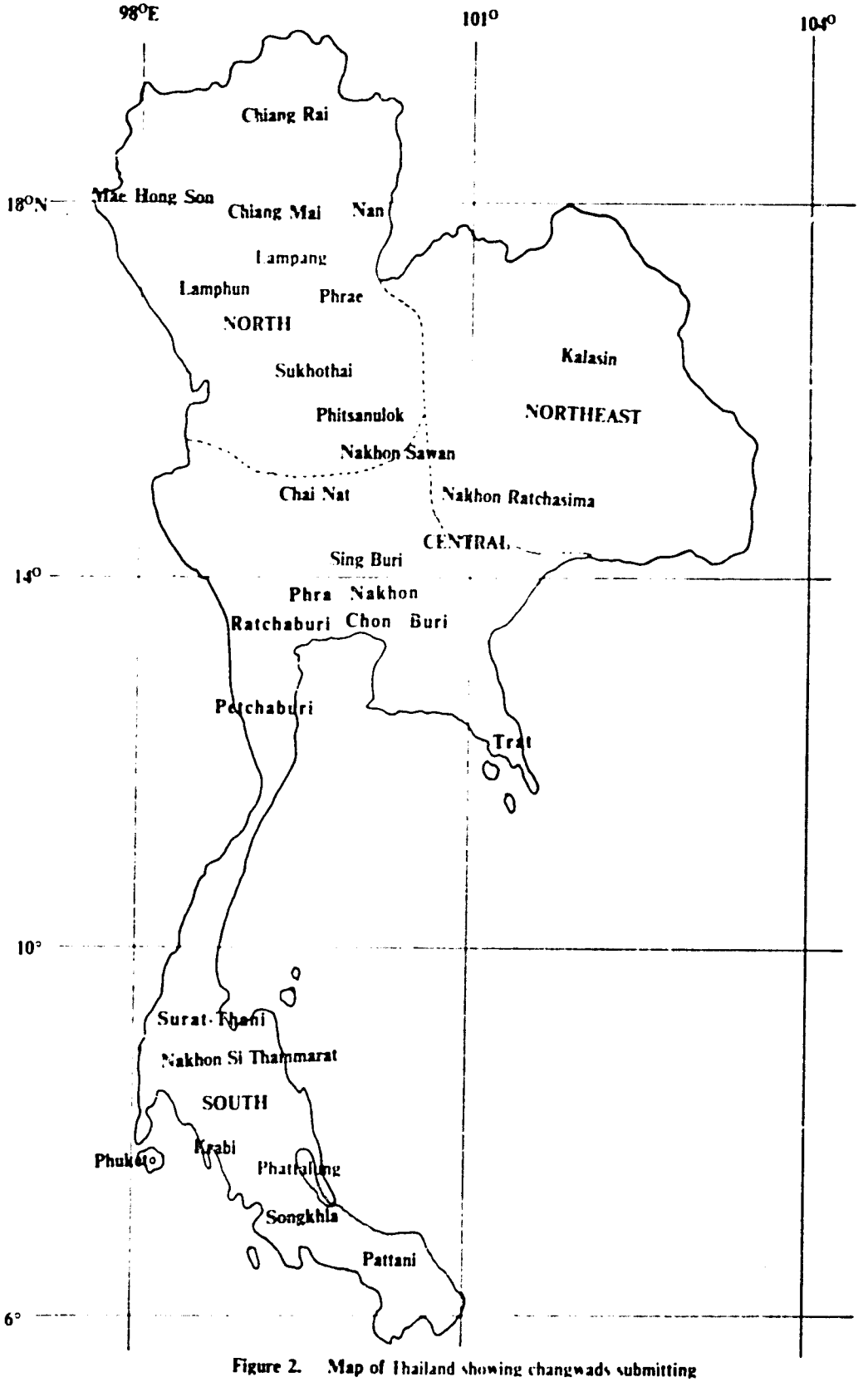



Figure 2. Map of Thailand showing changwads submitting the winged bean seeds.

**Table 2. Variation in qualitative characters in winged bean.**

| Variation in Seed Color | No. of accessions | Percentage |
|---|---|---|
| 1. Cream | 12 | 6.82 |
| 2. Very light brown* | — | 0 |
| 3. Light brown | 6 | 3.41 |
| 4. Medium brown | 14 | 7.95 |
| 5. Brown | 43 | 24.43 |
| 6. Dark brown | 23 | 13.07 |
| 7. Reddish brown | 23 | 13.07 |
| 8. Reddish purple | 12 | 6.82 |
| 9. Dark purple | 5 | 2.84 |
| 10. Black | 1 | 0.57 |
| 11. Light brownish green | 3 | 1.70 |
| 12. Brownish green | 9 | 5.11 |
| 13. Dark brownish green | 25 | 14.21 |
| Total | 176** | 100.00 |

| Variation in Flower Color | | |
|---|---|---|
| 1. White | 3 | 2.86 |
| 2. Very light blue | 1 | 0.95 |
| 3. Light blue | 1 | 0.95 |
| 4. Blue | 42 | 40.00 |
| 5. Blue purple | 57 | 54.29 |
| 6. Dark purple | 1 | 0.95 |
| Total | 105 | 100.00 |

| Variation in Leaf Shape | No. of accessions | Percentage |
|---|---|---|
| 1. Deltoid | 158 | 94.61 |
| 2. Lanceolate | 7 | 4.19 |
| 3. Long Lanceolate | 2 | 1.20 |
| Total | 167 | 100.00 |

| Variation in Pod Color | | |
|---|---|---|
| 1. Light green | 6 | 13.95 |
| 2. Green | 33 | 76.74 |
| 3. Dark green | 4 | 9.31 |
| Total | 43 | 100.00 |

| Variation in Pod Surface | | |
|---|---|---|
| 1. Smooth | 19 | 46.34 |
| 2. Moderately rough | 11 | 26.83 |
| 3. Contour | 11 | 26.83 |
| Total | 41 | 100.00 |

| Variation in Pod Shape | | |
|---|---|---|
| 1. Rectangular | 20 | 42.55 |
| 2. Semiflat | 20 | 42.55 |
| 3. Flat on side | 3 | 6.39 |
| 4. Flat on suture | 4 | 8.51 |
| Total | 47 | 100.00 |

*No such color was observed in the present study but it was observed in the introduced materials. It was decided to designate the same number of seed color in this study.

**Nine accessions died during the seedling stage.

Three basic leaf shapes were observed, namely, deltoid, lanceolate, and long lanceolate. A great majority of lines possessed deltoid leaves (94.61%).

Although flower color was arbitrarily classified into 6 categories, this character to be recorded since there was a continuous variation in the color of the flower. On the same plant, different shades of color could be observed at different times of the day. The two most prevalent colors were blue purple (54.29%), and blue (42%).

Pod shape could be classified as rectangular, semiflat, flat on side, and flat on suture. The first two shapes were equally abundant (42.55%) among the lines so far investigated.

Although the majority of the pods were green (76.74%), two other shades of green were also observed, namely, light green and dark green. The distinction of color is, however, not clear cut, since there were some pods on the same plants which exhibited graded series of green. Environmental factors, particularly light, may have some effect on pod coloration.

The pod surface on the sides could be classified into smooth, moderately rough, and contour (to fit the shape of the seeds). Smooth pod was the most prevalent type (46.34%) whereas the other two were equally abundant (26.83%).

As far as yields are concerned, it was observed that the following accessions were high-yielding: 12-10, 12-03, 13-03, 14-03, 16-03, 18-02, 21-05, 26-03, 28-01 (all from Nakhon Sawan), 43-05 (Ratchaburi), 63-02 (Phattalung), and 60-01 (Nakhon Ratchasima).

It was observed with great interest that most of the accessions were sensitive to photoperiod classified as short day plants which started to bloom in October. Judging from the pattern of photoperiod that prevails in

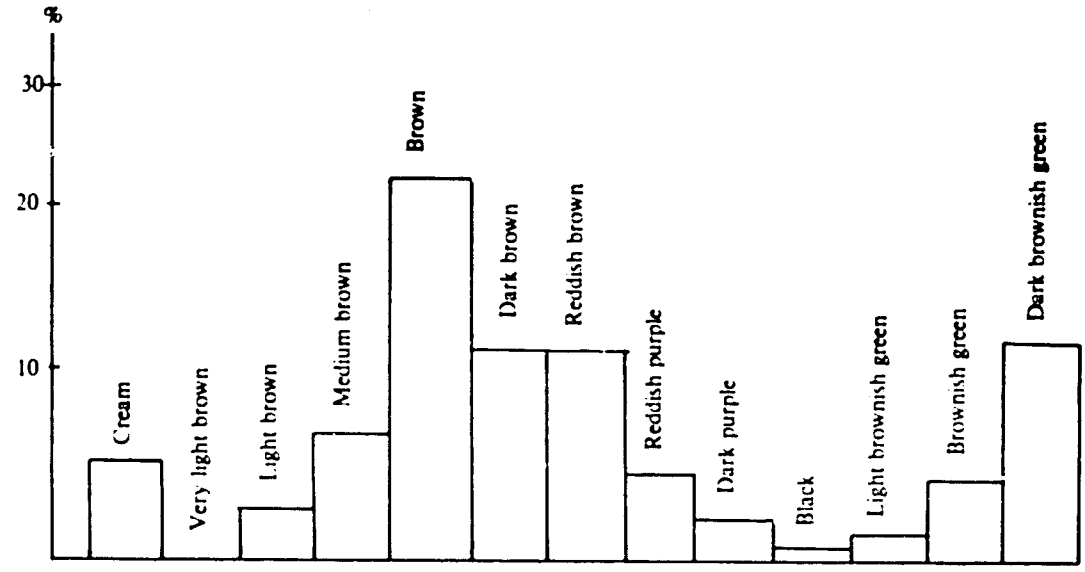
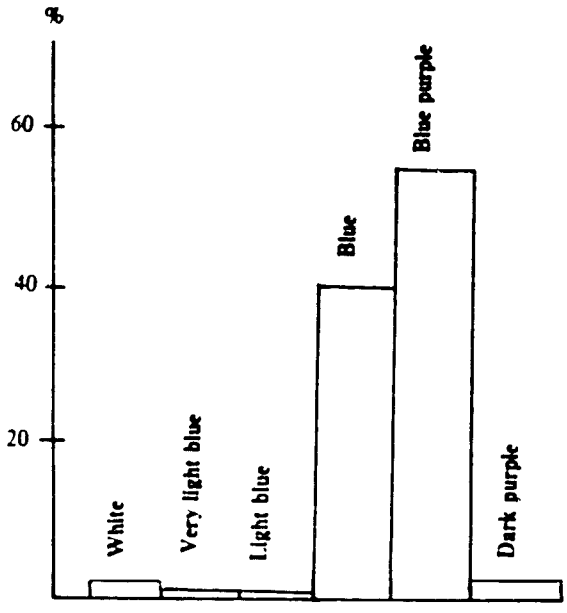



Fig. 3a Variation in seed color




Fib. 3b. Variation in flower color

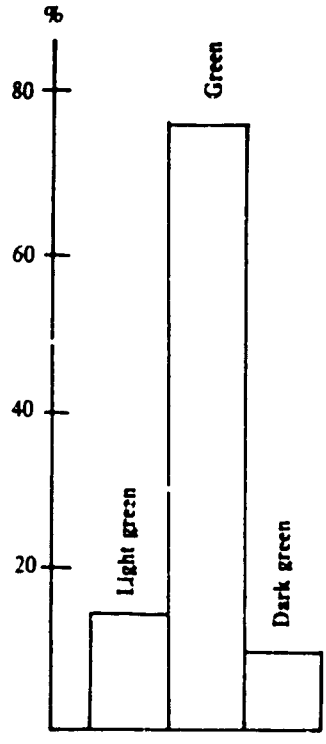



Fig. 3c. Variation in Pod Color

Fig. 3. Variation in qualitative characters in winged bean.

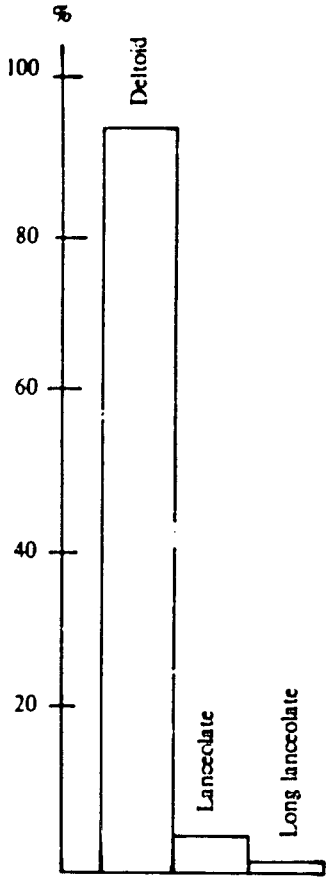



Fig. 3d. Variation in leaf shape

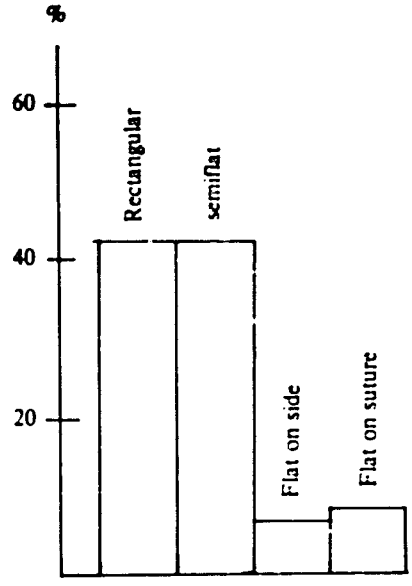



Fig. 3e. Variation in pod shape

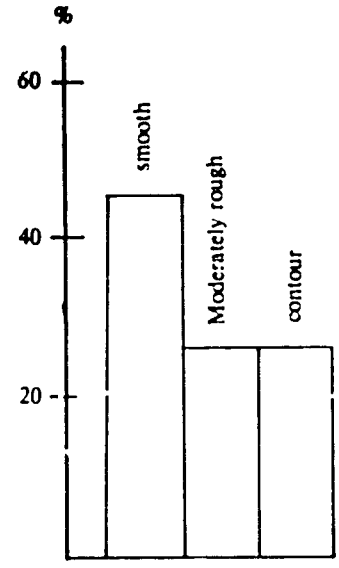



Fig. 3f. Variation in pod surface

Thailand, the critical value for winged bean is estimated at 12 1/2 hrs. Short day conditions was also found to have some influence on tuber formation.

## DISCUSSION

When on talks about winged bean in Thailand, one always has the feeling that it is one of the most common crop which grows in the backyard of most houses, both in town and in the village. Surprisingly enough, no varietal designation was ever given to the winged bean, not even the locality name. This is in contrast to most other native crops which bear numerous varietal names. Thus, it is taken for granted by most people that there is no variation in the winged bean in Thailand.

The present study, incomplete as it is due to time limitations, reveals for the first time that there exists a considerable amount of variation in many of the morphological characters such as seed color, leaf shape, flower color, pod shape, and pod surface. Upon further study, it would be expected that quantitative characters would also be greatly variable.

It is not surprising at all if one relates this finding to the fact that the winged bean has been grown in Thailand for quite a long time and that the system of growing has been very primitive, i.e. as the backyard crop. The climatic and edaphic conditions in all parts of the country are quite different from each other. This may have some effect on certain morphological characters. For example, the lanceolate and long-lanceolate leaves were found among accessions which came exclusively from the South (Accessions 04-01, 63-02, 63-07, 67-01, 68-01, 68-02, and 77-02). Furthermore, these leaf shapes are closely correlated with the apperance of the dark green pod. They were found in Accessions 63-02, 63-07, 67-01, and 77-02.

Another example can be seen in white (cream) seed accessions which came almost exclusively from the North, with one exception, Accession 43-06 from Ratchaburi. White seed character was also found to be associated with white flowers.

It is interesting to note that, although the winged bean believed to be a self pollinated crop which is expected to be completely homozygous, variation was observed among plants growing from seeds of the same pod. This was observed in two characters, namely:

Leaf shape: Accessions 67-01, 77-02, and 63-07 exhibited two leaf shapes, namely deltoid and lanceolate.

Pod shape: Accessions 58-02, 62-02, 63-03 have rectangular and semiflat pods. Accession 65-01 possessed pods which were rectangular, flat on side, and flat on suture. Accession 68-03 had flat on side and flat on suture pods. Accession 68-02 had semiflat and flat on suture pods.

It must, therefore, be concluded that, in contrast to the situation in Papua New Guinea (Khan 1976), upon which the extent of cross pollination appeared to be very low, and, consequently, variation that existed in the PNG lines may have evolved mainly through mutation, there are evidences of cross pollination in Thailand, probably with the aid of appropriate insect pollinators, particularly, the bumble bee. It appears that variation which exists in all the accessions under the present investigation may have derived through one or more of the following mechanisms: (1) introduction from other regions within Southeast Asia, (2) mutation, and (3) recombination. While the exact time of its arrival to Thailand is uncertain, it is clear that the winged bean must have been introduced into Thailand for so long to have evolved the amount of variation revealed in the present study. Recent archeological studies reveal that cultivation of crop plants in Thailand dates back to almost 7,000 years ago. Moreover, the system of agriculture in Thailand in the olden days was subsistence farming. In contrast to Papua New Guinea, Burma, and Indonesia where winged bean is more or less an "all purpose plant", in Thailand, it is traditionally a "single purpose plant", since only the young pods are eaten.

The variation occurring in Thailand will contribute greatly in developing the potential of winged bean. Even at this early stage, a few lines have been selected; and multiplication of seeds has been accelerated so that large scale plantation may commence shortly. Since the winged bean is now considered a native crop which is well adapted to the climatic conditions of Thailand, to launch a project on large scale plantation will not be so difficult, provided that the market outlook is bright.

Although all of the winged bean varieties in existence at the present time still possess the indeterminate viny growth habit which is considered by some to be a hindrance, such a character may be advantageous to underdeveloped and developing countries where labor is abundant. If an erect, self-supporting variant were discovered which will make machine harvesting possible the chances for these countries to produce winged bean on a large scale would be slim. On the other hand, the merit of such a type of plant is doubtful since winged bean pods are much larger than that of other beans, to clump a large number of large pods on a short stature plant with a determinate habit of flowering seems almost impossible. To have an indeterminate type of flowering along with vines which extends the growth along the 3 m pole will be much more productive than the short stature, determinate type. A breeding program should, therefore, be concentrated on increasing seed and tuber yields with higher nutritive values. A day neutral variant should also be looked for so that it can be grown throughout the year and the growing area extended to the higher altitude regions.

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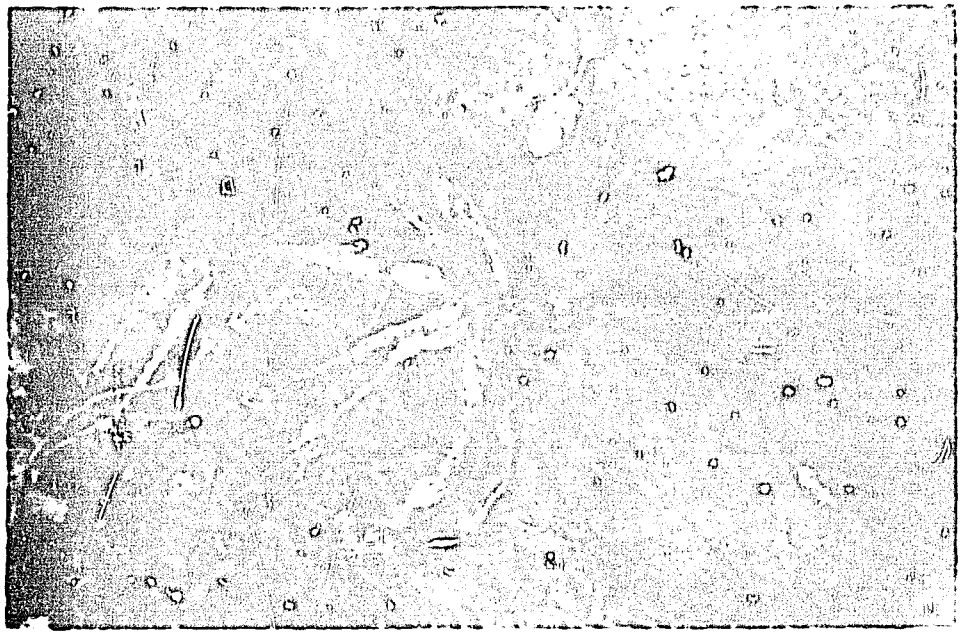
1.



2.

*1. Tuber yields in Thailand 2. Prolific pod bearing variety*

**Appendix 1. Characteristics of 167 accessions of winged bean germplasm.**

| No. | Source | Entry | Line | Seed color[1] | wt. of 20 seeds (gm) | Leaf shape[2] | Flower color[3] | Pod | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Shape[4] | Color[5] | Surface[6] |
| 1 | Phuket | 01 | 01 | 5 | 4.9 | 1 | 5 | — | — | — |
| 2 | Phuket | 02 | 01 | 6 | 4.8 | 1 | — | — | — | — |
| 3 | Chai Nat | 33 | 01 | 6 | — | 1 | 5 | — | — | — |
| 4 | Chai Nat | 03 | 02 | 7 | — | 1 | 5 | — | — | — |
| 5 | Chai Nat | 03 | 05 | 12 | — | 1 | 4 | — | — | — |
| 6 | Chai Nat | 03 | 06 | 13 | — | 1 | 5 | — | — | — |
| 7 | Songkhla | 04 | 01 | 5 | — | 3 | — | — | — | — |
| 8 | Songkhla | 04 | 02 | 6 | — | 1 | — | — | — | — |
| 9 | Phetchabun | 05 | 01 | 5 | 8.7 | 1 | 5 | — | — | — |
| 10 | Phetchabun | 06 | 01 | 5 | 7.7 | 1 | 4 | — | — | — |
| 11 | Phetchabun | 07 | 01 | 5,6,7,8 | 5.3 | 1 | — | — | — | — |
| 12 | Chon Buri | 08 | 03 | 5 | 7.2 | 1 | 5 | — | — | — |
| 13 | Nakhon Sawan | 12 | 01 | 7,12 | 8.86 | 1 | 5 | — | — | — |
| 14 | Nakhon Sawan | 12 | 02 | 5 | 7.14 | 1 | 5 | — | — | — |
| 15 | Nakhon Sawan | 12 | 03 | 8 | 8.38 | 1 | 4 | — | — | — |
| 16 | Nakhon Sawan | 13 | 01 | 13 | 9.71 | 1 | — | — | — | — |
| 17 | Nakhon Sawan | 13 | 02 | 10 | 6.60 | 1 | 5 | — | — | — |
| 18 | Nakhon Sawan | 13 | 03 | 8 | 6.16 | 1 | 4 | — | — | — |
| 19 | Nakhon Sawan | 13 | 04 | 7 | 6.40 | 1 | 4 | — | — | — |
| 20 | Nakhon Sawan | 14 | 01 | 7 | 6.98 | 1 | 4 | — | — | — |
| 21 | Nakhon Sawan | 14 | 03 | 5 | 6.18 | 1 | 5 | — | — | — |
| 22 | Nakhon Sawan | 14 | 04 | 12 | 6.3 | 1 | 5 | — | — | — |
| 23 | Nakhon Sawan | 14 | 05 | 5 | 7.72 | 1 | 5 | — | — | — |
| 24 | Nakhon Sawan | 15 | 01 | 12,13 | 6.1 | 1 | 5 | — | — | — |
| 25 | Nakhon Sawan | 15 | 02 | 12 | 8.0 | 1 | 5 | — | — | — |
| 26 | Nakhon Sawan | 15 | 03 | 4 | 6.7 | 1 | 5 | — | — | — |
| 27 | Nakhon Sawan | 16 | 01 | 12 | 5.65 | 1 | 5 | — | — | — |
| 28 | Nakhon Sawan | 16 | 02 | 7 | 7.56 | 1 | 4 | — | — | — |
| 29 | Nakhon Sawan | 16 | 03 | 5 | 7.27 | 1 | 5 | — | — | — |
| 30 | Nakhon Sawan | 17 | 02 | 6 | 5.80 | 1 | 5 | — | — | — |
| 31 | Nakhon Sawan | 18 | 02 | 5 | 5.1 | 1 | 4 | — | — | — |
| 32 | Nakhon Sawan | 18 | 03 | 4 | 7.8 | 1 | 4 | — | — | — |
| 33 | Nakhon Sawan | 19 | 02 | 13 | 7.20 | 1 | 4 | — | — | — |
| 34 | Nakhon Sawan | 19 | 03 | 9 | 7.98 | 1 | — | — | — | — |
| 35 | Nakhon Sawan | 19 | 04 | 8 | 7.53 | 1 | — | — | — | — |
| 36 | Nakhon Sawan | 19 | 05 | 5 | 7.60 | 1 | 5 | — | — | — |
| 37 | Nakhon Sawan | 20 | 01 | 13 | 6.60 | 1 | — | — | — | — |
| | Nakhon Sawan | 20 | 02 | 8 | 8.25 | 1 | 4 | — | — | — |
| 39 | Nakhon Sawan | 20 | 03 | 5 | 7.21 | 1 | 5 | — | — | — |
| 40 | Nakhon Sawan | 21 | 01 | 7 | 9.8 | 1 | 5 | — | — | — |
| 41 | Nakhon Sawan | 21 | 02 | 12,13 | 7.58 | 1 | 4 | — | — | — |
| 42 | Nakhon Sawan | 21 | 03 | 13 | 8.5 | 1 | 4 | — | — | — |
| 43 | Nakhon Sawan | 21 | 04 | 7 | 8.9 | 1 | 4 | — | — | — |
| 44 | Nakhon Sawan | 21 | 05 | 4,5,6,7 | 9.5 | 1 | 5 | — | — | — |
| 45 | Nakhon Sawan | 22 | 01 | 12 | 8.75 | 1 | 5 | — | — | — |
| 46 | Nakhon Sawan | 22 | 02 | 9 | 6.74 | 1 | 5 | — | — | — |
| 47 | Nakhon Sawan | 22 | 03 | 7 | 6.81 | 1 | 4 | — | — | — |
| 48 | Nakhon Sawan | 22 | 04 | 7 | 6.55 | 1 | — | — | — | — |
| 49 | Nakhon Sawan | 23 | 01 | 13 | 6.69 | 1 | — | — | — | — |
| 50 | Nakhon Sawan | 23 | 02 | 7 | 6.2 | 1 | 4 | — | — | — |
| 51 | Nakhon Sawan | 24 | 01 | 6 | 7.0 | 1 | — | — | — | — |
| 52 | Nakhon Sawan | 25 | 01 | 13 | 7.85 | 1 | 5 | — | — | — |
| 53 | Nakhon Sawan | 25 | 02 | 8 | 7.32 | 1 | 5 | — | — | — |
| 54 | Nakhon Sawan | 25 | 03 | 5 | 8.36 | 1 | 4 | — | — | — |
| 55 | Nakhon Sawan | 26 | 01 | 7 | 7.12 | 1 | — | — | — | — |
| 56 | Nakhon Sawan | 26 | 02 | 4,5 | 6.87 | 1 | 5 | — | — | — |
| 57 | Nakhon Sawan | 26 | 03 | 5 | 5.57 | 1 | 4 | — | — | — |
| 58 | Nakhon Sawan | 27 | 02 | 12 | 6.21 | 1 | 5 | — | — | — |
| 59 | Nakhon Sawan | 27 | 03 | 8,9 | 6.33 | 1 | 5 | — | — | — |
| 60 | Nakhon Sawan | 27 | 04 | 6 | 5.97 | 1 | 5 | — | — | — |
| 61 | Nakhon Sawan | 28 | 01 | 13 | 9.07 | 1 | 4 | — | — | — |
| 62 | Nakhon Sawan | 28 | 03 | 5 | 6.81 | 1 | 5 | — | — | — |
| 63 | Chiang Mai | 36 | 02 | 6 | 6.80 | 1 | 5 | — | — | — |
| 64 | Ratchaburi | 43 | 02 | 7 | 6.1 | 1 | 5 | — | — | — |
| 65 | Ratchaburi | 43 | 03 | 4,5 | 7.0 | 1 | 5 | — | — | — |
| 66 | Ratchaburi | 43 | 04 | 5 | 7.4 | 1 | 5 | — | — | — |
| 67 | Ratchaburi | 43 | 06 | 1 | 5.5 | 1 | 5 | — | — | — |

**Appendix 1. continued...**

| No. | Source | Entry | Line | Seed color[1] | wt. of 20 seeds (gm) | Leaf shape[2] | Flower color[3] | Pod Shape[4] | Pod Color[5] | Pod Surface[6] |
|---|---|---|---|---|---|---|---|---|---|---|
| 68 | Phrae | 44 | 01 | 7 | 7.4 | 1 | 4 | — | — | — |
| 69 | Phrae | 46 | 01 | 7 | 7.4 | 1 | 4 | — | — | — |
| 70 | Phrae | 46 | 02 | 6 | 8.2 | 1 | 5 | — | — | — |
| 71 | Phrae | 46 | 03 | 5 | 8.6 | 1 | 5 | — | — | — |
| 72 | Phrae | 49 | 01 | 13 | 5.2 | 1 | 5 | — | — | — |
| 73 | Phrae | 50 | 01 | 13 | 5.8 | 1 | 4 | — | — | — |
| 74 | Phra Nakhon | 51 | 01 | 5 | 8.5 | 1 | 5 | — | — | — |
| 75 | Phra Nakhon | 52 | 01 | 7 | 7.0 | 1 | — | — | — | |
| 76 | Chai Nat | 53 | 01 | 5,6 | 7.85 | 1 | — | 1 | 2 | 3 |
| 77 | Chai Nat | 53 | 02 | 5 | 10.0 | 1 | — | 1 | 1 | 3 |
| 78 | Chai Nat | 53 | 03 | 6 | 4.46 | 1 | 4 | 1 | 2 | 3 |
| 79 | Chai Nat | 53 | 04 | 5 | 7.23 | 1 | — | 1 | 2 | 3 |
| 80 | Kalasin | 54 | 01 | 5 | 5.83 | 1 | — | 2 | 1 | 1 |
| 81 | Kalasin | 55 | 01 | 5 | 7.67 | 1 | 5 | 2 | 2 | 3 |
| 82 | Kalasin | 56 | 01 | 6 | 7.2 | 1 | — | 2 | 2 | 3 |
| 83 | Kalasin | 56 | 02 | 5 | 7.09 | 1 | — | 2 | 1 | 2 |
| 84 | Kalasin | 57 | 01 | 3 | 5.23 | 1 | 5 | — | — | — |
| 85 | Pattani | 58 | 01 | 3,4 | 4.0 | 1 | 4 | — | — | — |
| 86 | Pattani | 58 | 02 | 5 | 6.1 | 1 | 4 | 1,2 | 2 | 2 |
| 87 | Phetchabun | 59 | 01 | 4,5 | 5.56 | 1 | 4 | 2 | 2 | 1 |
| 88 | Nakhon Ratchasima | 60 | 01 | 5 | 7.5 | 1 | — | 1 | 1 | 1 |
| 89 | Surat Thani | 61 | 01 | 5 | 4 | 4.8 | 1 | 5 | 2 | 2 |
| 90 | Surat Thani | 61 | 02 | 5 | 8.47 | 1 | 4 | 1 | 2 | 1 |
| 91 | Surat Thani | 62 | 01 | 4 | 8.82 | 1 | 4 | 4 | 2 | 1 |
| 92 | Surat Thani | 62 | 02 | 6 | 10.73 | 2 | 4 | 1,2 | 2 | 1 |
| 93 | Surat Thani | 62 | 03 | 4 | 9.62 | 2 | 4 | 2 | 2 | 1 |
| 94 | Surat Thani | 62 | 04 | 6 | 7.2 | 1 | 6 | — | — | — |
| 95 | Phatthalung | 63 | 01 | 5 | 7.33 | 1 | 4 | — | — | — |
| 96 | Phatthalung | 63 | 02 | 5 | 7.43 | 3 | 4 | 1 | 3 | 1 |
| 97 | Phatthalung | 63 | 06 | 8 | 8.50 | 1 | — | — | — | — |
| 98 | Phatthalung | 63 | 07 | 3 | 5.56 | 1,2 | 4 | 1 | 3 | 3 |
| 99 | Phatthalung | 63 | 08 | 5 | 9.25 | 1 | 3 | 1,2 | 2 | 3 |
| 100 | Sing Buri | 64 | 01 | 4 | 6.50 | 1 | 4 | 2 | 2 | 2 |
| 101 | Sing Buri | 64 | 02 | 4 | 5.75 | 1 | — | — | — | — |
| 102 | Sing Buri | 64 | 03 | 5 | 6.50 | 1 | 5 | 2 | 2 | 2 |
| 103 | Phetchabun | 65 | 01 | 5 | 6.50 | 1 | — | 1,3,4 | 2 | 1 |
| 104 | Phetchabun | 65 | 02 | 6 | 6.91 | 1 | — | 2 | 1 | 1 |
| 105 | Phetchabun | 65 | 03 | 13 | 6.62 | 1 | — | — | — | — |
| 106 | Phetchabun | 65 | 04 | 6 | 3.82 | 1 | 2 | 1 | 2 | 2 |
| 107 | Phetchabun | 65 | 05 | 5 | 5.0 | 1 | — | 2 | 1 | 2 |
| 108 | Phetchabun | 65 | 06 | 5 | 6.57 | 1 | 5 | 1 | 2 | 1 |
| 109 | Nan | 66 | 01 | 5 | 6.0 | 1 | 4 | 2 | 2 | 2 |
| 110 | Nan | 66 | 02 | 9 | 5.17 | 1 | 4 | 2,3 | 2 | 2 |
| 111 | Nan | 66 | 03 | 6 | 5.09 | 1 | 5 | 2 | 2 | 2 |
| 112 | Krabi | 67 | 01 | 3 | 5.80 | 1,2 | 5 | 2 | 3 | 1 |
| 113 | Krabi | 67 | 02 | 5 | 6.30 | 1 | 5 | — | — | — |
| 114 | Pattani | 68 | 01 | 3,4 | 7.07 | 2 | 4 | — | — | — |
| 115 | Pattani | 68 | 02 | 5 | 8.18 | 2 | 4 | 2,4 | 2 | 1 |
| 116 | Phitsanulok | 69 | 01 | 8 | 5.44 | 1 | 5 | 3 | 2 | 3 |
| 117 | Phitsanulok | 69 | 02 | — | 6.20 | 1 | — | — | — | — |
| 118 | Sukhothai | 70 | 01 | 5 | 7.43 | 1 | 5 | 1 | 2 | 2 |
| 119 | Sukhothai | 70 | 02 | 6 | 6.91 | 1 | 5 | 1 | 2 | 2 |
| 120 | Trat | 71 | 01 | 13 | 5.80 | 1 | 4 | 4 | 2 | 2 |
| 121 | Mae Hong Son | 72 | 01 | 1 | 8.89 | 1 | — | — | — | — |
| 122 | Mae Hong Son | 72 | 02 | 11 | 7.50 | 1 | 1 | — | — | — |
| 123 | Mae Hong Son | 72 | 03 | 11 | 8.57 | 1 | — | — | — | — |
| 124 | Mae Hong Son | 73 | 01 | 1 | 8.86 | 1 | 1 | — | — | — |
| 125 | Mae Hong Son | | 02 | 1 | 5.0 | 1 | 1 | — | — | — |
| 126 | Nakhon Si Thammarat | 74 | 04 | — | 6.0 | 1 | — | — | — | — |
| 127 | Lamphun | 75 | 01 | 13 | 5.56 | 1 | 5 | 1 | 2 | 1 |
| 128 | Lampang | 76 | 01 | 7 | 6.83 | 1 | 5 | 1 | 2 | 1 |
| 129 | Lampang | 76 | 02 | 7 | 6.83 | 1 | 5 | 2 | 2 | 1 |
| 130 | Lampang | 76 | 03 | 13 | 7.33 | 1 | 5 | 4 | 2 | 3 |
| 131 | Phatthalung | 77 | 01 | 6 | 7.08 | 1 | 4 | 1 | 2 | 1 |
| 132 | Phatthalung | 77 | 02 | 3 | 6.40 | 1,2 | 5 | 1 | 1,3 | 1 |

**Appendix 1. continued...**

| No. | Source | Entry | Line | Seed color[1] | wt. of 20 seeds (gm) | Leaf shape[2] | Flower color[3] | Pod | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Shape[4] | Color[5] | Surface[6] |
| 133 | Chiang Rai | 77 | 01 | 1 | 5.67 | 1 | – | – | – | – |
| 134 | Chiang Rai | 78 | 03 | 8 | 7.52 | 1 | – | – | – | – |
| 135 | Chiang Rai | 78 | 04 | 13 | 5.87 | 1 | – | – | – | – |
| 136 | Chiang Rai | 78 | 05 | 13 | 6.70 | 1 | – | – | – | – |
| 137 | Chiang Rai | 78 | 06 | 13 | 5.89 | 1 | – | – | – | |
| 138 | Chiang Rai | 78 | 07 | 8 | 6.33 | 1 | – | – | – | – |
| 139 | Chiang Rai | 79 | 02 | 1 | 5.88 | 1 | – | – | – | – |
| 140 | Chiang Rai | 80 | 03 | 7 | 4.27 | 1 | – | – | – | – |
| 141 | Chiang Rai | 81 | 01 | – | 5.20 | 1 | – | – | – | – |
| 142 | Chiang Rai | 81 | 02 | 7 | 5.76 | 1 | – | – | – | – |
| 143 | Chiang Rai | 81 | 03 | – | 5.0 | 1 | – | – | – | – |
| 144 | Chiang Rai | 81 | 04 | 9 | 5.56 | 1 | – | – | – | – |
| 145 | Chiang Rai | 82 | 02 | 12 | 10.60 | 1 | – | – | – | – |
| 146 | Chiang Rai | 82 | 03 | 13 | 8.11 | 1 | – | – | – | – |
| 147 | Chiang Rai | 82 | 05 | 13 | 7.37 | – | – | – | – | – |
| 148 | Chiang Rai | 83 | 02 | 1 | 6.40 | 1 | – | – | – | – |
| 149 | Chiang Rai | 83 | 03 | 1 | 6.41 | 1 | – | – | – | – |
| 150 | Chiang Rai | 83 | 04 | 6 | 5.41 | 1 | – | – | – | – |
| 151 | Chiang Rai | 83 | 05 | 6 | 5.94 | 1 | – | – | – | – |
| 152 | Chiang Rai | 84 | 02 | 1 | 5.98 | 1 | – | – | – | – |
| 153 | Chiang Rai | 84 | 03 | 4 | 7.40 | 1 | – | – | – | – |
| 154 | Chiang Rai | 84 | 04 | – | 9.30 | 1 | – | – | – | – |
| 155 | Chiang Rai | 84 | 05 | 7 | 7.11 | 1 | – | – | – | – |
| 156 | Chiang Rai | 85 | 01 | 1 | 7.72 | 1 | – | – | – | – |
| 157 | Chiang Rai | 85 | 03 | 13 | 7.53 | 1 | – | – | – | – |
| 158 | Chiang Rai | 85 | 04 | 6 | 8.10 | 1 | – | – | – | – |
| 159 | Chiang Rai | 85 | 05 | 8 | 7.95 | 1 | – | – | – | – |
| 160 | Chiang Rai | 86 | 01 | – | 2.50 | 1 | – | – | – | – |
| 161 | Chiang Rai | 86 | 02 | – | 2.53 | – | – | – | – | – |
| 162 | Chiang Rai | 86 | 03 | 13 | 5.55 | 1 | – | – | – | – |
| 163 | Chiang Mai | 88 | 01 | 1 | 6.70 | 1 | – | – | – | – |
| 164 | Chiang Mai | 89 | 01 | 7 | 8.51 | 1 | – | – | – | – |
| 165 | Chiang Mai | 91 | 01 | 1 | 9.54 | 1 | – | – | – | – |
| 166 | Chiang Mai | 94 | 01 | 13 | 10.09 | 1 | – | – | – | – |
| 167 | Phra Nakhon | 95 | 01 | 4 | – | 1 | – | – | – | – |

[1]Seed color – 1 = Cream; 2 = Very light brown; 3 = Light brown; 4 = Medium brown; 5 = Brown; 6 = Dark brown; 7 = Reddish brown; 8 = Reddish purple; 9 = Dark purple; 10 = Black; 11 = Light brownish green; 12 = Brownish green; 13 = Dark brownish green.

[2]Leaf shape – 1 = Deltoid; 2 = Lanceolate; 3 = Long lanceolate.

[3]Flower color – 1 = White; 2 = Very light blue; 3 = Light blue; 4 = Blue; 5 = Blue purple; 6 = Dark purple.

[4]Pod shape – 1 = Rectangular; 2 = Semiflat; 3 = Flat on side; 4 = Flat on suture.

[5]Pod color – 1 = Light green; 2 = green; 3 = dark green.

[6]Pod surface – 1 = smooth; 2 = moderately rough; 3 = contour.

# Collection, Evaluation, and Conservation of Winged Bean Germplasm in the Philippines

*N. G. Mamicpic and M. M. Movillon*[1]

**Winged bean was introduced into the Philippines in prehistoric or within early historical times from the Malay region. The first account of it in Philippine literature was in 1837 by Fr. Manuel Blanco in his Flora de las Filipinas which contains the first botanical illustration based on Philippine plant material. The species is widely distributed in the archipelago and is referred to by many interesting local names. The two more commonly used names are *kalamismis* and *segadillas*. Its principal use is as vegetable, particularly the immature pod.**

**Germplasm collection and crop improvement is just beginning and to date the Philippine collection consists of 88 local accessions and 37 foreign introductions. Preliminary data on 15 morphological and agronomic traits indicate significant genetic variability in the Philippine winged bean germplasm. Further exploration, collection, evaluation and proper conservation is expected to enrich the present genetic resource for winged bean improvement.**

## INTRODUCTION

The attention now given to winged by those concerned with food and agriculture in the Philippines is very recent, no doubt as a result of the current drive to develop the winged bean as a highly nutritious crop in the tropics. This is very timely since the emphasis of the Philippine Nutrition Program is to grow indigenous, easy to grow, and already acceptable nutritious crops, like winged bean.

The winged bean, *Psophocarpus tetragonolobus* (L) DC was introduced to the Philippines from the Malay region either in pre-historic or within early historical times long before the advent of the Europeans in the Orient (Merill 1912). It first appeared in Philippine literature in Fr. Manuel Blanco's Flora de las Filipinas (1837) under the name *Dolicos tetragonolobus* L. Fr. Blanco stated that he saw living plants cultivated in Manila, and noted that it flowers in December. A plate (Tab. 293) approximately 20" x 15" with a satisfactory botanical illustration of the plant based on Philippine material was drawn by F. Domingo. The caption reads, *Dolichos tetragonolobus* Linn-Blanco *Psophocarpus tetragonolobus* DC var. macropterus Hassk-Miq.

The winged bean is known by many local names in the Philippines indicating its widespread distribution among various ethnic groups in the archipelago. More commonly, it is called "kalamismis" (Tagalog) or segadillas (Panay, Bisaya). Its wide acceptance as a food crop in the Philippines is immortalized in a very popular Philippine folk song "Bahay Kubo" which enumerates "segadillas" third of seventeen crops[2] usually grown in the yard of the Filipino's nipa hut (bahay kubo).

## COLLECTION

Local collection efforts are very recent mostly within the last two years. Major efforts to collect local varieties are those of the Institute of Plant Breeding (IPB), University of the Philippines at Los Baños, with United Nations Environment Program funds, the Palawan National Agricultural College (PNAC) in Aborlan, Palawan which has a good number of accessions from the island of Palawan, and the Bureau of Plant Industry (BPI). Several foreign introductions are included in the collections of these institutions.

As of December 31, 1977, the winged bean germplasm in the National Plant Genetic Resources Laboratory Institute of Plant Breeding consists of 88 local and 37 foreign accessions listed in Table 1.

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[2]**Singkamas** (*P. erosus*), **talong** (*S. melongena*), **segadillas** (*P. tetragonolobus*), **mani** (*A. hypogea*), **sitaw** (*V. sesquipedalis*), **bataw** (*D. lablab*), **patani** (*P. lunatus*), **kundol** (*B. hispida*), **patola** (*Luffa sp.*), **upo** (*L. siceraria*), **kalabasa** (*C. maxima*), **labanos** (*R. sativa*), **mustasa** (*B. juncea*), **kamatis** (*L. esculentum*), **bawang** (*A. sativum*), **luya** (*Z. officinalis*), **linga** (*S. orientale*).

**Table 1. Winged Bean Accession of the National Plant Genetic Resources Laboratory Institute of Plant Breeding, UPLB as of December 31, 1977.**

| Accession # | Pedigree/Origin/Source | Accession # | Pedigree/Origin/Source |
|---|---|---|---|
| 001 | BPI, Dingras, Ilocos Sur | 055 | Puerto Princesa, Palawan |
| 002 | Dingras, Ilocos Sur | 056 | Puerto Princesa, Palawan |
| 003 | MMSMCST | 057 | WB-29 Puerto Rico |
| 004 | BPI, Ilocos Norte | 058 | FLB-1, Davao |
| 005 | WB 6-6, Puerto Rico | 059 | FLB-2, Iloilo |
| 006 | WB 10-8, Puerto Rico | 060 | FLB-3, Sta. Barbara, Iloilo |
| 007 | WB 11-2, Puerto Rico | 061 | FLB-4, Bacolod City |
| 008 | WB 12-1, Puerto Rico | 062 | FLB-5, Los Baños, Laguna |
| 009 | WB 12-4, Puerto Rico | 063 | FLB-6, Santa, Ilocos Sur |
| 010 | WB 12-8, Puerto Rico | 064 | FLB-7, Ballesteros, Cagayan |
| 011 | WB 12-11, Puerto Rico | 065 | FLB-8, Malalan, Ilagan, Isabela |
| 012 | WB 15-12, Puerto Rico | 066 | FLB-9, Carumatan, Ilagan, Isabela |
| 013 | WB 16-1, Puerto Rico | 067 | FLB-10, BPI, Ilagan, Isabela |
| 014 | WB 16-11, Puerto Rico | 068 | FLB-11, San Antonio, Ilagan, Isabela |
| 015 | WB 19-4, Puerto Rico | 069 | FLB-12, Simminbaoon, Roxas, Isabela |
| 016 | WB 19-9, Puerto Rico | 070 | FLB-13, San Juan, La Union |
| 017 | WB 21-4, Puerto Rico | 071 | FLB-14, San Juan, La Union |
| 018 | Taiwan | 072 | FLB-15, San Juan, La Union |
| 019 | Perez, Calauan, Laguna | 073 | FLB-16, San Juan, La Union |
| 020 | Batac, Ilocos Norte | 074 | FLB-17, San Juan, La Union |
| 021 | Nueva Ecija | 075 | FLB-21, Ballesteros, Cagayan |
| 022 | Rosario, Batangas | 076 | FLB-22, Alimodian, Iloilo |
| 023 | Pangasinan | 077 | FLB-23, Baclaran, Metro Manila |
| 024 | Tanauan, Batangas | 078 | Pangasinan (Medium), Veg. Crops, UPLB |
| 025 | Casiguran, Sorsogon | 079 | Pangasinan (Small), Veg. Crops, UPLB |
| 026 | Torrijos, Marinduque | 080 | Pangasinan (Long), Veg. Crops, UPLB |
| 027 | Mogpog, Marinduque | 081 | Puerto Princesa 4-9, PNAC[1] |
| 028 | Mogpog, Marinduque | 082 | Puerto Princesa 5-9, PNAC |
| 029 | Mogpog, Marinduque | 083 | Puerto Princesa 7-9, PNAC |
| 030 | Torrijos, Marinduque | 084 | Puerto Princesa 11-8, PNAC |
| 031 | Torrijos, Marinduque | 085 | Aborlan 3-1, PNAC |
| 032 | Nabua, Camarines Sur | 086 | Aborlan 3-2, PNAC |
| 033 | Pili, Camarines Sur | 087 | Aborlan 7-1, PNAC |
| 034 | Sibuyan, Romblon | 088 | Aborlan 11-2, PNAC |
| 035 | Sibuyan, Romblon | 089 | Aborlan 14-9, PNAC |
| 036 | Sibuyan, Romblon | 090 | Narra 2-2, PNAC |
| 037 | Pili, Camarines Sur | 091 | Narra 8-5, PNAC |
| 038 | Valenzuela, Bulacan | 092 | Narra 12-5, PNAC |
| 039 | Pangasinan | 093 | Narra 19-6, PNAC |
| 040 | Pangasinan | 094 | Narra 21-6, PNAC |
| 041 | Pangasinan | 095 | Brookspoint 4-2, PNAC |
| 042 | TPT-1, Nigeria | 096 | Brookspoint 5-8, PNAC |
| 043 | TPT-2, Nigeria | 097 | Brookspoint 9-2, PNAC |
| 044 | TPT-3, Nigeria | 098 | Brookspoint 9-3, PNAC |
| 045 | TPT-4, Nigeria | 099 | Brookspoint 14-2, PNAC |
| 046 | TPT-6, Nigeria | 100 | Roxas 2A-6, PNAC |
| 047 | TPT-16, Nigeria | 101 | Roxas 5-8, PNAC |
| 048 | UPS 122, Nigeria | 102 | Roxas 6-8, PNAC |
| 049 | LBN 902 (1), LBN, Indonesia | 103 | Roxas 8-9, PNAC |
| 050 | LBN 902 (3), LBN, Indonesia | 104 | Roxas 10, PNAC |
| 051 | LBN 1000, LBN, Indonesia | 105 | Batarasa 1-2, PNAC |
| 052 | Wanosari Mkt., Yogya, Indonesia | 106 | Batarasa 3-2, PNAC |
| 053 | Wanosari Mkt., Yogya, Indonesia | 107 | Batarasa 4-4, PNAC |
| 054 | Puerto Princesa, Palawan | 108 | Batarasa 6-4, PNAC |

**Table 1. continued...**

| Accession # | Pedigree/Origin/Source |
|---|---|
| 109 | UPS-122, IITA; PI-7042, BPI[2] |
| 110 | UPS-31, IITA; PI-7045, BPI |
| 111 | UPS-47, IITA; PI-7046, BPI |
| 112 | UPS-121, IITA; PI-7048, BPI |
| 113 | PI-7241, BPI, Mindoro |
| 114 | PI-7242, BPI, Mindoro |
| 115 | PI-7247, BPI; Cabuyao |
| 116 | UPS-113, IITA, PI-7252, BPI |
| 117 | UPS-115, IITA; PI-7253a, BPI |
| 118 | UPS-67, IITA; PI-7254, BPI |
| 119 | UPS-66, IITA, PI-7257, BPI |
| 120 | PI-7266, BPI, Cavite |
| 121 | SJC-77-1, BPI |
| 122 | SJC-77-2, BPI |
| 123 | SJC-77-3, BPI |
| 124 | UPS-112, IITA, PI-7256 |
| 125 | UPS-22, |

[1]Palawan National Agricultural College, Aborlan, Palawan; seeds provided by PCARR.
[2]Seeds provided by PCARR from BPI La Granja.

## EVALUATION OF GERMPLASM

Information on the present collection of the winged bean is very sketchy because these are recent collections which are still being multiplied. Based on these information, the range in variability of some characters are shown as follows:

**Seed Color**

1. **Local collection.** Based on 47 accessions, seed color ranges from light brown; biege; brown; maroon; dark brown to black.
2. **Foreign collection.** Based on 29 accessions seed color ranges from light brown; brown; maroon; dark brown to black.

**Epicotyl Color**

All 20 local accessions observed had green epicotyl.

**Stem Color**

Based on 10 local and 10 foreign accessions stem color ranges from light green; green; dark green; light purple to purple.

**Leaf Color**

Based on 10 local and 10 foreign accessions leaf color ranges from light green; green to dark green.

**Flower Color**

Based on 24 local and 9 foreign accessions flower color ranges from very light blue; light blue; blue violet; violet; purplish violet to purple.

**Fresh Pod Color**

Based on 24 local and 12 foreign accessions fresh pod color ranges from green; green with purple wing to purple.

**Growth Habit**

Based on all observations, viny or trailing growth habit.

**Seed Size**

Seed size among 32 local accessions range from 0.19 to 0.34 g/seed, while seed size among 28 foreign accessions ranges from 0.19 to 0.54 g/seed.

**Pod Length**

Pod length among 22 local accessions ranges from 11.2 to 47.8 cm. while among 14 foreign acessions pod length ranges from 10.3 to 30.7 cms.

**Number of Seeds per Pod**

The number of seeds among 22 local accessions ranges from 9 to 15 while among 8 foreign accessions the range was 9 to 19.

**Weight per Pod (Fresh)**

The fresh weight per pod among 19 local accessions ranges from 17.4 to 31.0 g/pod while among 15 foreign accessions, the range was from 6.8 to 30.4 g/pod.

**Days to Flower and Maturity**

1. **January planting.** Among 20 local accessions, the number days to flower and the number of days to maturity range from 42 to 57 days and 105 to 125 days. Fifteen foreign accessions generally tend to flower and mature earlier at a range of 38 to 55 days to flower and 99 to 132 days to maturity.
2. **June planting.** Seven local accessions have a wider range at 34 to 97 days to flower than the January plantings. Nine foreign accessions have a range at 34 to 98 days.

**Fresh Pod Yield**

1. **Local accessions.** Based on 19 local accessions, number of pods/plant ranges from 1.6 to 10.8 pods while potential yields range from 0.6 to 7.8 tons/ha.
2. **Foreign accessions.** Based on 15 foreign accessions, the number of pods/plant ranges from 2.3 to 22.4 pods while potential yields range from 0.6 to 7.2 tons/ha.

**Seed Yield**

1. **Local accessions.** The number of seeds/plant among 19 local accessions range from 2.8 to 44.5 seeds while potential hectarage yields range from 0.10 to 1.5 tons/ha.
2. **Foreign accessions.** The number of seeds/plant among 14 foreign accessions range from 6.2 to 61.3 seeds while potential yields range from 0.14 to 1.6 tons/ha.

**Seed Quality**

Four local accessions have a % protein content ranging from 34.67 to 40.17%.

## GERMPLASM MAINTENANCE AND EXCHANGE

At present the seed collection of winged beans are maintained in a seed storage room with temperature controlled at about 5°C. Well dried seeds are contained either in glass bottles with rubberized caps or in heat-sealed plastic pockets 5 mil thick. The seeds are still in their first year of storage. At present, the capability for distribution and exchange is low because of insufficient seeds. Most of the collection are now in the field for seed multiplication.

## PLANS AND PROSPECTS FOR GERMPLASM CONSERVATION AND UTILIZATION

There is a need for a coordinated and systematic effort for winged bean germplasm conservation and utilization in the Philippines. The following are the projections for the immediate future.

**Collection and Cataloguing of Germplasm**

Local collection of winged bean varieties has just begun and will probably peak in two years to an estimated 500 or more accessions. The current lead agencies in collection are the IPB, BPI and PNAC. The IPB shall coordinate activities to systematize collection, description and recording of accessions. Foreign materials shall be introduced to enrich Philippine germplasm. With respect to foreign collections, the IPB and BPI shall cooperate regarding plant introduction and quarantine requirements. Incoming collections are therefore channeled through these agencies for plant introduction and quarantine purposes. In this connection, the IPB is presently negotiating to set-up necessary facilities.

**Maintenance and Seed Exchange**

It is the primary responsibility of the IPB as the national plant genetic resources laboratory to conserve and enrich genetic resources of winged bean for the country. It has also been designated as a regional seed store jointly with Papua New Guinea for this species. Plans are being made so that seed exchanges shall be channeled through IPB as the national germplasm resource center.

To serve this purpose the IPBGR has recently granted financial support to establish at IPB a long term seed storage facility of 45 cu. m. capacity. This facility will be operational by mid-1978. At the same time, negotiations are on-going for an expansion of the facilities of the National Genetic Resources Laboratory at IPB to improve present capabilities for seed maintenance, documentation and exchange.

**Germplasm Documentation**

With assistance of the Biometrics Laboratory of the Institute of Plant Breeding and tapping the computer services and facilities of the Agricultural Resource Center, Inc. at UPLB, germplasm data management will be computerized for ease, efficiency, and accuracy.

**Program for Evaluation, Selection, and Utilization of Germplasm**

Agronomic and ecological evaluation, breeding and selection will be the primary concern of breeders and agronomists in research stations of the national research system. This program needs to be well coordinated to ensure maximum utilization of available germplasm and rapid development and selection of improved varieties for immediate multiplication and distribution to backyard and commercial growers. In this connection, the germplasm collection shall be made freely available to the researcher and research agencies within the national research system as well as for international seed exchange.

## ACKNOWLEDGEMENT

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# The Genetics and Physiology of Tuber Production in Winged Bean

*A. A. Bala* and *R. A. Stephenson*[1]

## INTRODUCTION

The winged bean has recently been recognized as a nutritious crop (Masefield, 1973 and Claydon, 1975) which has a potential to be developed into a major food crop to combat the protein deficiency in most developing countries. Essentially all parts of the plant (young pods, young leaves and shoots, flowers and tubers) can be eaten (Anon, 1975 and Khan, 1976).

Winged bean roots contain a higher percentage of protein on dry weight basis than any other tropical root crop known (Claydon, 1975). The challenge then is to develop the present tuber crops, and with the help of breeding increase their protein yield. On the other hand, efforts could be concentrated on a plant that is already high in protein and develop it into a tuber crop. Winged bean appears to be the only plant with promising potential to be developed into a tuber crop.

## MATERIALS AND METHODS

The winged bean varieties UPS 121, UPS 62 and UPS 32 were selected for physiology studies on the basis of their previous yield records. Variety UPS 121 is the tuber-producing type and does not give high grain yield. The opposite is true for UPS 32 while UPS 62 is medium in both grain and tuber yield. Physiology trials were conducted over two seasons in one location at University garden in Port Moresby. The dry season experiment was carried out from June to December, 1975 and the wet season experiment from January to June, 1975.

Physiology experiments were based on pruning treatments only and these treatments were control (No pruning), Vegetative Pruning (VP), Reproductive Pruning (RP), and V & RP. Pruning was started at the time of flowering and continued once a week until the control plots stopped flowering.

Grass mulch was applied on ridges to help reduce the temperature. Yields from mulched ridges however were recorded also and the effects on yield evaluated using (t) tests.

Plants were germinated in the green house and transplanted to the field 16 days after sowing. Spacing was 1m x 1m between the plants and the ridges were 1 meter apart. Size of the replications was 120 sq. m. and the main plots 40 sq. m. The experimental design used was split-plot with varieties as main plot and treatments as sub-plots.

Methods of analysis used were those found in Snedecor and Cochran (1966), Baily (1959), Panse and Sukhane (1967). One other physiology experiment was done but since it was not replicated, only graphical analysis was made (Fig. 1,2,3).

## GENETIC EXPERIMENT

The four populations, F1, F2, BC1 and BC2 (BC = Backcross) were derived from the parental lines UPS 31 and UPS 122 which were similar in yield to 32 and 121 mentioned earlier in that 31 was non-tuber-producing line while 122 was tuber-producing line. All the crosses for F1 and the back-crosses were made in the green house. Some of the F1 progenies were grown out in the field for F2 generations. Flowers from the

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F1 in the field were taken to the parents in the green house to make backcrosses. The six populations mentioned above were then planted out in a randomized block experimental designed field at a spacing of 1m x 1m between the plants and between the rows. There were four replications with ten plants per population per replicate. Every single plant was pruned both vegetatively and reproductively.

Experimental area was adequately fertilized and mulch was applied on all ridges. Water was applied twice daily.

At harvest, underground yield and number of tubers per plant were recorded on dry weight bases. Plant parts were dried for 24 hours at 80°C in a drying oven.

For all characters mentioned above, analysis of variance was done as in Baily (1959) and variance component analysis was calculated as in Allard (1960) for each of the replicates and the estimates are reported here as means of four replicates. Negative estimates were taken as zero and carried equal weight in calculation of the means (Sidwell et al. 1976). Original data on underground weights were transformed into logs as means and standard deviations varied directly. Heritabilities are reported here as means of the heritability estimates for each replicate. The standard errors (S.E.) of variance estimates are also reported here as means of S.E. for each replicate.

## RESULTS AND DISCUSSION

The yield of underground parts was significantly different for the three varieties used in the pruning experiment in both seasons (Tables 1a and 2a). This is in agreement with Khan's statement (1974) that "potentially high seed yielding plant is likely to produce little tubers or no tubers at all and the tuber yielding plant to have high flower drop and low seed yield". The table of means for varieties (1b and 2b) confirm that UPS 32 which is a high grain — yielding type bears no tubers at all. On the other hand, UPS 121 chosen for this work also on the strength of its tuber yielding ability showed higher mean tuber yield. This trend was true for both seasons. Only UPS 121 and UPS 62 had tubers, so at the time of harvest, dry weights of underground parts were also recorded for all varieties. Most of the tubers varied in size but none was found to be bigger than a thumb. However, in the highlands of Papua New Guinea, bigger-sized tubers are harvested and sold in the markets.

The most important pruning treatment was that of reproductive pruning. Means for reproductive pruning were much higher than those for vegetative pruning. Combined vegetative and reproductive pruning yielded only two grams more indicating perhaps that vegetative pruning is not so important. Vegetative pruning actually gave lower yields than the control. The wet season experiment did not give significant results for treatments. Perhaps wet season is usually the warmer time of the year and may be high temperatures are not conducive to tuber production. When the soil is saturated and highly water-logged, the oxygen in the root zone may be deficient which when coupled with high temperatures hinder tuber production; the reverse is true for the dry season. This is only a speculation and more work is needed to clarify this line of thought.

Combined analysis of variance for the experiments of both seasons (not shown here) showed that seasons and varieties were highly significant at 1% probability. Effects of seasons are also shown in tables 3a and 3b where mulching effects are compared. In single seasons, mulch versus no mulch was significant but when two mulching treatments were compared against each other from both seasons, results were highly significant at $P = 0.001$.

Treatment effects were partitioned in the combined analysis described above. This showed that reproductive treatment is perhaps the most important treatment. The effect of reproductive treatment did not vary from season to season while vegetative pruning gave variable results and did not show significant effects.

Pruning not only encouraged tuber development but also leaf production. Although this may be taken for granted due to removal of apical dominance, we note with interest that while control plants have almost lost all their leaves, there was still very high leaf area in the pruned plants 23 weeks after sowing (Fig 1). Maintenance of larger leaf area for longer time is important for tuber production and bulking as shown Fig. 2. Control and pruned plants initially grew at the same rate to 17th to 18th weeks, where control plants reached their peak. Pruned plants from then on bulked at a faster rate to reach their peak at the 21st week. Percent underground parts was much more reduced than percent pods in control plants. Increased percentage of underground parts was seen in pruned plants (Fig. 3) where pruning involves that of removing flowers and leaves. This perhaps supports the view expressed earlier that reproductive pruning treatment is very important and that reproductive sink seems to be a major pathway for photosynthetic material.

**Genetics of Tuber Production**

In the genetic experiment, it was found that the two parental lines UPS 31 and UPS 122 and their F1, F2 and back cross progenies were highly significant with respect to their mean tuber yield and the number of tubers per plant (Tables 4a and 5a). The mean tuber yield of the better parent was distinctively different from the rest of the population (Tables 4b and 5b) and the mean of F1, F2 and BC, show similarities in yield. Mid parent (UPS 31) and its back cross (BC) gave the lowest yields for roots and tubers as well as for number of tubers per plant.

For the root and tuber yields, UPS 31 was very variable, as the coefficent of variation (C.V.) shows (Table 5). Had tuber weights been used, mid parent which had no tubers at all would have had zero C.V. as in table 5c for number of tubers per plant. A high C.V. for roots and tubers is perhaps due to low mean yield. From the value for $P_1$, $P_2$, $F_1$ and $F_2$ populations, it can be seen that if mean yield of better parent was used, we get negative heterosis while small but positive heterosis is realized if mid parent mean was used. Negative heterosis obtained using better parent indicates that for tuber yield, hybrid vigour could not be utilized. However, heterosis manifests itself in many ways and is not common in most legumes (Allard 1960). Kesavan and Erskine (Personal Comm.) also found that for most of the yield related characters, specific combining ability seems to be lower than general combining ability. Low or lack of specific combining ability indicates no dominance. In tables 4d and 5d, the variance component analysis shows that most of the variation is due to additive effects rather than dominance or environmental effects. Since additive effects are genetic effects that get passed on, resulting to high heritability figure, improvement through breeding may prove very worthwhile. Narrow sense heritability figures do not differ very much. Broad sense heritabilities could therefore be taken as rough and yet close estimate of narrow sense heritabilities.

## GENERAL CONCLUSIONS

1. Reproductive pruning is more important than other forms of pruning.
2. Season effects are significant.
3. Additive effects are much higher than dominance and environmental effects.
4. Utilization of hybrid vigour for tuber production may not be practical but improvement through selection may be worthwhile due to high heritability values.

If reproductive and season effects are important, perhaps male sterility may create a self-pruned crop. This role of male sterility therefore needs to be investigated. Alternately, if plants are grown at a certain day-length, flowering may not happen in same day lengths. Perhaps these latitudes where flowering does not occur could grow winged bean varieties that are tuber producing.

## ACKNOWLEDGMENT

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## APPENDIX 1. Table 1a - 3b derived from physiology experiments.

### Table 1. Dry season physiology experiments.

**Table 1a. Analysis of variance for dry season physiology experiment.**

| Sources | d.f. | M.S. | F |
|---|---|---|---|
| Blocks | 2 | 7903.68 | 2.49 |
| Varieties | 2 | 25940.80 | 8.19* |
| Error (a) | 4 | 3164.60 | |
| Treatments | 3 | 4469.82 | 4.36* |
| Variety x Treatments | 6 | 1814.38 | 1.77 |
| Error (b) | 18 | 1023.89 | |

**Table 1b. Table of varietal and the treatment means for dry season experiment with their L.S.D. (P = 0.05).**

| Variety | Mean | L.S.D. | Treatment | Mean | LSD |
|---|---|---|---|---|---|
| UPS 22 | 212.07 | | N P | 228.77 | |
| UPS 62 | 401.57 | 56.34 | V P | 225.73 | 48.79 |
| UPS 121 | 554.00 | | R P | 355.73 | |
| | | | V + RP | 357.40 | |

### Table 2. Wet season physiology experiment.

**Table 2a. Analysis of variance for wet season physiology experiment.**

| Sources | d.f.+ | M.S. | F |
|---|---|---|---|
| Blocks | 2 | 16.4 | 2.9 |
| Varieties | 2 | 158.89 | 28.12* |
| Error (a) | 4 | 5.65 | |
| Treatments | 3 | 18.94 | 0.95 |
| Var. x Treat. | 6 | 38.50 | 1.93 |
| Error (b) | 16 | 19.88 | |

+ = Degrees of freedom reduced by two due to two missing plots.

**Table 2b. Table of varietal means and their L.S.D. (P = 0.05) for wet season experiment.**

| Variety | Mean | L.S.D. |
|---|---|---|
| UPS 32 | 13.4 | |
| UPS 62 | 22.57 | 5.39 |
| UPS 121 | 41.91 | |

### Table 3. Effects of mulching.

**Table 3a.**

| Season | Treatment | Mean | t[a] | N |
|---|---|---|---|---|
| Dry | Mulch | 123.84 | 2.76* | 18 |
| | No Mulch | 75.71 | | |
| Wet Season | Mulch | 8.87 | 2.42* | 17 |
| | No Mulch | 4.74 | | |

a = t value from paired comparison.

**Table 3b.**

| Treatment | Season | Mean | d[b] | N |
|---|---|---|---|---|
| Mulch | Wet | 8.87 | 8.13*** | 33 |
| | Dry | 123.84 | | |
| No Mulch | Wet | 4.74 | 5.75*** | 33 |
| | Dry | 75.70 | | |

b = d value from pooled variance.

**Effects of mulching are significant if looked over a single season. Comparison of a single treatment only over both seasons is highly significant at (P = .001).**

**APPENDIX 2. Tables 4a - 5d derived from genetic experiment.**

## Table 4. Anova on Mean Root and Tuber Dry Weights (gms.).

**Table 4a.**

| Sources | d.f. | M.S. | F |
|---|---|---|---|
| Populations | 5 | 37 | 7 36** |
| Replications | 3 | 03 | |
| Error | 15 | 05 | |

**Table 4b.**

| | Population | | | | | |
|---|---|---|---|---|---|---|
| | $P_2$ | $BC_2$ | $F_1$ | $F_2$ | $BC_1$ | $P_1$ |
| Mean | 0 19 | 0 48 | 0 70 | 0.77 | 0.87 | 1 04 |

L.S.D. at (P = 0.05) = .47

**Table 4c.**

| Population | Mean | S.D. | C.V. |
|---|---|---|---|
| $P_1$ | 1.04 + —0.125 | 0 25 | 0 24 |
| $P_2$ | 0.19 + —11 | 0.22 | 1.16 |
| $F_1$ | 0.70 + —0.105 | 0 21 | 0 30 |
| $F_2$ | 0.77 + —0.18 | 0 36 | 0.47 |

**Table 4d.**

| | $S_E^2$ | $S_A^2$ | $S_D^2$ | $h^2_{BS}$ | $h^2_{NS}$ |
|---|---|---|---|---|---|
| Reps | | | | | |
| 1 | 0 11 | 0 17 | 0 13(0) | 0 39 | 0 39 |
| 2 | 0 04 | 0 20 | 0 08 | 0 17 | 0 17 |
| 3 | 0 03 | 0 05 | 0 01 | 0 67 | 0 56 |
| 4 | 0 03 | 0 10 | 0 01(0) | 0 77 | 0 77 |
| Mean | 0 05 | 0 13 | 0 0025 | 0 50 | 0.47 |
| S.E. of Mean | ±0 02 | ±0 07 | ±0 0025 | ±0 13 | ±0 12 |

## Table 5. Anova on number tubers/plant.

**Table 5a.**

| Sources | d.f. | M.S. | F |
|---|---|---|---|
| Populations | 5 | 6.56 | 25 23** |
| Replications | 3 | 0 87 | 3.33 |
| Error | 15 | 0 26 | |

**Table 5b.**

| Population | $P_2$ | $BC_2$ | $F_1$ | $F_2$ | $BC_1$ | $P_1$ |
|---|---|---|---|---|---|---|
| Mean | 1.0 | 1.43 | 2.79 | 3.11 | 3.5 | 4.46 |

L.S.D at (P = 05) = .77

**Table 5c.**

| Population | Mean | S.D. | C.V. |
|---|---|---|---|
| $P_1$ | 4.46 ± 65 | 1 3 | 0 29 |
| $P_2$ | 1 00 ± 0 | 0 | 0 |
| $F_1$ | 2.79 ± 49 | 0.99 | 0 35 |
| $F_2$ | 3.11 ± .87 | 1 75 | 0 56 |

**Table 5d.**

| Reps. | $S^2_E$ | $S^2_A$ | $S^2_D$ | $h^2_{BS}$ | $h^2_{NS}$ |
|---|---|---|---|---|---|
| 1 | 0.90 | 4 41 | -2 04(0) | 0 84 | 0.84 |
| 2 | 0 97 | 0 23 | -0 39(0) | 0 19 | 0.19 |
| 3 | 1 64 | 8 14 | 4 60(0) | 0 83 | 0 83 |
| 4 | 0 83 | 2 80 | 0 38 | 0 79 | 0.70 |
| Mean | 1 09 | 3 97 | 0 10 | 0 66 | 0.64 |
| Std. Error | ±0.19 | ±1 67 | ±0 09 | ±0 158 | ±0.153 |

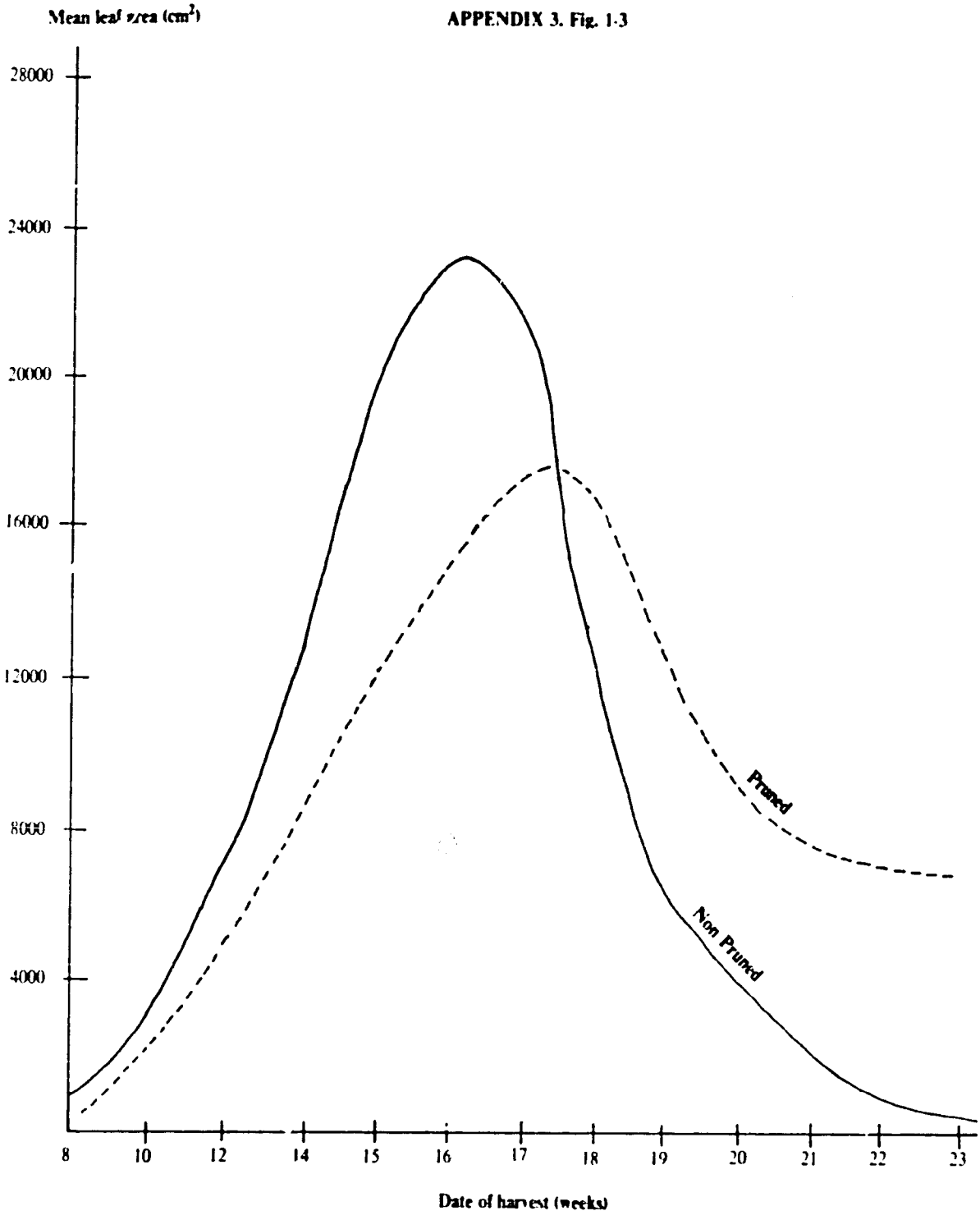


**Fig. 1. Effect of pruning on mean leaf area of winged bean harvested at different dates.**

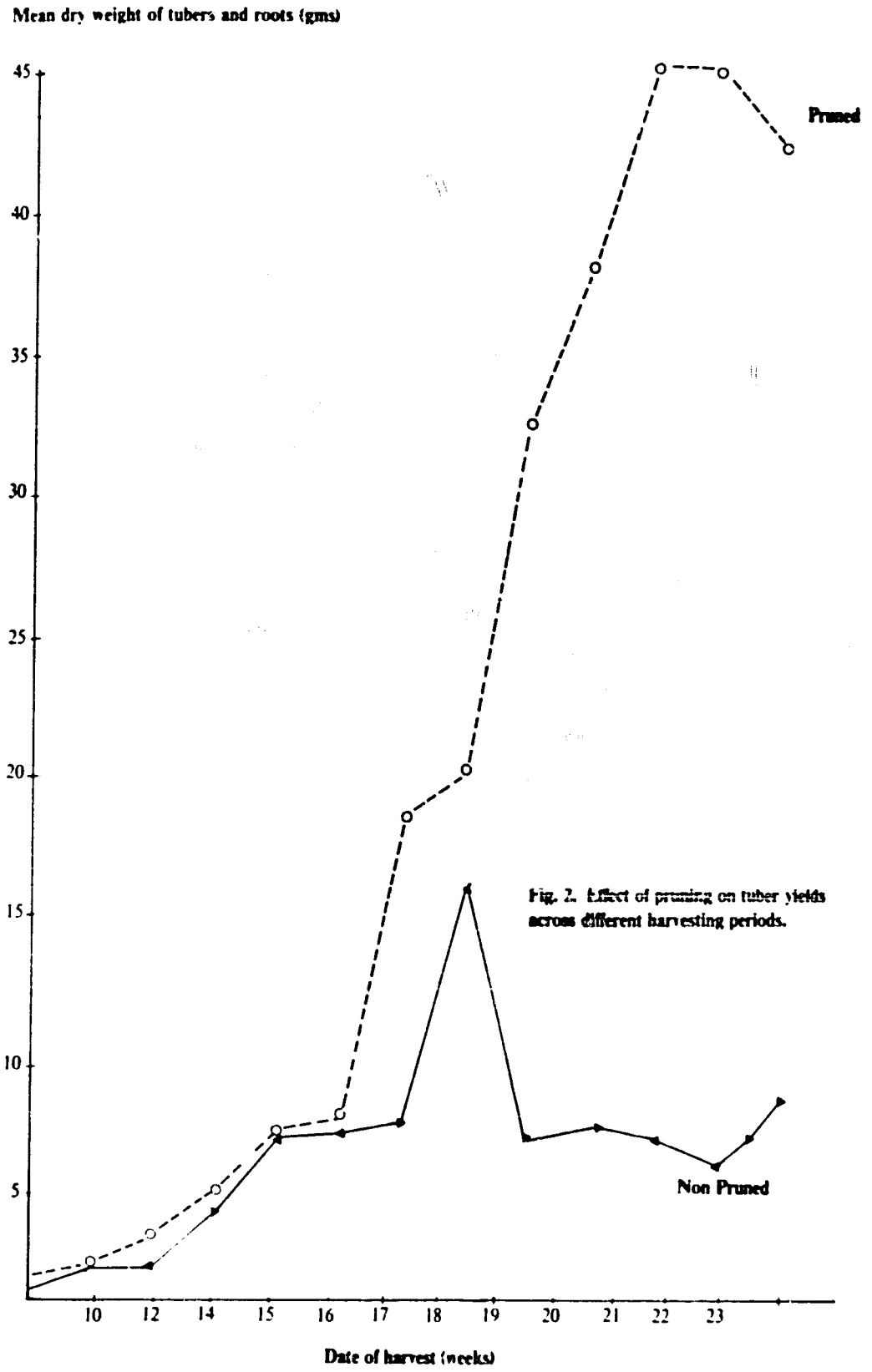


Fig. 2. Effect of pruning on tuber yields across different harvesting periods.

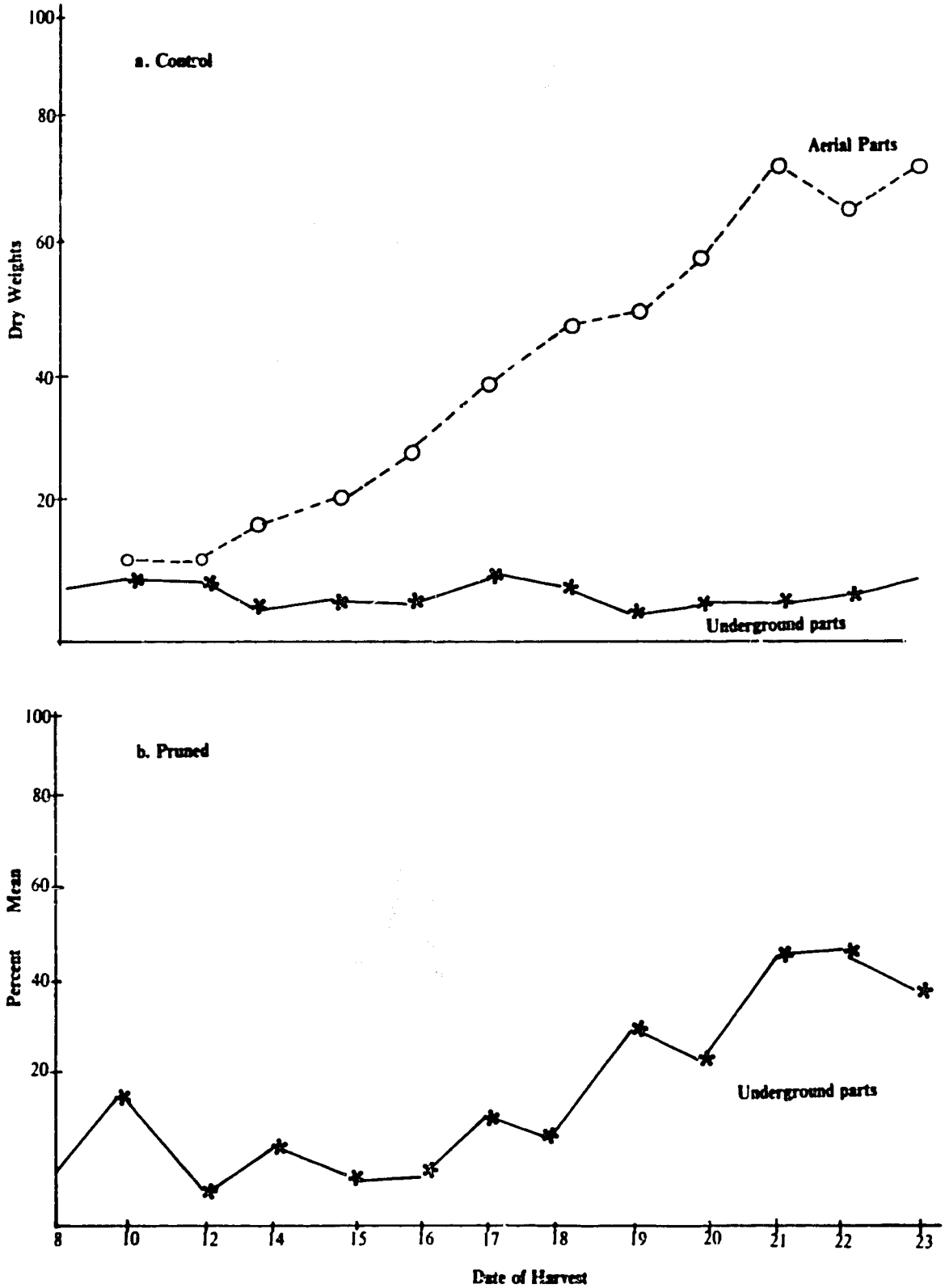


Fig. 3a, b. Effect of pruning on dry weight of winged bean parts.

# Some Investigations on the Indigenous and Exotic Collections of Winged Bean In India

*Rajendran, R., A. Satyanarayana, Y. Selvaraj* and *B.S. Bhargava*[1]

**Winged bean has been under cultivation in India in scattered pockets in the states of Goa, Maharashtra, Karnataka, Tamilnadu, Kerala, Madhya Pradesh, Orissa, Bengal and Tripura. Indigenous and exotic collections were assessed for phenotypic, quantitative and qualitative characters. Seed-coat colour varied from black, purple, brown, tan, light green to white. Weight of hundred seeds varied from 5 to 20, with pod length between 5 cm to 25 cm in different lines. The earliest line flowered in 50 days after sowing and one line flowered as late as in 140 days.**

**Seed protein varied from 21 to 41 per cent in winged bean, as compared to 33.4 per cent in pea, 32.1 per cent in sword bean, 30 per cent in southern pea and 23.4 per cent in french beans. In winged bean crude protein of fresh pod (on dry weight basis) was 25 per cent as compared to 26.7 per cent in sword bean, 26.2 per cent in dolichos bean, 23 per cent in southern pea, 21 per cent in french beans and 26.2 per cent in shelled lima bean when all were cultivated under similar agro-climate.**

**Correlation studies indicate that seed protein in winged bean is not correlated with the agronomic characters giving scope for selection of large seeded, long podded lines, with higher number of pods per plant, without affecting protein content of seed.**

**Winged bean is rich in protein and scope exists for further improvement as a crop of tropical areas of high humidity and also where irrigation water is available. For drier areas other legumes like sword bean, southern pea and dolichos bean could be recommended for solving protein malnutrition.**

## INTRODUCTION

Work on winged bean was initiated considering the unusually high yield potentials with appreciable quantities of dietary protein in seeds, pods, flower, tender leaf and shoots, as well as the root tubers. (Arkord 1964), Cerny *et al* (1971) Anonymous (1971-1974, 1975), Khan (1975). It has been characterized as follows: Acceptable taste and palatability (Tracy Hubbard 1950; Bailey and Boulter 1971; Liener 1969); good residual effect on soil and increase in yield of subsequent crop (Doku 1967; Borke 1971); its suitability as a green manure crop, pasture crop and a cover crop for fallow as well as gardens and plantations (Walch 1958; Wilson and Lausbury 1958; Tong *et al* 1960); its high bacterial nodulation capacity (Masefield 1970; Lyer 1976); its adaptation to high rainfall regions, where cultivation of other legumes like peas, beans and cowpea is limited due to phytoclimate (Anonymous 1969), possibility of its cultivation in tropical and sub-tropical areas under irrigation (Rolfs 1916; Mac Million 1935); its seeds are rich in oil and protein rich oil cake and existence of adapted local cultivars (Roxburghs 1814, 1832, 1874; Hooker 1879; Koeing 1894; Prain 1903; Burkill 1906; De Candolle 1966, Bailey 1966, Pursglove 1968; Anonymous 1969).

## MATERIALS AND METHODS

Existence of winged bean in India has been reported from 1799 onwards. Efforts made to collect the indigenous germplasm from different locations by personal contact and communication were fairly fruitful. Fig. 1 shows the areas where the materials have been collected. Efforts are being made to get the materials from other states like; Andhra Pradesh, Uttar Pradesh, Bihar, Assam, Chittagong, border areas near Burma and the foot hills of eastern Himalayas from where availability is reported by Prain (1903).

Indigenous collection include accessions from eight different states in India. The proportions of different germplasm received from Kerala, Karnataka, Maharashtra, Goa, Bengal, Tripura, and Madhya Pradesh is represented in Fig. 2. Initial accessions were sown as soon as they were received to ensure their survival without loss of viability in storage; seed stocks were subsequently raised. For assessment the seeds were sown on the sides of 5 m channels raised 22 cm on the sides. The growing plants were supported by gunny twine to train in 3 parallel rows of galvanized iron wire running one over the other 50 cm apart.

[1]**Contribution No. 628, Indian Institute of Horticultural Research, Banglore — 560 006.**

Observations were recorded on seed coat color, 100 seed weight, volume (by water displacement), number of days to flower, pod length, pod weight, number of seeds per pod, pod color and shape. Seed protein contents were evolved to study the correlation of seed protein with other agronomic characters.

Harvested tender pods were distributed to selected individuals, thrice at an interval of 15 days to work out consumer preference.

Vegetable legumes of both major and minor importance like cowpea, southern pea, french beans, jack bean, sword bean, cluster bean, pea and winged bean etc. were cultivated under similar agroclimate and seed and fresh pod protein content and some minerals were analyzed as no information for comparison was available on these crops. Nitrogen was determined by modified Kjeldahl method as described by Chapman and Pratt (1961). The samples were digested in diacid mixture (5:3:Nitric:Perchloric acid), for P, K, Na, Ca analysis. P was determined by colorimetic method of Fiske and Subbaraw (1925). K, Na and Ca were determined using AIMIL Flame Photometer. Crude Protein on dry weight basis was calculated as Nitrogen multiplied by 6.25.

## RESULTS AND DISCUSSION

Vast variation has been observed in seed coat colour as represented in Fig. 3. It is observed that light tan or buff color of seed coat predominates in the collection: splashed seed coat as well as dark eyed varieties were not observed in this collection.

Seed weight varied from 9.1 to 54.5 g per 100 seeds (Fig. 4) majority of them falling in 27.1 to 51 g per 100 seeds (Fig. 5), varied from 7 cc to 56 cc with concentration in 21 cc to 42 cc groups, 32 per cent of them were in the group 28 to 35 cc per 100 seeds.

Variations in earliness to flower (Fig. 6) ranged from 50 days to 140 days. Majority of the lines (over 50 per cent) flowered between 61 to 65 days. Results indicated that there is wide variation in the photoperiodic requirement of this crop. This aspect should be studied to get a line completely photo insensitive. Variation in seed protein content in the collection ranged between 27 to 41 per cent (Fig. 7). Thirty per cent of the collection was in the range 35 to 37. It was observed that individual plant selections in different lines varied in protein content (Table 2).

Marked variability in pod weight was observed with a range of 4.3 g to 27 g per pod (Fig. 8), 35 per cent of the collection were in the group 15 to 18 g weight and 30 per cent in 12 to 15 g per pod. Pod length also varied from 5 cm to 25 m; 38 per cent of the collection were in the group 17 to 20 cm (Fig. 9).

Number of seeds per pod (Fig. 10) varied from 5 to 20. Majority of them had 17, closely followed by 14 seeds per pod.

Pod shape variation in a cross section was studied as described by Khan (1976) except for the division into 5 groups (Fig. 11) instead of 4, rectangular shape was observed in 34 per cent of the collection, 28 per cent semi flat on suture; only 6 per cent were flat on suture and 8 per cent were flat on side.

Consumers preference indicate acceptance of winged bean pods as vegetable (Fig. 12), and liking for the flat types. Breeding for stringless varieties is important. Initial selection of flat, stringless types will make it easy for mass popularization of this crop.

Correlations for crude protein content with other agronomic characters were determined to create a base for selection for improvement. The results presented in Table 1 indicate that there is no significant correlation of crude protein content in seed, with pod length, pod weight, seed per pod, 100 seed weight, as well as 100 seed volume, indicating that these characters can be improved without affecting the seed protein content.

Pod length had a highly significant correlation with pod weight, seeds per pod, 100 seed weight as well as seed volume, which indicates that the larger the seed, the heavier the seed, the greater the number of seed per pod, the larger is the pod.

Pod weight had highly significant correlation with pod length as well as seeds per pod and 100 seed weight. In the collection some lines with larger seeds had small pod. Number of seeds per pod was highly correlated with pod length, pod weight, seeds per pod as well as volume of 100 seeds, whereas volume of 100 seeds was highly correlated with 100 seed weight, seeds per pod and pod length.

It is concluded that for protein, individual plant selection among high yielding lines has to be made as differences in protein of different selection in the same accession was observed, (Table 2). Select lines with larger seeds, larger pods and larger number of pods per plant to increase total yield per plant, increase the plant

**Table 1. Table of correlations.**

| | Crude Protein | Pod Length | Pod Weight | No. of Seeds per Pod | 100 Seed Weight | Volume of 100 seeds |
|---|---|---|---|---|---|---|
| Crude protein | — | 0.1876 | 0.0140 | 0.1592 | 0.0304 | 0.0012 |
| Pod Length | | — | 0.8786 | 0.6236** | 0.5994** | 0.4794** |
| Pod Weight | | | — | 0.4564* | 0.4520* | 0.3256 |
| Number of Seeds Per Pod | | | | — | 0.5750** | 0.4808 |
| 100 Seeds Weight | | | | | — | 0.9171** |
| Volume of 100 Seeds | | | | | | |

*Significant at 5% level.
**Significant at 1% level.

population to an optimum and to achieve maximum advantage in protein yield per unit area.

The protein content of seeds of winged bean was compared with some of the vegetables which is presented in Fig. 13. Winged bean seed has the highest protein content of about 40 percent. Pea 33 percent, Sword bean 32 percent, Jack bean 27 percent French bean 24 percent, Southern Pea variety Crowder 30 percent, Cowpea Pusa Phalguni 23 percent. Results show that the winged bean has very high seed protein.

Comparison of dry matter, protein, phosphorous, potassium, sodium and calcium content of the full pod at edible maturity and shelled bean of some of the lines are shown in Table 2.

**Table 2. Variation in crude protein content of seed on dry weight basis in different selections of the same accession in winged bean.**

| A.C. No. | Source | Nitrogen (%) | Crude Protein (%) |
|---|---|---|---|
| IHR 12 | Pt-14 Nigeria | 5.71 | 35.66 |
| IHR 12-1 | — | 6.30 | 39.38 |
| IHR 12-2 | — | 5.85 | 36.53 |
| IHR 12-3 | — | 5.95 | 37.19 |
| IHR 12-4 | — | 6.30 | 39.38 |
| IHR 15 | EC 38826 | 4.87 | 30.41 |
| IHR 15-1 | — | 5.46 | 34.13 |
| IHR 16 | Indian collection | 5.33 | 34.56 |
| IHR 16-1 | — | 5.25 | 32.81 |
| IHR 26 | EC 38958 | 4.87 | 30.41 |
| IHR 26-1 | — | 4.41 | 27.56 |
| IHR 26-2 | — | 5.04 | 31.50 |

Results in Table 3 indicate that winged bean is rich in protein and calcium (Fig. 14). Other beans that are of interest are cowpea, dolichos and sword bean which will be suitable in dry areas.

It is concluded that the winged bean collection has a lot of variability in seed colour, seed volume, seed weight, plant habit, pod shape, yielding capacity, pod colour and protein and mineral composition. It is recommended that we go for individual plant selection for earliness (Fig. 6), high yield and protein content (Fig. 13). We have to breed for stringless and semi-stringless plants which would need less support because it is preferable to have larger number of plants to increase total yield per unit time and area. Photo insensitive lines, if selected, could fit in rotation between regular crops.

**Table 3. Comparison of percentage of dry matter, protein and some minerals in the edible part of some leguminous vegetable on dry weight basis cultivated under similar agroclimate.**

| Plant Part | Dry matter (%) | Protein (%) | Phosphorus (%) | Potassium (%) | Sodium (%) | Calcium (%) |
|---|---|---|---|---|---|---|
| **Green Pod** | | | | | | |
| Winged bean | 8.14 | 25.00 | 0.39 | 1.14 | 0.48 | 0.560 |
| Southern Pea IHR-66 B | 11.86 | 25.19 | 0.41 | 2.00 | 0.46 | 0.228 |
| Cowpea | | | | | | |
| Pusa Phalguni | 22.10 | 23.25 | 0.39 | 1.68 | 0.42 | 0.336 |
| Asparagus Bean | 9.93 | 18.19 | 0.45 | 1.72 | 0.92 | 0.240 |
| Cluster Bean | 14.01 | 15.25 | 0.33 | 1.12 | 0.32 | 0.544 |
| French Beans | | | | | | |
| Bush Bluelake Supreme | 9.41 | 22.75 | 0.37 | 1.88 | 0.28 | 0.320 |
| French Beans Silvert | 9.91 | 17.89 | 0.39 | 1.76 | 1.00 | 0.265 |
| Jack Bean White Seeded | 12.14 | 19.06 | 0.23 | 1.68 | 0.20 | 0.198 |
| Sword Bean Red Seeded | 12.26 | 26.44 | 0.27 | 1.66 | 0.24 | 0.288 |
| Sword × Jack Bean $F_1$ | 12.64 | 19.06 | 0.23 | 1.68 | 0.20 | 0.416 |
| Dolichos Bean Pusa Early Prolific | 12.33 | 27.31 | 0.45 | 1.52 | 0.34 | 0.224 |
| **Shelled Bean** | | | | | | |
| Southern Pea Crowder | 33.03 | 23.63 | 0.41 | 1.48 | 0.15 | 0.106 |
| Cowpea California Blackeye | 37.82 | 17.69 | 0.42 | 1.38 | 0.40 | 0.106 |
| Dolichos Bean Hebbal III | 41.52 | 25.87 | 0.49 | 1.36 | 0.16 | 0.100 |
| Lima Bean, Butter bean | 26.60 | 26.44 | 0.42 | 1.68 | 0.36 | 0.128 |

## ACKNOWLEDGEMENT

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*Tuber yields of winged bean from approximately 1m² of land*

Appendix I. Fig. 1-14

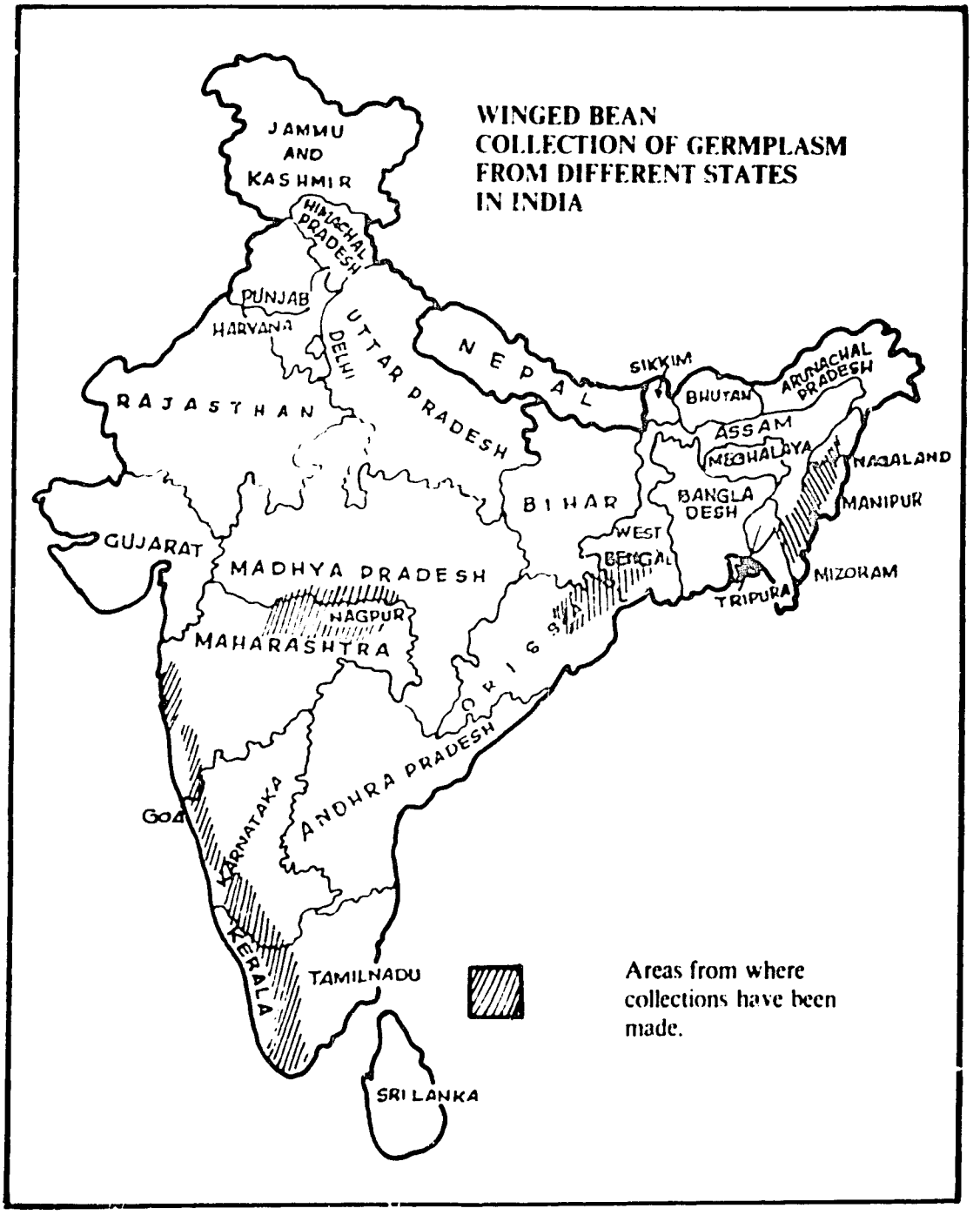


Fig. 1. Winged bean collection of germplasm from different states of India.

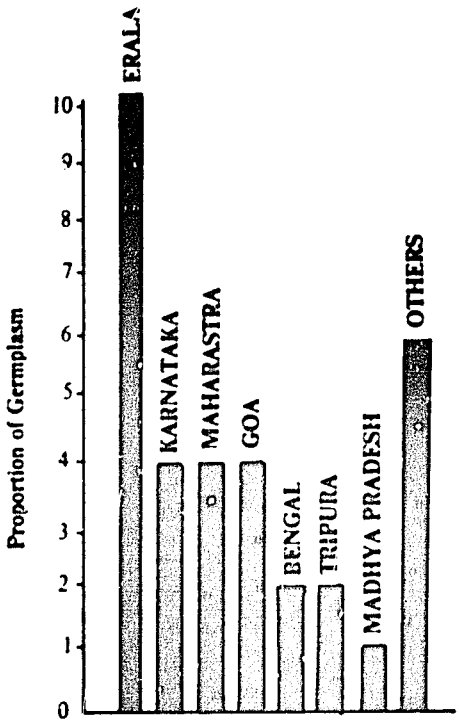


Fig. 2. Proportion of winged bean collections from different states in India.

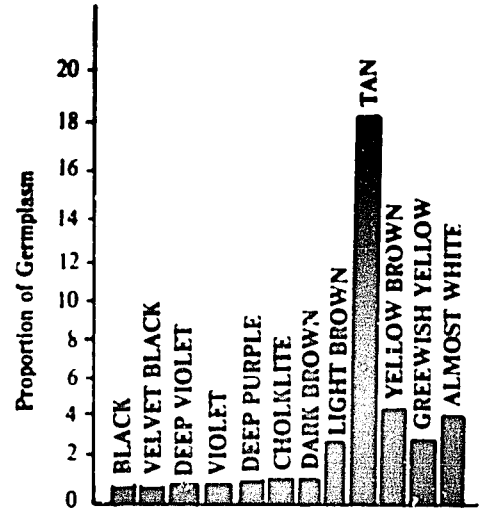


Fig. 3. Winged bean variations in seed coat color.

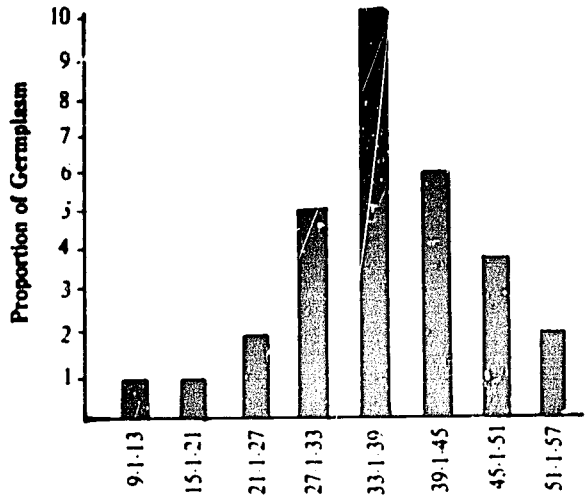


Fig. 4. Winged bean variation in 100 seed weight.

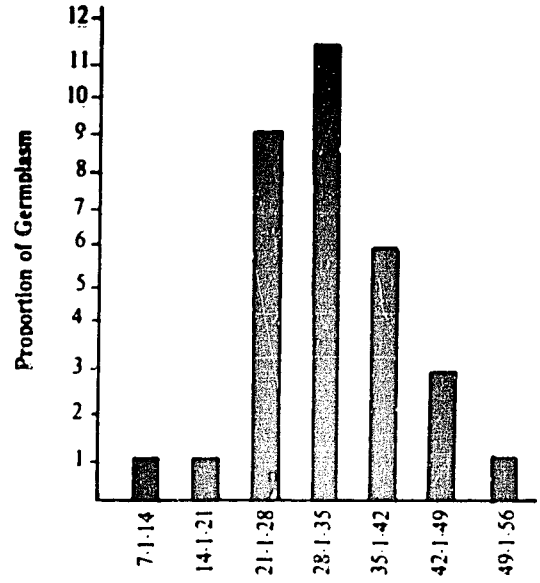


Fig. 5. Variation in volume of 100 seeds in winged bean

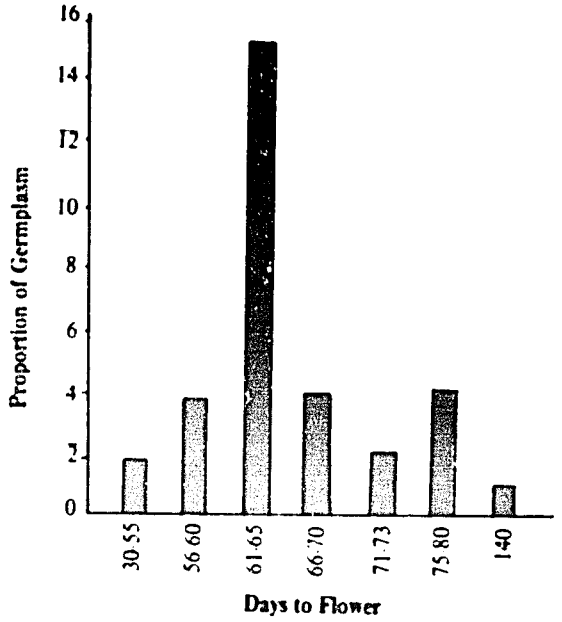


Fig. 6 Variation in days to flower winged bean.

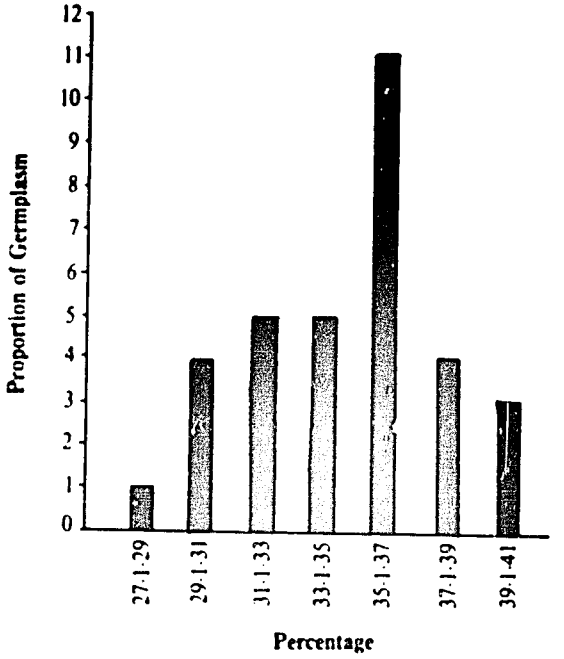


Fig. 7. Seed protein variation in winged bean.

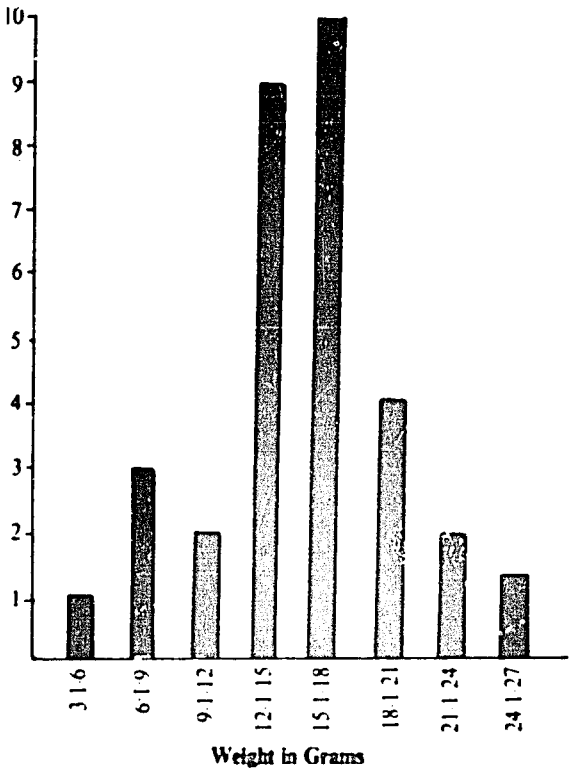


Fig. 8. Winged bean variation in pod weight.

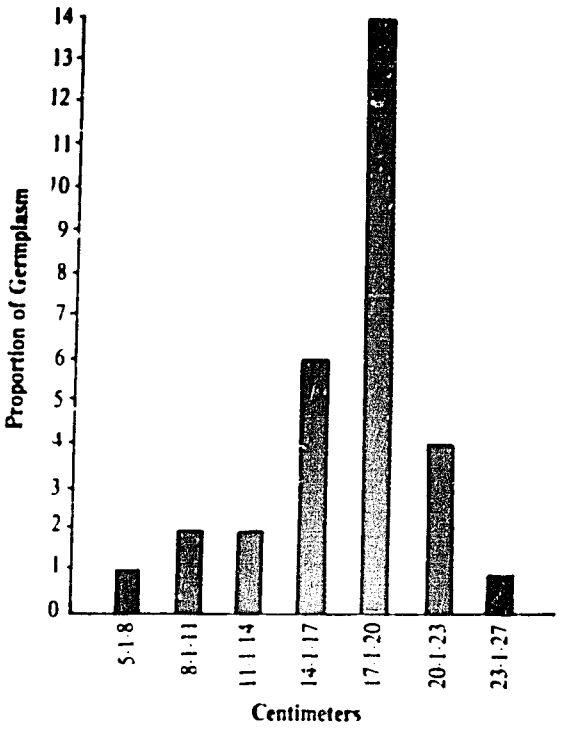


Fig. 9. Variation in pod length winged bean.

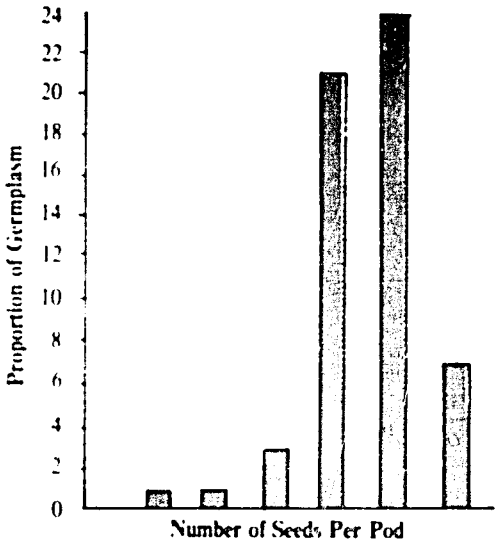


Fig. 10. Variation in number of seeds per pod in winged bean.

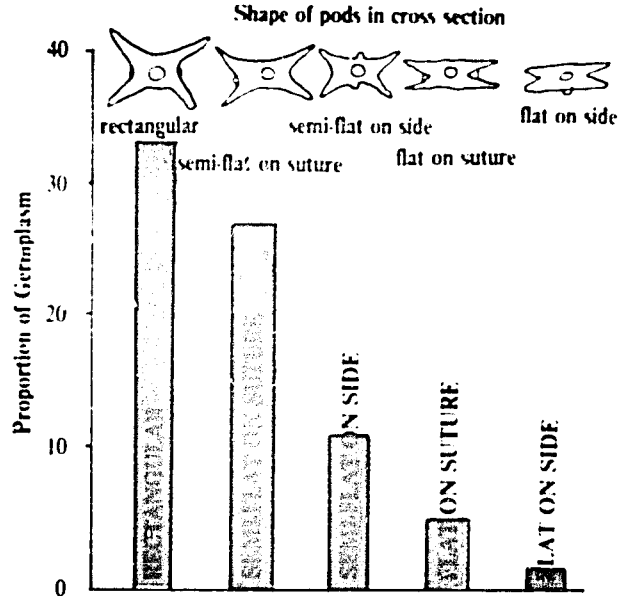


Fig. 11. Pod shape variations in winged bean.

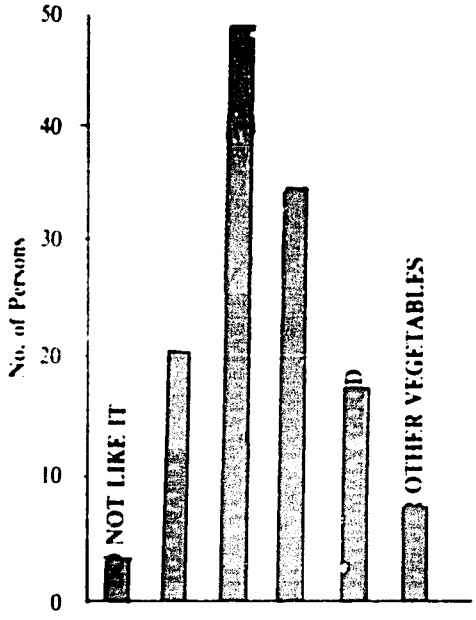


Fig. 12. Consumers preference for tender green pods.

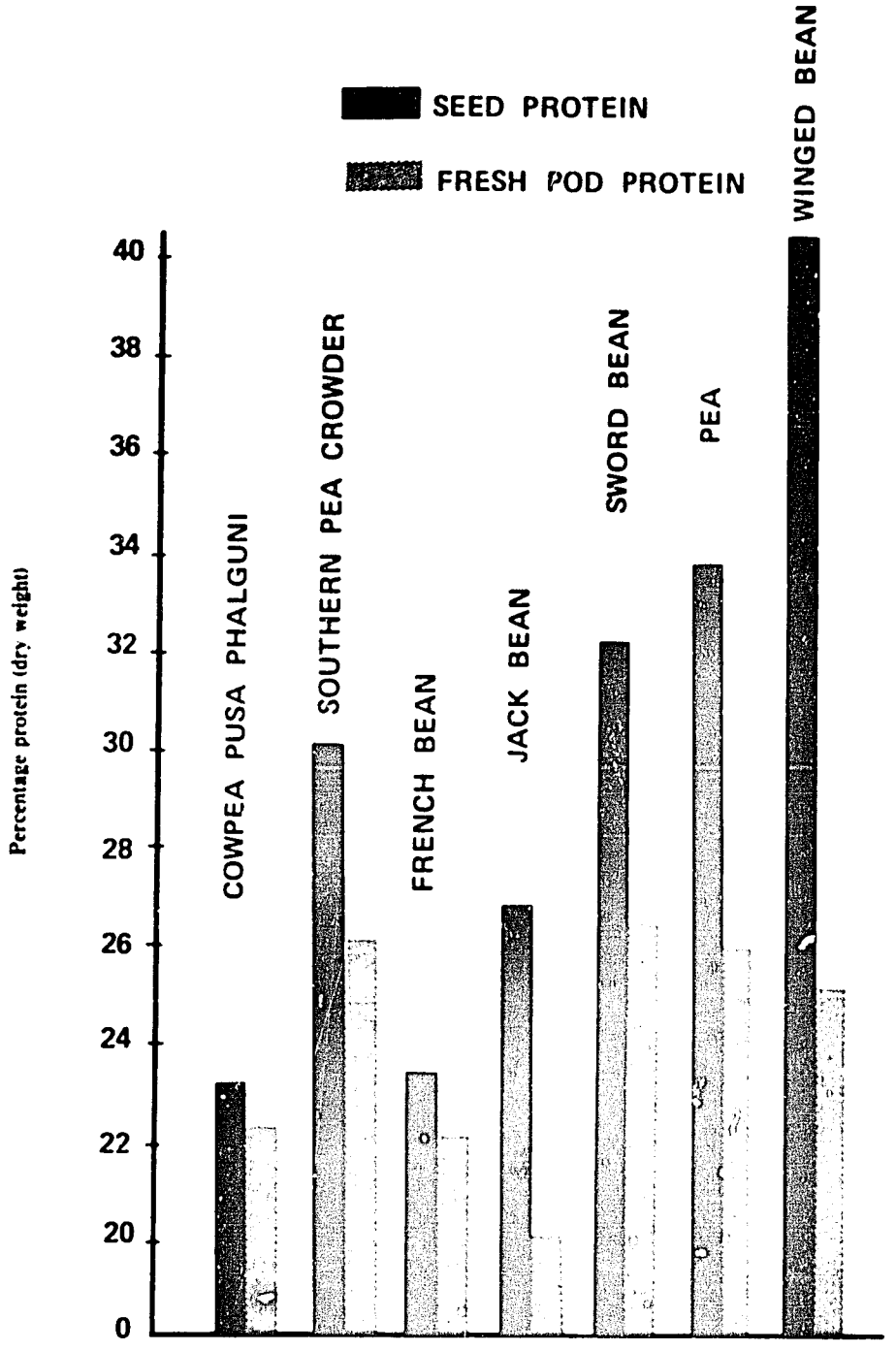


Fig. 13. Comparison of seed and fresh pod protein in some vegetable legume (on dry weight).

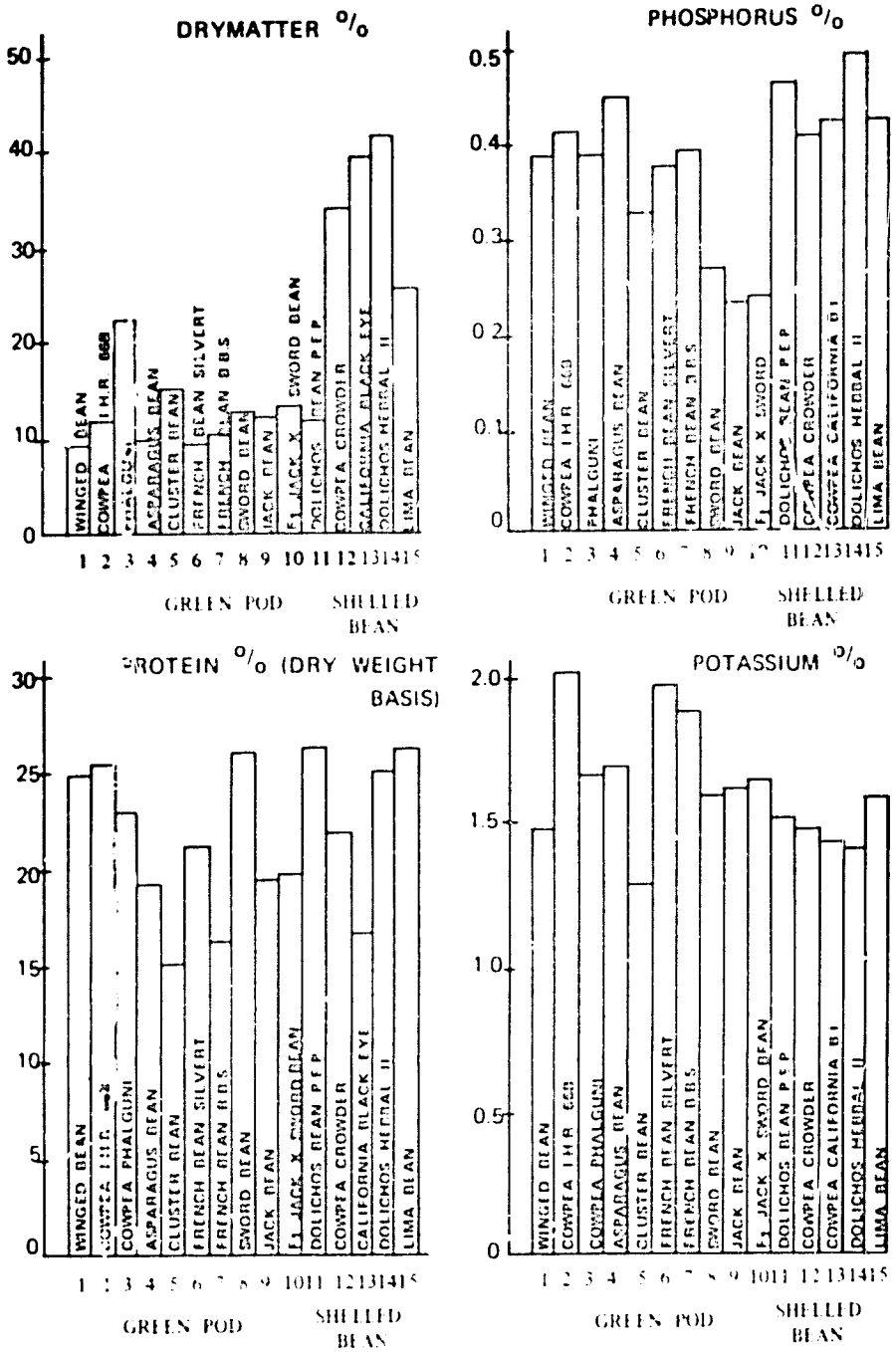


**Fig. 14. Comparison of Dry Matter, Protein, Phosphorus and Potash Content of Different Vegetable Legumes Cultivated Under Similar Agroclimate.**

# Some Growth Characteristics of Indigenous and Introduced Selections of Winged Bean

*H. M. W. Herath, E. M. P. Dharmawansa*[1] *and D.P. Ormrod*[2]

**Yield related characteristics of 10 University of Papua New Guinea selections (UPS) and three Sri Lanka selections (LS) of winged beans *Psophocarpus tetragonolobus* were studied under controlled environment and field growing conditions. UPS 80, UPS 78 and 45 recorded the greatest height and most of the selections showed two cycles of height increase at two of the four times of growth measurement. The fresh weights and dry weights of plants after 28 days of growth were high in UPS 80, UPS 45 and UPS 59 when grown at 27-21°C day night temperature. Under field growing conditions, Sri Lanka selections had greater leaf area and longer petiole length than UP selections except UPS 121. The petiole length was positively correlated with leaf area. The number of seeds per pod varied with the selection. Larger seed numbers were associated with greater pod weight. UP selections had higher seed pod ratios compared with Sri Lanka selections, but the latter recorded higher seed weights. At the end of 49 days of growth, UPS 80 and UPS 121 had the greatest shoot weight. The dry matter accumulations in Sri Lanka selections were initially low, but tend to increase by 49 days of growth. Some of the UP selections, particularly UPS 80 and UPS 121 could be utilized for a plant improvement program in Sri Lanka.**

## INTRODUCTION

There is an increasing interest in the cultivation of grain legumes such as soybeans and ground nuts in tropical regions. These crops have long been cultivated and are consumed as a source of protein in the human diet in many countries (Al-Jibouri, 1975). Low income levels and prohibitive animal protein costs make grain legumes a chief source of protein (Shakoor, 1975). While developing the use of the more commonly used legumes, there is interest shown in other leguminous crops such as the winged bean. The winged bean is one of the crops that has shown a great potential for development and is referred to as the future soybean (N.R.C. Sri Lanka and N.A.S. U.S.A., 1975).

Although there are several species of *Psophocarpus*, the most commonly cultivated is *P. tetragonolobus*. Within this species are several cultivars or selections that originate from winged bean growing countries including Papua New Guinea, Burma, Thailand and Sri Lanka. These cultivars or selections are known to differ in their morphological characteristics (Khan and Claydon, 1975).

The objective of this study was to compare some morphological characteristics, growth and yield of several New Guinea selections of winged bean with the locally selected types grown in Sri Lanka. It was also considered that a study of this kind would help initiate a plant improvement program for winged bean.

## MATERIALS AND METHODS

Three winged bean cultivars collected from various parts of Sri Lanka were obtained from the Botanist of the Department of Agriculture. Ten Papua New Guinea selections were obtained from the University of Papua New Guinea. These were grown in multiplication plots during 1975 and subsequent investigations were carried out with the seeds obtained from these plantings.

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Controlled environment studies were conducted in cabinets at the Department of Horticultural Science, University of Guelph. Nine New Guinea selections (UPS 31, UPS 45, UPS 46, UPS 61, UPS 66, UPS 78, UPS 80 and UPS 102) were grown in 15 cm diameter pots containing a soil peat vermiculite mixture. Four plants of each selection were grown in a 26/21°C day/night temperature regime. A 12/12 hour thermoperiod and a 14/10 hour photoperiod were maintained with a light intensity of 20 klux. Plant heights were recorded at 10, 14, 18, 24 and 28 days. Fresh and dry weights were recorded at the 28th day.

For the field study, 10 New Guinea selections (9 selections used in controlled environment studies and UPS 121) and 3 Sri Lanka selections were grown in plots with 5 replicates at the Gannoruwa Experimental Station, Peradeniya, Sri Lanka from October 1975 to March 1976. The plot size was 10 x 10 m and plants were spaced at 1 x 1 m apart. The plants that were grown to maturity were supported by 2 meter stakes. Leaf area, petiole length and weight of shoots at 21, 35 and 49 days of growth were recorded. In the mature plants, the mean dry pod weight, number of seeds per pod, weight of 100 seed/pod ratio were recorded.

## RESULTS

Of the UP selections tested in the growth cabinet, UPS 31, UPS 45, UPS 78 and UPS 80 [illegible] added greater heights than the other selections (Table 1). UPS 46 and UPS 102 had less than half the he[illegible] of the tallest selections. The rate of increase in height varied with the selection. UPS 45, UPS 78 and UPS 80 almost always had the greatest height at all 4 stages of growth (Table 1). Generally, the increment in plant height occurred at two stages, 14 to 18 days and 24 to 28 days. The increase from the first stage to the second stage for the tall growing selections was over three fold and for the short growing selections (UPS 46 and UPS 102) was 1.5 to 2.0 times over the previous stage. The increase in height from 14 to 18 days was between 2 to 3 times compared to the previous value for all the selections. The increase from 24 to 28 days compared to 24 days was nearly two fold for the tall growing selections and greater than the short growing selections.

**Table 1. Height (cm) of nine winged bean selections grown at 27/21°C at five stages of growth.**

| | Days after planting | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Selection** | **10** | | **14** | | **18** | | **24** | | **28** | |
| UPS 31 | 3.80[y] | 0.3[z] | 9.18[y] | 1.8[z] | 32.88[y] | 2.7[z] | 49.25[y] | 2.0[z] | 84.50[y] | 2.0[z] |
| UPS 45 | 4.05 | 0.2 | 8.78 | 1.7 | 31.68 | 1.0 | 53.25 | 3.0 | 92.38 | 2.6 |
| UPS 46 | 3.93 | 0.2 | 6.48 | 0.3 | 10.23 | 0.3 | 16.10 | 0.8 | 44.10 | 2.1 |
| UPS 59 | 4.00 | 0.2 | 6.05 | 0.4 | 15.55 | 2.0 | 27.38 | 2.0 | 58.00 | 3.2 |
| UPS 61 | 3.65 | 0.2 | 6.48 | 0.4 | 15.75 | 0.3 | 25.68 | 1.1 | 57.63 | 1.4 |
| UPS 66 | 4.63 | 0.4 | 7.45 | 0.2 | 23.38 | 2.2 | 37.80 | 3.2 | 66.88 | 1.7 |
| UPS 78 | 5.50 | 0.6 | 12.75 | 1.0 | 39.13 | 3.1 | 56.25 | 2.3 | 95.13 | 2.2 |
| UPS 80 | 6.30 | 0.9 | 17.43 | 1.8 | 55.88 | 3.0 | 74.00 | 3.5 | 114.13 | 2.4 |
| UPS 102 | 2.75 | 0.3 | 5.63 | 0.3 | 10.98 | 0.7 | 17.88 | 1.3 | 43.05 | 2.2 |

[y]mean of 4 plants
[z]standard error

There were differences among selections in fresh and dry weight (Table 2). UPS 45, UPS 59 and UPS 80 had more both fresh and dry weights than the other 6 selections. The percent dry weight was rather consistent for all selections except for UPS 31 and UPS 80 for which the percentages were higher than the other 7 selections.

The comparison of the leaf area and the petiole length for ten New Guinea selections and three Sri Lanka selections indicated that the latter selections had greater leaf area and petiole lengths than the UP selections, except UPS 121 which had the greatest leaf area and the longest petiole length among the UP selections. The smallest leaf areas were recorded from UPS 31 and UPS 102. These were about six fold less than those recorded for the three Sri Lanka selections or UPS 121. The petiole length was different among selections, for example, UPS 78 and UPS 102 were about four-fold shorter than the Sri Lanka selections. Generally, the petiole length was associated with the leaf area. However, plants that had larger leaves possessed longer petioles.

**Table 2. Fresh weight, dry weight and percent dry weight of nine winged bean selections grown at 27-21°C for 28 days.**

| Selection | Fresh Weight | | Dry Weight | | Percent Dry Weight | |
|---|---|---|---|---|---|---|
| UPS 31 | 3.98[y] | 0.17[z] | 0.50[y] | 0.02[z] | 12.57[y] | 0.03[z] |
| UPS 45 | 6.83 | 0.31 | 0.79 | 0.14 | 11.56 | 0.14 |
| UPS 46 | 3.53 | 0.18 | 0.40 | 0.03 | 11.42 | 0.10 |
| UPS 59 | 5.88 | 0.39 | 0.65 | 0.05 | 11.03 | 0.22 |
| UPS 61 | 4.38 | 0.09 | 0.48 | 0.01 | 11.08 | 0.19 |
| UPS 66 | 3.93 | 0.46 | 0.47 | 0.06 | 11.96 | 0.08 |
| UPS 78 | 4.65 | 0.26 | 0.54 | 0.03 | 11.76 | 0.14 |
| UPS 80 | 6.25 | 0.36 | 0.80 | 0.06 | 12.89 | 0.35 |
| UPS 102 | 4.08 | 0.19 | 0.32 | 0.01 | 11.63 | 0.07 |

[y]mean of 4 plants
[z]standard cover

The mean dry pod weight varied according to the selection (Table 3). UPS 45, UPS 59, UPS 121, $L_1$, $L_2$ and $L_3$ had greater pod weight than the other selections. The number of seeds per pod varied among strains and the largest number was recorded for those with greater pod weight. There was a higher seed/pod ratio among UP selections. UPS 78, UPS 66 and UPS 102 recorded the highest and the three Sri Lanka selections ($L_1$, $L_2$ and $L_3$) recorded the lowest ratios. However, the latter selections recorded higher seed weight than the UP selections and the differences between $L_1$ or $L_2$ and $L_3$ were significant. The lowest weights were recorded for UPS 78.

**Table 3. Pod characteristics in 13 selections of winged bean.**

| Selection | Mean Dry Pod Weight (g/plant) | No. of Seeds/ Pod | Weight of 100 Seeds (g) | Seeds/Pod Ratio |
|---|---|---|---|---|
| $L_1$ | 8.34[a] | 10-15 | 55.8 | 0.43 |
| $L_2$ | 8.52 | 10-16 | 54.0 | 0.41 |
| $L_3$ | 7.96 | 8-12 | 37.0 | 0.41 |
| UPS 31 | 5.20 | 7-10 | 31.2 | 0.45 |
| UPS 45 | 8.10 | 8-14 | 25.7 | 0.45 |
| UPS 46 | 5.30 | 8-13 | 26.3 | 0.48 |
| UPS 59 | 7.42 | 9-13 | 36.5 | 0.42 |
| UPS 61 | 5.60 | 8-10 | 27.5 | 0.49 |
| UPS 66 | 4.23 | 6-9 | 26.5 | 0.53 |
| UPS 78 | 4.95 | 7-12 | 20.9 | 0.54 |
| UPS 80 | 6.52 | 8-11 | 32.3 | 0.44 |
| UPS 102 | 4.64 | 7-10 | 26.9 | 0.53 |
| UPS 121 | 10.00 | 15-18 | 33.8 | 0.47 |

[a]each value is a mean of 5 plants

There were differences among selections in the dry matter accumulation in the shoots of winged beans at 21 days after planting. The largest weight was recorded for UPS 45 and the smallest for UPS 78. Selections $L_1$, $L_2$, $L_3$, UPS 31, UPS 46, UPS 59, UPS 61 and UPS 80 had intermediate values while the rest of the selections had low values. After 35 days of growth, greater accumulation of dry matter was observed in all selections with UPS 80 recording the highest and UPS 78 the lowest. UPS 46, UPS 59, UPS 61, UPS 66, UPS 78, UPS 120 and UPS 121 increased from 2 to 3 times compared to weights obtained after 21 days of growth. The dry matter increase in the shoots from 35 to 49 days was over two-fold in UPS 121, UPS 80, UPS 31, $L_1$, $L_2$, and $L_3$. The highest dry matter accumulation was recorded for UPS 80 and UPS 121 (2.16 and 2.10 gm) for this age of plants.

## DISCUSSION

Little information is available on the varieties of winged bean and their growth performance (N.A.S. U.S.A., 1975). Khan and Claydon (1975) initiated a program for the improvement of this species. They reported high genetic variation in traditional winged bean cultivars grown in New Guinea. The growth characters recorded in the present investigation for 10 New Guinea selections and 3 Sri Lanka selections also showed much variation in yield and yield related characters. These selections varied in leaf characteristics, pod characteristics and dry matter accumulation.

The selections that had greater plant heights generally recorded a 1.5 to 3 times increase from one stage of measurement to the other. The data indicate that plant height increase, particularly among tall growing types, has a cyclic pattern. The first cycle occurs between the 14th to 18th day and the second from the 24th to 28th day. This fluctuation in dry matter increase may be due to some form of endogenous system which is operative in tall growing selections. The height of plants was associated with dry matter accumulation. For example, UPS 80, UPS 78 and UPS 45 recorded increased heights at all stages of growth with increased dry weights.

Generally the Sri Lanka selections ($L_1$, $L_2$ and $L_3$) had greater leaf area and petiole length. The only New Guinea selection that had greater leaf area and petiole length was UPS 121. Generally, greater leaf area was associated with greater petiole length. The Sri Lanka selections were more spreading and vigorously growing and a general feature of such types are their larger leaf blades and longer petioles. The selection of plants with greater leaf area is important with respect to this crop as it is grown for various uses including the use of the foliage for green manure and livestock food (Burkill, 1906).

Greatest pod weights were recorded for three UP selections (UPS 121, UPS 45, UPS 59) and the three Sri Lanka selections ($L_1$, $L_2$ and $L_3$). The lowest ratio of seed weight to pod weight was recorded for the Sri Lanka selections. It shows that although the weight of seed is higher, the ratio of seed to pod is lower in these selections. Under outdoor growing conditions, the total yield of both seed and pods per plant was more than the total yield of UP selections (unpublished data).

There was a variation among the strains with respect to the rate of dry matter accumulation in the shoot of plants from one stage to the other. Sri Lanka selections had an initial slow accumulation followed by a greater increase from the 35th to the 49th day. Two New Guinea selections, UPS 80 and UPS 121 also showed a similar trend.

In general the Sri Lanka selections, although growing slowly at the beginning, tend to accumulate greater amounts of dry matter during the latter stages of growth. Of the UP selections tested, UPS 121, UPS 45, UPS 80 and UPS 78 show a great potential for use in a breeding program along with the Sri Lankan selections. It would therefore be possible to initiate a plant improvement program for winged bean using some of the selections from both sources and taking into consideration the plant type, disease resistance, physiological adaptation and high protein content (N.S.C. Sri Lanka and N.A.S. U.S.A., 1975).

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# The Evolution of the Winged Bean Flyer

*Joan W. Levy* and *Theodore Hymowitz*[1]

**The historical development of the Winged Bean Flyer (WBF) is summarized. An analysis is made as to who receives copies of the WBF and how the WBF serves as a medium for rapid exchange and dissemination of information. A bibliography of winged bean literature and a list of winged bean germplasm curators are presented in the paper.**

In May 1977, the first issue of the Winged Bean Flyer (WBF) was published. This paper will sketch the evolution of the WBF, why it was published, who have contributed to its development, and what kinds of responses have been generated by it.

An ad hoc advisory panel of the U.S. National Academy of Sciences (NAS) met in March 1974 at Airlie, Virginia to identify neglected but seemingly useful tropical plants, both wild and domesticated, that have economic potential. The publication "Underexploited Tropical Plants with Promising Economic Value" resulted from the panel meeting. Among the plants discussed in the report was the winged bean — *Psophocarpus tetragonolobus* (L.) DC.

The seemingly exceptional merits of the winged bean suggested that another panel be brought together to examine in depth the potential of the crop and bring it to the attention of the international development community. An ad hoc advisory panel of the NAS for the winged bean met at Airlie, Virginia in October, 1974. The publication "The Winged Bean, A High Protein Crop for the tropics" resulted from the meeting. Both NAS advisory panels were sponsored by the Bureau for Technical Assistance, Agency for International Development (AID), Washington, D.C.

The winged bean bulletin published by the NAS became a free best seller. Thus far over 10,000 copies of the bulletin have been mailed. At present, the bulletin is in its third printing.

Among the recommendations made by the NAS winged bean panel was that an informal newsletter be established to provide the interested research community with continuous information. The panel members believed that rapid exchange and dissemination of information could best be accomplished by an informal newsletter. The newsletter might contain a bibliography of published papers, preliminary experimental data, reports on observations, opinion letters, sources for seed germplasm, etc. An incorrigible punster named T. Hymowitz, who was a panel member, suggested that the newsletter be called the Winged Bean Flyer.

In August 1977, at a meeting in Maui, Hawaii under the sponsorship of the Asia Foundation, a winged bean steering committee made up of members from several countries was established to help guide international activities regarding the crop. At this meeting, the steering committee agreed with the earlier NAS panel recommendation to establish the WBF as a service to the international community interested in the winged bean. Dr. T. Hymowitz, a member of the steering committee, was asked to take on the responsibility of publishing the WBF. Subsequently, Mrs. Joan Levy became the first editor of the WBF. The Asia Foundation agreed to underwrite the cost of publishing several issues.

In May 1977, the first issue of the WBF was published by the Department of Agronomy, University of the Illinois in cooperation with the Steering Committee of the Winged Bean. The mailing list was compiled from names provided by the NAS, the Asia Foundation, the Agency for International Development, United Nations and research scientists around the world.

The WBF mailing list divided by region is shown in Table 1. Over 1000 copies of the WBF have been mailed out. Several AID officers and Asia Foundation representatives have requested multiple copies but are listed only once. Although the winged bean is not grown commercially or as a garden crop in the U.S. over 300 copies were sent to individuals, companies, institutes and foundations within the U.S. dealing in some aspect of international development programs.

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**Table 1. Distribution of the Winged Bean Flyer by region.**

| Region | | No. of Countries | | No. of Copies |
|---|---|---|---|---|
| Asia | | 22 | | 217 |
| Central | 7 | | 72 | |
| Far East | 10 | | 139 | |
| Middle East | 5 | | 6 | |
| Africa | | 12 | | 46 |
| Europe | | 9 | | 50 |
| North America | | 2 | | 333 |
| South America | | 9 | | 36 |
| Central America and Caribbean | | 22 | | 81 |
| Oceania | | 5 | | 86 |
| Grand Total | | 81 | | 829 |

The WBF mailing list divided by interest group is shown in Table 2. The list reveals that the WBF has reached a broad spectrum of interest groups. Of particular note is the impact of a copy sent to a representative of the communication media. For example, a notice about the availability of the WBF was printed in the Co Evolution Quarterly which has a circulation of 50,000.

The entire WBF mailing list arranged alphabetically by country is available from the Asia Foundation, P.O. Box 3223, San Francisco, CA 4119, U.S.A.

**Table 2. Distribution of the Winged Bean Flyer by interest groups.**

| Interest Group | No. of Copies |
|---|---|
| Private industry | 105 |
| Foundations | 35 |
| International agencies | 40 |
| Religious organizations | 29 |
| Communications media | 10 |
| Government officials | 117 |
| Research scientists | 351 |
| Individuals | 142 |
| Grand Total | 829 |

Below is a list of 155 literature references relevant to the study of the winged bean. Only those publications which have been verified are included in the list. The numbers in parentheses are the Dewey Decimal System card catalogue numbers. As a direct result of the WBF, a total of 73 publications have been reproduced and mailed to scientists who otherwise could not obtain the articles or who would have to wait several months to a year for an interlibrary reprint copy.

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One positive result of the increased interest in the winged bean has been the establishment of a number of germplasm collections. They are listed in Table 4. Some of these collections have been enlarged as a result of requests made in the WBF. Not all of those who have collections have enough seed for distribution to others, however, all appear to be working on this problem. The WBF has helped to disseminate information on the efforts underway to multiply seed and where to write to obtain seed.

The contributions of many have gone into the substance of the WBF. Reports have been received from 32 different countries, with multiple reports coming from some countries. Abstracts and bibliographical entries have appeared as a result of materials sent directly to the editor.

The editor receives about 50 inquiry letters per month. Some letters request copies of the WBF or reprints of an article. About 110 letters have been received requesting seed or information about where to obtain seed. Occasionally letters request information about who else is working in a particular area of research or information about who else is working on the winged bean in a country. Requests have also been received for information on general gardening procedures and cooking recipes.

In summation, the WBF has accomplished what its founders intended to do; that is, to sere as a medium for rapid exchange and dissemination of information. However there are many questions to be answered concerning the future of the WBF: 1) Should the WBF continue to be published?; 2) If it is to be continued, where should it be published; 3) Who should subsidize the publication of the WBF?; and 4) Should the format be continued, modified or greatly changed?

**Table 4. Winged Bean Germplasm Collections.**

| Country | Curator |
|---|---|
| Australia | — **Dr. T. N. Khan**<br>Department of Agriculture<br>South Perth 6151, Australia |
| | — **Mr. Ron Williams**<br>Plant Introduction Officer<br>C.S.I.R.O.<br>Division of Tropical Agronomy<br>St. Lucia, Brisbane |

**Table 4.** *continued*

| Country | Curator |
|---|---|
| Bangladesh | — **Dr. M. A. Mannan**<br>Bangladesh Agricultural Research Council<br>130/C, Dhanmondi Residential Area<br>Road No. 1<br>Dacca — 5 |
| Columbia | — **Dr. Kenneth O. Rachie**<br>International Center of Tropical Agriculture (CIAT)<br>Apartado Aereo 67 13<br>Cali |
| Ghana | — **Mr. S. K. Karikari**<br>Agricultural Research Station<br>University of Ghana<br>Kade |
| India | — **Dr. A. Satyanarayana**<br>Indian Institute of Horticulture Research<br>255 Upper Palace Orchards<br>Bangalore 560006 |
| Indonesia | — **Dr. Setijati Sastrapradja**<br>Mrs. S. H. Aminah Lubis<br>Lembaga Biologi Nasional<br>P.O. Box 110<br>Bogor |
| Malaysia | — **Dr. B. S. Jalani**<br>Jabatan Biologi<br>The National University of Malaysia<br>Jalan Pentai Baru<br>Kuala Lumpur 22 12 |
| Nigeria | — **Dr. W. M. Steele**<br>International Institute of Tropica Agriculture<br>Private Mail Bag 5320, Oyo Road<br>Ibadan |
| Papua New Guinea | — **Dr. V. Kesavan**<br>Faculty of Agriculture<br>University of Papua New Guinea<br>P.O. Box 4820, University Post Office |
| Philippines | — **Dr. Noel G. Mamicpic**<br>Chief, National Plant Genetics Resources Laboratory<br>Institute of Plant Breeding<br>University of the Philippines at Los Baños<br>College, Laguna |

**Table 4.** *continued . .*

| Country | Curator |
|---|---|
| Sri Lanka | — **Dr. H. M. W. Herath**<br>Department of Agricultural Biology<br>Faculty of Agriculture<br>University of Sri Lanka<br>Peradeniya |
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# Cytology of *Psophocarpus* spp.

*Nazmul Haq* and *Joseph Smartt*[1]

**Chromosome counts were made on somatic cells of several accessions of *Psophocarpus tetragonolobus* obtained from different geographical regions and were found to be 2n = 18 and 2n = 20. It is thought that the chromosome number of the species might well vary in different geographical areas. A chromosome count was also made of *Psophocarpus palustris* obtained from West Africa and found also to be 2n = 18. This study suggests that variation of chromosome number may be of great significance to breeders and a cytogenetical survey of this genus is urgently needed. A detailed karyotypical study on the genus *Psophocarpus* is in progress. The possible status of *Psophocarpus tetragonolobus* and its allies is discussed.**

## INTRODUCTION

Three species of the genus *Psophocarpus* Neck., *Psophocarpus tetragonolobus*, *P. palustris* and *P. scadens* have been grown either as food or cover crops for many years in the humid tropics. Among them *P. tetragonolobus* has been grown widely on a field scale in Burma (Burkill, 1906), in the highland of Papua New Guinea (Powell, 1974) and in many other areas of Asia, Africa, the Carribean and South America as a backyard garden crop. The origin evolution of this crop and its history under domestication is very imperfectly known and a comprehensive biosystematic study is urgently required. Among areas in which investigation is lacking or has failed to yield consistent results is that of chromosome cytology. There is no consistency in the chromosome number found in species of *Psophocarpus*. Ramirez (1960) has reported that the chromosome number for *P. tetragonolobus* is 2n = 26 and subsequently Tixier (1965) recorded 2n = 18 which has been confirmed by Dr. Brock of CSIRO as mentioned by Khan (1976) whereas for *P. palustris* complements 2n = 20 and 22 have been found (Ibrahim Lehved, 1960; Westphal, 1974). All these counts have been reported from different geographical regions. As there has been no consistency in reports of chromosome numbers and a large morphological variation has been observed in many geographical regions, it was decided to study the correlation pattern of morphological and cytological variation in order to clarify the nature of potentially valuable breeding materials. This paper reports out initial work in a program on the winged bean which was initiated in late 1976 at Southampton University.

## MATERIALS AND METHODS

The materials used were obtained from different geographical regions as described in Table 1. All plants were grown in a greenhouse (temperature 26°C ±) and one week after germination the plants were transferred to 6" plastic pots containing John Innes No. 2 compost and from then on the plants were grown in 11 to 12 hours day length. The plants were transferred to 12" diameter plastic pots 1 1/2 months after germination.

The technique for root tip preparations was similar to that of Smartt and Gregory (1967) and the measurement of hilum and stem were taken with micrometer.

## RESULTS

Four seeds were sown of each available accession obtained from different geographic regions. They were germinated within 8 to 12 days except for K-12 and the variety Chimbu which took longer to germinate (18 to 21 days).

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**Table 1. Accessions of *P. tetragonolobus* and *P. palustris*.**

| Name of accession | Supply | Primary source |
|---|---|---|
| *P. tetragonolobus* | | |
| UPS-32 | Agricultural University, Papua New Guinea | Papua New Guinea |
| UPS-38 | Agricultural University, Papua New Guinea | Papua New Guinea |
| UPS-45 | Agricultural University, Papua New Guinea | Papua New Guinea |
| UPS-53 | Agricultural University, Papua New Guinea | Papua New Guinea |
| UPS-99 | Agricultural University, Papua New Guinea | Papua New Guinea |
| Tpt-1 | IITA, Nigeria | — |
| Tpt-2 | IITA, Nigeria | — |
| WB4 | Cambridge | Papua New Guinea |
| Chimbu | Illinois, U.S.A. | Papua New Guinea |
| K-12 | Florida, U.S.A. | — |
| 902(1) | National Biological Institute, Indonesia | Indonesia |
| 903 | National Biological Institute, Indonesia | Indonesia |
| 1000(4) | National Biological Institute, Indonesia | Indonesia |
| 1102(d) | National Biological Institute, Indonesia | Indonesia |
| *P. Palustris* | | |
| Tpt-7 | IITA, Nigeria | — |

## Chromosome Number

Chromosome counts were made on 14 accessions of *P. tetragonolobus* and found to vary within some varieties from the same geographical area (Table 2). Polymorphism was found to be present in a single accession of an Indonesian variety 1000 (4) and also in the accession UPS-45; chromosome numbers were found of 2n = 18 and 2n = 20 (Figs. 1—4).

**Table 2. Chromosome number in different accessions of *P. tetragonolobus* and *P. palustris*.**

| | | | | | | |
|---|---|---|---|---|---|---|
| *P. tetragonolobus* | | | | | | |
| UPS-32 | UPS-38 | UPS-45 | UPS-53 | UPS-99 | Tpt-1 | Tpt-2 |
| 18 | 18 | 18, 20 | 18 | 18 | 18 | 18 |
| WB4 | Chimbu | K-12 | 902(1) | 903 | 1000(4) | 1102(d) |
| | 18 | 18 | 18 | 18 | 20 | 18 |
| *P. palustris* | | | | | | |
| Tpt-17 | | | | | | |
| 18 | | | | | | |

Chromosome counts were also made on one accession (Tpt-7) of *P. palustris* and found to be 2n = 18 (Fig. 5).

Three classes of chromosomes were found to be present, long, medium and short with median, submedian or sub-terminal centromeres. Three to four pairs of satellites were present and the chromosomes bearing satellites were acrocentric.

## Morphological Variation

A variation is observed in different morphological characters studied e.g. seed weight, length and width of hilum, seed color and stem color. The highest seed weight (0.41 gms) was found in an accession obtained from Indonesia and the lowest was found to be in the accession WB4 (0.2 gms.). The greatest length and width of the hilum were observed in the accession 1000(4) obtained from Indonesia (length X-4.9 ± 0.7, width X-3.1 ± 0.5) and the lowest length and width are observed in the accession UPS-53 (length X-3.6 ± 0.6, width X-2.3 ± 0.4).

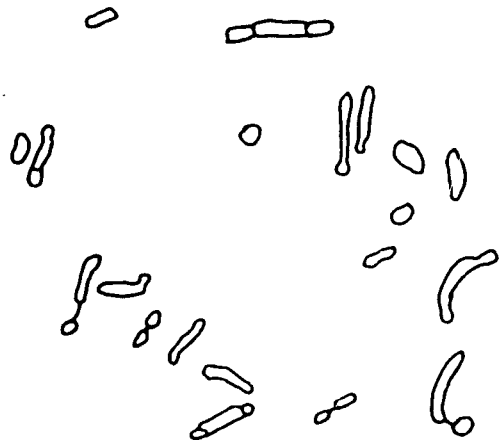

Fig. 1. UPS-45: 2n = 20

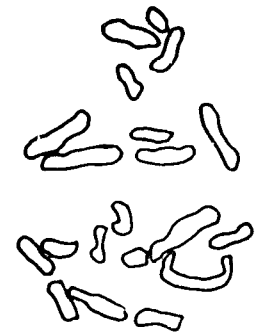

Fig. 2. UPS-45: 2n = 20

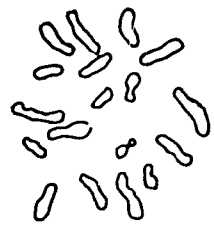

Fig. 3. UPS-45: 2n = 18

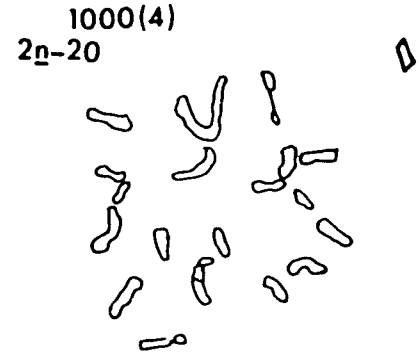


Fig. 4. Var. 1000(4): 2n = 20

Fig. 5. *P. Palustris* (Tpt-7) 2n = 18

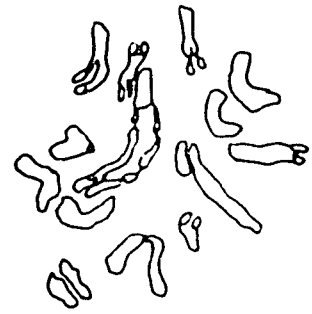

Fig. 6. Var. WB-4: 2n = 16

The seed colors were found to be dark brown, brown and yellowish brown.

Variation was also observed in stem color within the different accessions obtained from different regions except for the Indonesian accessions which were all green. Both brown and green variants were observed within the accessions UPS-45, UPS-99, Tpt-2 and Chimbu. The green variants found in UPS-45 and 1000(4) were also found to differ in chromosome number $2n = 20$.

Differences in diameter of the stem were observed in the materials studied. The greatest thickness of the stem was found to be in the accessions Tpt-1 and Tpt-2.

No variation was observed in the shape and size of the leaf and stipule of the Indonesian varieties. Stipules are small and fused at the base. Stipules of the variety Chimbu are however large but also fused except at the apex. Stipules are small in all the accessions from Papua New Guinea except UPS-99 and UPS-32 which are similar to the Indonesian varieties. Variation in leaf size was observed only in Papua New Guinea accessions (ovate and rhomboid).

Only one accession (Tpt-7) of *P. palustris* was studied and no variation was observed within it.

## DISCUSSION

The results obtained in this study are of interest from three points of view: (a) evolution (b) taxonomic status and (c) implication in breeding.

The material studied both of *Psophocarpus tetragonolobus* and *P. palustris* appears to have a basic number of $2n = 18$. However, there are indications that some variation around this number can occur. Counts of $2n = 20$ have been obtained in some *P. tetragonolobus* material accessions 1000(4) and UPS-45 The basis for this numerical polymorphism may be due to centric fusions tending to reduce the chromosome numbers, the lower chromosome numbers being derived from the higher. Individuals containing $2n = 18$ chromosomes have an extra pair of longer chromosomes and two pairs less of short chromosomes which perhaps result from centric fusion. This tendency has developed further in one individual of the accession WB4 (Fig. 6) where a pair of very long chromosomes with a large medium centromere region has been observed, chromosome counts of this individual showed $2n = 16$. However these counts could not be adequately confirmed due to shortage of material. This perhaps indicates that the original chromosome number of *P. tetragonolobus* could well be $2n = 20$ and the observed $2n = 18$ and 16 might well be the result of contromere fusions.

Similar explanations can be advanced from a single accession of *P. palustris* where the counts of $2n = 18$ is recorded (Frahm Leliveld, $2n = 20$, Westphal, $2n = 20$ and 22). However, this suggests that the variation in chromosome numbers reported in the literature may have some real basis. Legume chromosomes are notoriously difficult cytological material and misinterpretation is likely to occur, but some published material e.g. that of Ramirez is incontrovertible, presuming that the material was correctly named in the first place.

The apparent production of chromosome races in *Psophocarpus* may well be the outcome of the incipient evolution of a particular type of isolating mechanism in the course of speciation and this numerical polymorphism could have a geographic basis (Ramirez, $2n = 26$, Tixier, $2n = 18$ and Khan, $2n = 18$). The trend apparently has been for centromeric fusion to occur between the smaller chromosome pairs.

There is at present some confusion over the taxonomy of *Psophocarpus*. It seems probable that some forms referred to as *P. tetragonolobus* are in fact *P. palustris* and what have been regarded as a pair of species may in fact prove to be a complex of sibling species. Verdcourt (personal communication) has already classified this genus into nine species. The taxonomic status of all accessions needs to be reviewed in the light of Verdcourt's forthcoming monograph of the genus. This presumably will establish which species are in cultivation and which are truly wild.

Chromosomal polymorphism could have very significant repercussions in breeding depending on the nature of the differences structurally between chromosome races and other forms of genetic isolation. Some disturbances of fertility could well result and some restriction on recombination could also result in hybrids between chromosome races. Plant breeders always look for stable genotypes with high yield capacity and good quality of the crop and the combination of desired characters from parental materials.

The chromosome differences may also have some cytotaxonomic significance. A detailed cytogenetic survey of the different species and hybrids between them is required in order to correlate as far as possible pat-

terns of morphological and cytological variation. Ultimately, a rational and definitive taxanomic revision of the genus may emerge based on the study of the affinities of a wide range of variant forms within the genus, this is a hope which will be of particular value to the plant breeders as well as general botanical interest.

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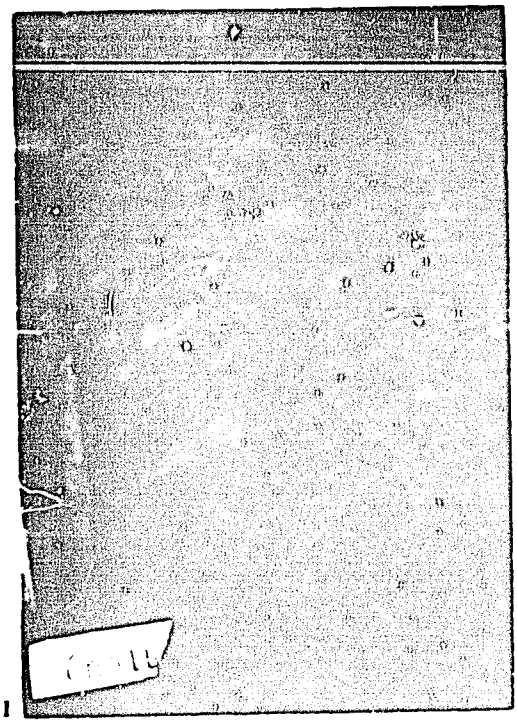
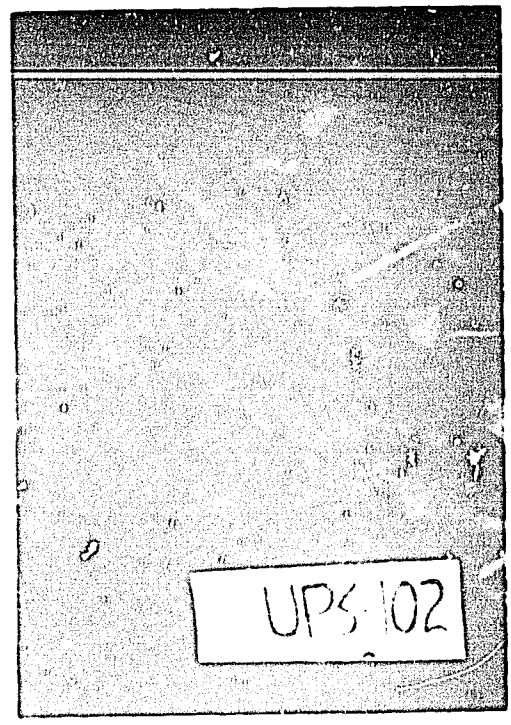
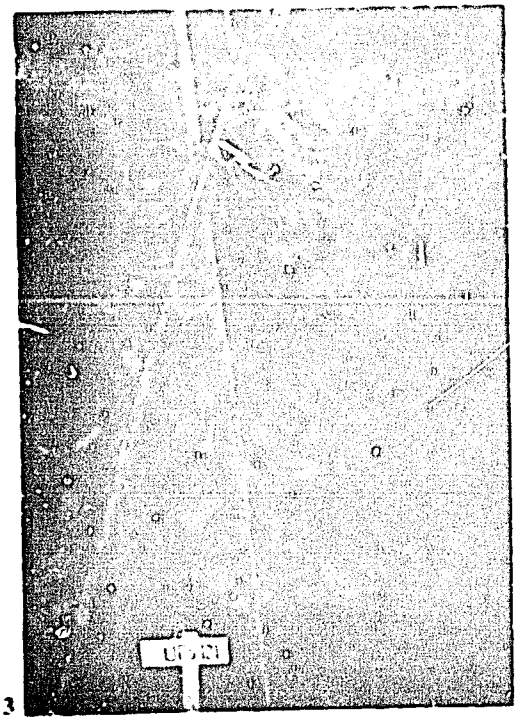
*A very prolific winged bean accession, (IHR 14) grown in Bangalore, India.*



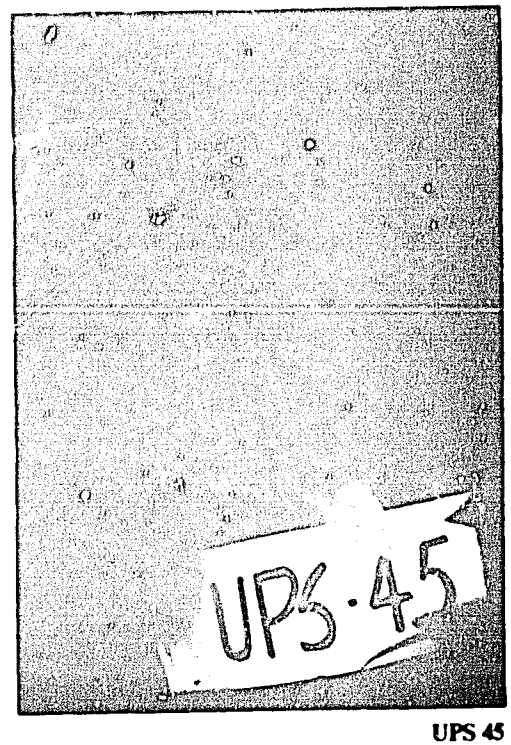
1 Chimbu




UPS 102



3 UPS 121




UPS 45

*1-4. Pod yields of 4 exotic varieties: Chimbu. (1); UPS 102. (2); UPS 121. (3); and UPS 45 (4).*

# Botany

- *Induced Mutations in Winged Bean: Effect of Gamma Rays and Ethyl Methane Sulphonate*
- *Variation in Flowering Habit in the Winged Bean and Its Implications for Sub tropical and Mediterranean Summer Conditions*
- *Flowering Behavior of the Winged Bean*
- *The Winged Bean (**Psophocarpus tetragonolobus**) (L) (DC)*
- *A Study of the Effect of Gamma irradiation on the Growth and Productivity of the Winged Bean*

# Induced Mutations in Winged Bean: Effect of Gamma Rays and Ethyl Methane Sulphonate

*V. Kesavan and T. N. Khan*[1]

**Winged bean, a legume rich in seed and tuber protein, is a climbing plant and needs staking. A project to obtain a dwarf mutant through the use of both gamma ray and chemical mutagen was initiated in mid 1975 at the University of Papua New Guinea.**

**Initially, the $LD_{50}$ dose of gamma ray radiation and cytology of this species was worked out. Winged bean is a diploid with 2n = 18 and the optimum dose of gamma rays was found to be 15-20 Kr. Post radiation storage reduced germination drastically. Ethyl methane sulphonate (EMS) was effective at lower concentrations (0.05 2%) with longer (8-12 hr) treatment time combined with 24 hr washing. Aeration during the EMS treatment was found unnecessary. However, mechanical shaking was needed to increase penetration of the chemical during treatment.**

**From each $M_1$ plant radiated with gamma rays or treated with EMS, about 20 seeds were collected to raise $M_2$ generation. To date, 20,000 single plants have been screened. Mutants for leaf color, shape, reduced internodes and early flowering types were noticed. But the desired mutant with determinate habit has not yet been isolated. In 1977 it was planned to screen more than 100,000 plants. Of these, about 20,000 $M_2$ plants have already been screened. The rest are in various stages of screening. The role of a broad genetic base in getting a desired mutant is discussed.**

## INTRODUCTION

The winged bean (*Psophocarpus tetragonolobus* (L.) DC.) is the only legume occupying a prominent place in subsistence agriculture in Papua New Guinea (PNG). It is grown widely in both Highlands and Sepik provinces for its pods, seeds, leaves, flowers and root tubers as an "all-purpose" crop. The importance of the crop both in human nutrition as a source of protein and in enriching the soil through abundant nodulation has been recognized (Masefield, 1973; Khan and Claydon, 1975). Collection work has revealed PNG as a centre of genetic diversity (Khan, 1976) for this species. Although a broad spectrum of variation is present for many qualitative and quantitative characters in the germplasm collection at the University of PNG, there is no accession possessing a plant architecture suitable for large scale cultivation of this bean (Khan and Claydon, 1975). All the available varieties are of an indeterminate, viny, climbing growth habit and require support. Such varieties are labor intensive and may not be suitable for medium or high level agricultural technology. An erect, determinate or dwarf growth habit would make this crop ideal for such a technology throughout the humid tropics. It was decided to use mutation breeding techniques in order to isolate a mutant with a determinate, bush type growth habit and also to enrich the genetic variation for other desirable characteristics.

With financial help from the International Atomic Energy Agency and technical collaboration of the Division of Plant Industry, CSIRO, Australia, a mutation breeding project on winged bean was initiated in 1975 at the University of PNG. The primary aim of this project is to isolate a determinate, dward mutant in winged bean. Other mutants of agronomic and chemical value, if found, would broaden the existing genetic variation of this species.

## MATERIALS AND METHODS

Fresh seeds of the pure line genotype UPS 31, an accession of winged bean, were treated with gamma

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rays and ethyl methane sulphonate (EMS). From March 1976, UPS 122, another accession from the Chimbu district of PNG was used for irradiation and chemical treatments. This high yielding genotype has a more robust stem than UPS 31. $M_1$ and $M_2$ generations were raised from the treated seeds.

The gamma ray treatment was given from a Cobalt 60 source located at the Division of Plant Industry, CSIRO, Canberra, Australia. The dose rate was adjusted according to the moisture content of the seeds and ranged from 70 to 80Kr. The treated seeds were speedily returned to Port Moresby to ensure good germination.

EMS treatments were undertaken at the University of PNG using concentrations of 0.05 to 1.2%. EMS solutions were made in 0.1M phosphate buffer with pH 7. Seeds were presoaked in water for a specific period (1.2 hr), treated with different concentrations of EMS combined with mechanical shaking for 2 to 3 hr, and washed in running water for 3 to 4 hr. The seeds thus treated with EMS were planted in "Jiffy" peat pots in the greenhouse along with fresh, untreated seeds as control (EC). Two weeks later, data on germination and seedling height were taken. Seedlings were then space planted in the field to raise the $M_1$ generation. In the sixth experiment with radiation treatment, and the fifth experiment with EMS, seeds of UPS 122 were used. In the previous experiments seeds came from the accession UPS 31.

When the plants were mature, 4 to 6 pods from different parts of each $M_1$ plant were collected to supply about 20 seeds for the next generation. The $M_2$ generation was raised at periodic intervals at two sides near Port Moresby and another at the Faculty farm in Lae.

The screening of the $M_2$ generation started in May 1976. Since then, batches of $M_2$ seedlings have been screened and evaluated continually. For screening these plants, seeds were drilled at 20 cm intra row spacing to make effective use of the available land area. The first screening of the $M_2$ plants was done six weeks after sowing. Promising mutants were retained for further observation. Other plant types, mainly climbing plants with a viny main stem, were pulled out and discarded.

## RESULTS AND DISCUSSION

### Radiation with Gamma Rays

A total of 8,976 seeds in six batches were irradiated with different doses of gamma rays in Canberra from June 1975 to April 1976. Of these 5,031 (56%) plants were transplanted to raise the $M_1$ generation. The results on seed viability of these six batches of irradiated seeds are summarized in Table 1.

The observations on seed viability were recorded 3 to 4 weeks after irradiation treatment in Canberra. It is clear that gamma ray radiation reduced seed germination, as the dosage increased except for experiment 1R. In this experiment, germination was 60 to 80% more than the untreated control. From the other experiments, the $LD_{50}$ dose appeared to be between 15 and 20 kr. Doses over 30 Kr (Expt. 2R) reduced germination drastically. Also, doses over 25 Kr reduced the plant height by 50%. Poor germination even with 15 Kr in this experiment was found to be related to post-irradiation storage. When seed viability was assessed by sowing seeds immediately after treatment in Canberra, poor germination (5 to 10%) was observed only at 25 and 30 Kr. Therefore the present work is confined to doses ranging from 10 to 25 Kr.

**Table 1. Summary of experiments on gamma ray radiation on winged bean seed germination.**

| Gamma rays dose | Experiment number and % of seed emergence | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1R | 2R[a] | 3R1 | 3R11 | 4R1 | 4R11 | 5R |
| Control | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 10 Kr | | 94.8 | 97.0 | 72.0 | | | 100.0 |
| 15 Kr | 179.7 | 0 | 97.0 | 54.0 | 95.8 | 188.0 | 95.6 |
| 20 Kr | 178.9 | 0 | 91.0 | 41.0 | 94.7 | 74.6 | 98.5 |
| 25 Kr | 162.5 | 0 | 62.0 | 21.0 | 94.7 | 115.3 | — |

[a]Doses of 30-80 Kr tried in Experiment 2R, also showed total loss of seed viability.

The effect of storage was studied in experiments 3R and 4R. Batches of seeds treated at the same time were split into two groups (3R1 and 3R11), and were planted on September 15, 1975 and October 3, 1975

respectively. The results indicated that a storage period of 18 days reduced germination by 40 to 50% at 20 and 25 Kr doses. However, in a similar experiment (4R1 and 4R11), with a time gap of only 7 days between plantings, conflicting results were obtained. Reduced germination with increasing gamma ray doses appeared to be consistent. All seedlings pretreated with gamma rays gave both the appearance of virescent, mottled and deformed cotyledons and leaves, and also a slow rate of growth.

**EMS Treatments**

Five batches of seeds were each treated with different concentrations of EMS prepared in a neutral phosphate buffer. The effect of EMS on survival (germination %) and on plant height, recorded 14 to 16 days after sowing, are summarized in Table 2. Two sets of controls were included in these experiments, one with the fresh, untreated seeds (FC) and another treated with the buffer solution (C).

In the first two experiments (I and II), seeds were soaked in water for 2 hr, treated with different EMS solutions and shaken mechanically for 8 hr and then washed in running water for 24 hr at room temperature. A reduction in germination and plant height was observed at the lower concentrations of EMS (0.05 to 0.2%). The growth rate of the treated seedlings was less compared to that of both controls. The germination was reduced by 20 to 80%. A height reduction of 20% was obtained from 0.05% EMS treatment. It was also found that treating seed with buffer solution alone could reduce seed germination.

Flask aeration also affected seed germination, since the passing of air through flasks at the time of EMS treatment (Expt. III) reduced germination by 47%. Experiments IV and V utilized higher concentrations of EMS (0.1 to 0.6%) with limited time for soaking (one hour pre soak in water, 2 hr in EMS and 3 hr washing). This limited time for treatment increased the germination by 10 to 40%. The growth rate was slower compared to the control but the difference was not as drastic as in the two previous experiments.

Increasing concentrations of the chemical had a significant negative association with the survival of the seedlings with r = 0.93** and 0.90** in experiments II and IV, respectively.

Since variable results were obtained from chemical treatments, only a limited number of plants (800) were raised in the field to get $M_2$ generation. It is planned to raise more $M_1$ plants using low concentrations of EMS in the coming year.

**Table 2. Effect of E.M.S. on germination and reduction in plant height.**
**Expt. I.**

| Treatments | Germination Mean | % | %C | Plant Height (cm) Mean | %C |
|---|---|---|---|---|---|
| Fresh Seed Control (FC) | 34.0 | 97.1 | | | |
| Buffer Control (C) | 17.67 | 50.5 | 100 | 37.88 | 100 |
| 0.10% EMS | 3.75 | 10.7 | 21.2 | 10.21 | 26.9 |
| 0.15% EMS | 3.57 | 10.2 | 20.2 | 5.31 | 14.0 |
| 0.20% EMS | 4.80 | 12.6 | 24.9 | 4.27 | 11.3 |

**Expt. II Effect of E.M.S. on germination and height**

| Treatments | Germination Mean | % | %C | Plant Height Mean | %C |
|---|---|---|---|---|---|
| Control | 19.3 | 48.3 | 100 | 22.2 | 100 |
| 0.05% EMS | 15.3 | 38.3 | 79.3 | 19.9 | 80.6 |
| 0.10% EMS | 11.0 | 27.5 | 56.9 | 4.1 | 18.6 |
| 0.15% EMS | 9.3 | 23.3 | 48.8 | 6.3 | 28.6 |
| 0.20% EMS | 8.7 | 21.6 | 44.8 | 2.2 | 9.9 |
| S.E. ± (P < 0.05) | NS | | | 5.0 | |

**Table 2.** *continued*

| **Expt. III The effect of aeration on germination** | | |
|---|---|---|
| Fresh control | 29.5 | 100.0 |
| Soaking | 10.5 | 35.6 |
| Aeration | 2.5 | 16.9 |

**Expt. IV**

| Treatment | Germination Mean | % | %C | Plant Height (cm) Mean | %C |
|---|---|---|---|---|---|
| FC | 44 | 88 | | 34.5 | |
| C | 18 | 36 | 100 | 23.7 | 100 |
| 0.4% E.M.S | 26 | 52 | 143 | 22.5 | 94.2 |
| 0.8% E.M.S | 17 | 34 | 95 | 22.3 | 94.2 |
| 1.2% E.M.S | 18 | 36 | 100 | 12.3 | 52.2 |
| 1.6% E.M.S | 13 | 26 | 73 | 22.1 | 44.2 |

**Expt. V Effect of different E.M.S. treatments on germination and plant height after 14 days.**

| Treatment | Germination Mean | % | %C | Plant Height (cm) Mean | %C |
|---|---|---|---|---|---|
| FC | 21.0 | 63 | 92.6 | 13.5 | 87.1 |
| C | 22.7 | 68 | 100 | 15.5 | 100.0 |
| 0.1% E.M.S | 24.6 | 62 | 108 | 13.4 | 86.4 |
| 0.2% E.M.S | 25.2 | 63 | 108 | 13.4 | 86.4 |
| 0.3% E.M.S | 26.0 | 65 | 115 | 12.8 | 82.6 |
| 0.4% E.M.S | 24.6 | 62 | 108 | 16.4 | 105.8 |
| S.E. ± (P < 0.05) | NS | | | 1.5 | |

## Screening of $M_2$ Generation

The first batch of $M_2$ seed obtained from gamma ray irradiation was screened in Lae during May to June, 1976. Four more batches of $M_2$ generation were screened before February, 1976. A total of 2,500 $M_1$ plants were carried forward to raise $M^2$ progenies, numbering about 20,000. Limitations of space and dry weather prevented raising approximately 30,000 $M^2$ plants by the end of 1976. These plants will be screened during 1977.

One mutant with shortened internodes and dark green miniature leaves was identified from plants receiving the 10 Kr treatment. Although flower buds were formed, the plant failed to produce any flowers after 90 days, and eventually died. Another interesting mutant was observed in the $M_2$ generation. This plant flowered on the 43rd day from the date of sowing (3 to 4 days earlier than any accession in the present germplasm), and it came from the 25 Kr treatment. No flowers on the first cluster set pods. So far, no determinate, bush type mutant has been detected.

Some of the other mutant, observed were: chlorophyll mutants with streaks on the leaves; albino types; small or miniature leaved mutants; plants with dark green foliage; distowed leaves; and mutants with a single cotyledon.

The variable results obtained from both the physical and chemical mutagen treatments on winged bean need further studies such as those undertaken by Konzak and his associates on cereals (Konzak *et al.* 1972, Narayanan and Konzak, 1969). These studies may reveal ways of increasing precision and reproductibility. However, to fulfill the objectives of the present program genetic variation in the $M_2$ generation is of more crucial importance. The present results indicate that the optimum dosage is in the range of 10 to 20 Kr for gamma rays, and at concentrations of 0.05 to 2% for EMS combined with 8 to 16 hr of washing in running water. Aeration during EMS treatment was found unnecessary as it reduced germination drastically. It appears that adding $O_2$ to the water may be related to the phenomenon of "water sensitivity" (Konzak *et al.* 1972).

In the limited population of 20,000 $M_2$ plants screened thus far, mutants for chlorophyll, leaf color and shape appear most frequently. Fertile mutants with the desired, determinate growth habit have not yet been isolated. If the growth habit is simply inherited, at least 100,000 $M_2$ progenies will have to be screened (Iran abd ;briejm 1972) to isolate a mutant with a dwarf or bush type growth habit. The main task in 1977 will be

to screen this large population of $M_2$ plants.

Following the discussions during the 4th Research Co-ordination Meeting, FAO/IAEA/GSF Seed Protein Improvement Programme, Baden, Austria, April, 1977, the scope of investigations on mutation breeding in winged bean was enlarged. Mutation research in other legumes, notably garden peas, indicate that the success in isolating a dwarf mutant depends on a broad genetic base of the original populations treated with mutagens (Prof. Gottschalk personal communication). With this aim, ten elite accessions of winged bean were treated with gamma rays during mid 1977. The $M_1$ progeny is now being grown in Port Moresby. It is also planned that the protein content of some of the segregating families in advanced generations will be monitored.

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# Variation in Flowering Habit in the Winged Bean and Its Implications for Subtropical and Mediterranean Summer Conditions

*G.F. Eagleton, N. Thurline, I.N. Khan*[1]

**Investigations carried out in Perth, Western Australia (32°S) aim to study the genetic basis of the winged bean's response to varying conditions of temperature and daylength. Reproductive development is emphasized. Approximately 200 introductions have been screened for basic qualitative and quantitative characters. A 3 × 3 factorial experiment is examining temperature and photoperiod responses of four select lines, and a diallele cross analysis of contrasting lines has been initiated to investigate the genetics of these responses.**

**Diversity within and between countries of origin has been encountered. There is a marked contrast between lines from Papua New Guinea and from Malaysia. Results so far suggest that a temperature of 27/22°C and a daylength somewhat below 12 hours is optimal for reproductive development. Of 132 crosses so far attempted, there has not been any indication of incompatibility between lines of different origin. Techniques for vegetatively propagating winged bean from cuttings has proven effective and may be useful for multiplying lines with marked photoperiod sensitivity.**

**These studies are seen to have implications for breeding winged bean lines with the capacity to quickly flower and set pod in the summer of subtropical Australia and Asia.**

## INTRODUCTION

The winged bean (*Psophocarpus tetragonolobus* (L) DC) has long been cultivated in Southeast Asia and the West Pacific between the latitudes 5°S and 25°N (Masefield, 1973; NAS, 1975; Khan *et al.*, 1977). This rather restricted distribution perhaps reflects patterns of human migration and cultural spread. Alternatively, the winged bean as a biological entity may be specifically adapted to the conditions of the humid tropics. In the study reported here, we have set out to examine this latter proposition.

Our aim has been to investigate the possibility of extending the geographic range of the winged bean to include subtropical environments. Much of the work is being carried out in Perth, Western Australia (32°S) which has a typically mediterranean climate (see Figure 1). Wet winters and hot dry summers predominate. Frosts are rare, but gale force winds are not uncommon.

Although this report emphasizes reproductive development, other aspects of winged bean biology are raised as fruitful avenues for investigation. At this stage in our work, definitive data are not possible, nor perhaps, a desirable objective at the present time. Rather, we have attempted to survey future directions. For convenience, we have divided the report into five sections.

## GERMPLASM ACQUISITIONS

Since November 1976 approximately 200 winged bean lines have been compiled to form the collection of the University of Western Australia (Table 1). Most of these lines have been described elsewhere (Sastrapradja and Arminah Lubis, 1975; Khan, 1976; Chomchalow, 1976) but not the Malaysian collection of Eagleton and Chai Nyet Fah, which figures largely in this report and which we therefore briefly describe.

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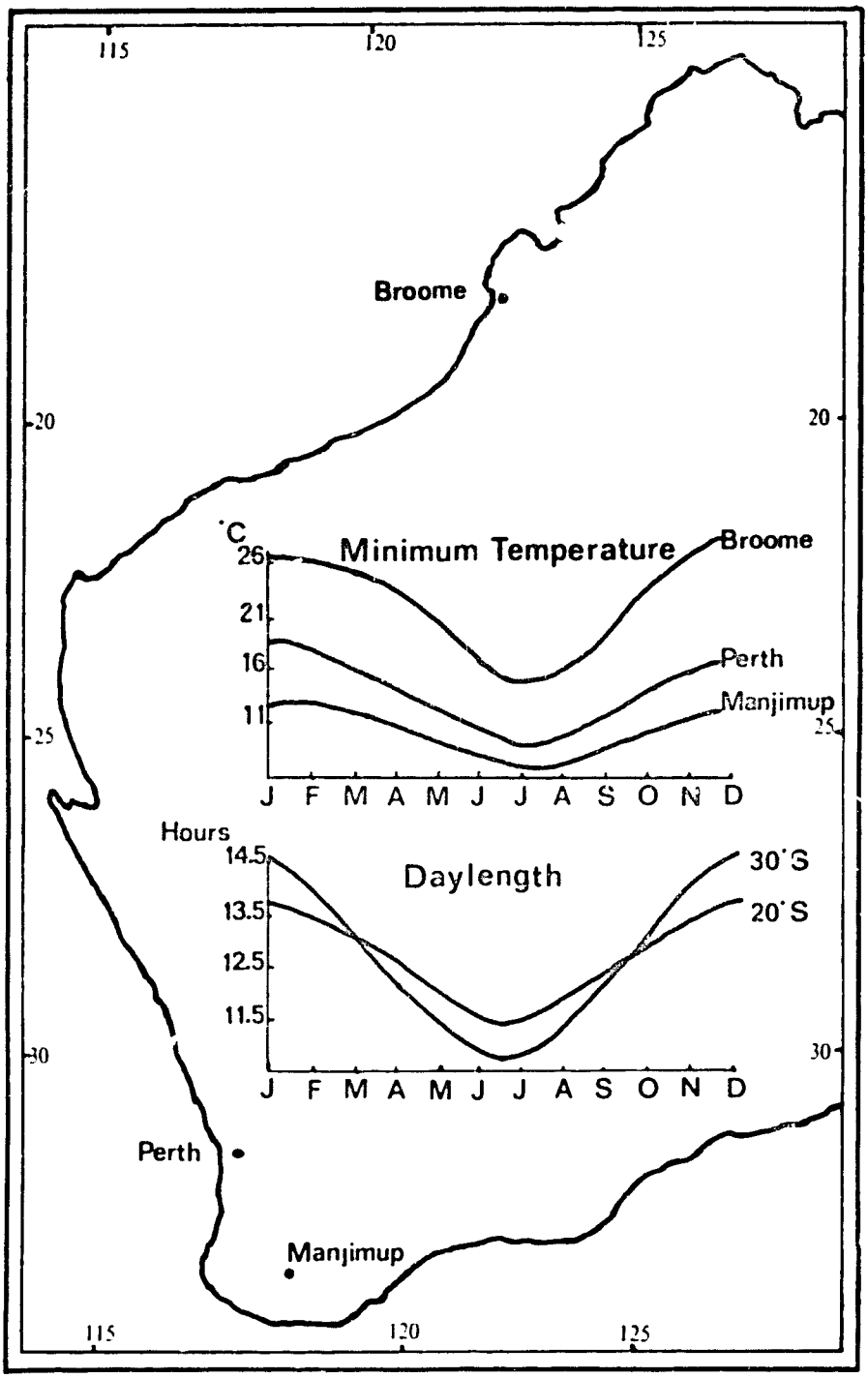


Figure 1. Climate of Western Australia

**Table 1. University of Western Australia winged bean collection.**

| Lines | Number of viable lines | Country of origin | Collection |
|---|---|---|---|
| UPSI — 122 | 88 | Papua New Guinea | Khan; UPNG, Port Moresby |
| UPMI — 97 | 72 | Malaysia | Eagleton and Chai; UPM, Serdang |
| M7/1 — 19/5 | 12 | Malaysia | Wong; UPM, Serdang |
| IPt 1 — 16 | 14 | Nigeria (mixed) | Rachie; IITA, Ibadan |
| Phrae 0101—Ratch 0106 | 12 | Thailand | Chomchalow, ASRC, Bangkok |
| Pt 901—Pt 909 | 5 | Indonesia | Sastrapradja; LIPI, Bogor |
| TTS 37—Jayapuri | 3 | Indonesia | De Neve; Padjadjaran U, Bandung |
| Acc. 1—7 | 4 | Sri Lanka | Herath; U Sri Lanka, Peradeniya |
| IC 15017—EC 27884 | 4 | India (mixed) | ICAR, New Delhi |

**Malaysian Collection**

This collection was compiled in October-November of 1976 and could be regarded as representative of the west coast states of peninsular Malaysia (Figure 2). At only two sites was winged bean grown on anything approaching commercial scale. At all other sites, the plant was cultivated as a "backyard" perennial, for its green pods. Nowhere, were tubers consumed, although medicinal uses were reported by a few Malay villagers.

A variety of Malay names were used to describe the plant *(kacang kelisah, kacang botor (botol)* and *kacang belimbing)* but there was not a strong association with one cultural group. It was to be found in the compounds of Chinese and Indian homes alike, although on rubber plantations, Tamil workers seemed to prefer Lablab bean *(Lablab purpureus)* as their minimum-care leguminous vegetable. Winged bean was more often found in towns and bigger villages than in remote regions.

In spite of the wide area sampled and the diversity of sites, there was considerable uniformity in the plants observed. This uniformity has since been confirmed in the preliminary germplasm screening.

## GERMPLASM SCREENING

Most of the germplasm has been grown to mature seed on at least one occasion in Perth, Western Australia. The plantings were carried out in several batches, the first three of which are reported here.

**Planting A**

Consisted of 105 lines of the Papua New Guinea (PNG) collection (Khan, 1976), 16 lines from IITA, Nigeria (including one line of *Psophocarpus scandens**), 12 lines from Malaysian (Wong, 1975) and one from Bogor, Indonesia. These were first planted in the field in the summer of December 1976, but because of poor growth were transplanted into polythene bags in open glasshouse conditions in March 1977.

**Planting B**

Consisted of 93 lines of Eagleton and Chai's collection planted into pots in January 1977, and transplanted into polythene bags in March.

**Planting C**

Consisted of lines from the PNG and Malaysian collections which had failed to establish in plantings A and B, together with a few lines from Indonesia and India. These were germinated in April and transplanted into polythene bags in May.

***One specimen of the line IPt 7 was examined and identified by Dr. B. Verdcourt, Royal Botanic Gardens, Kew.**

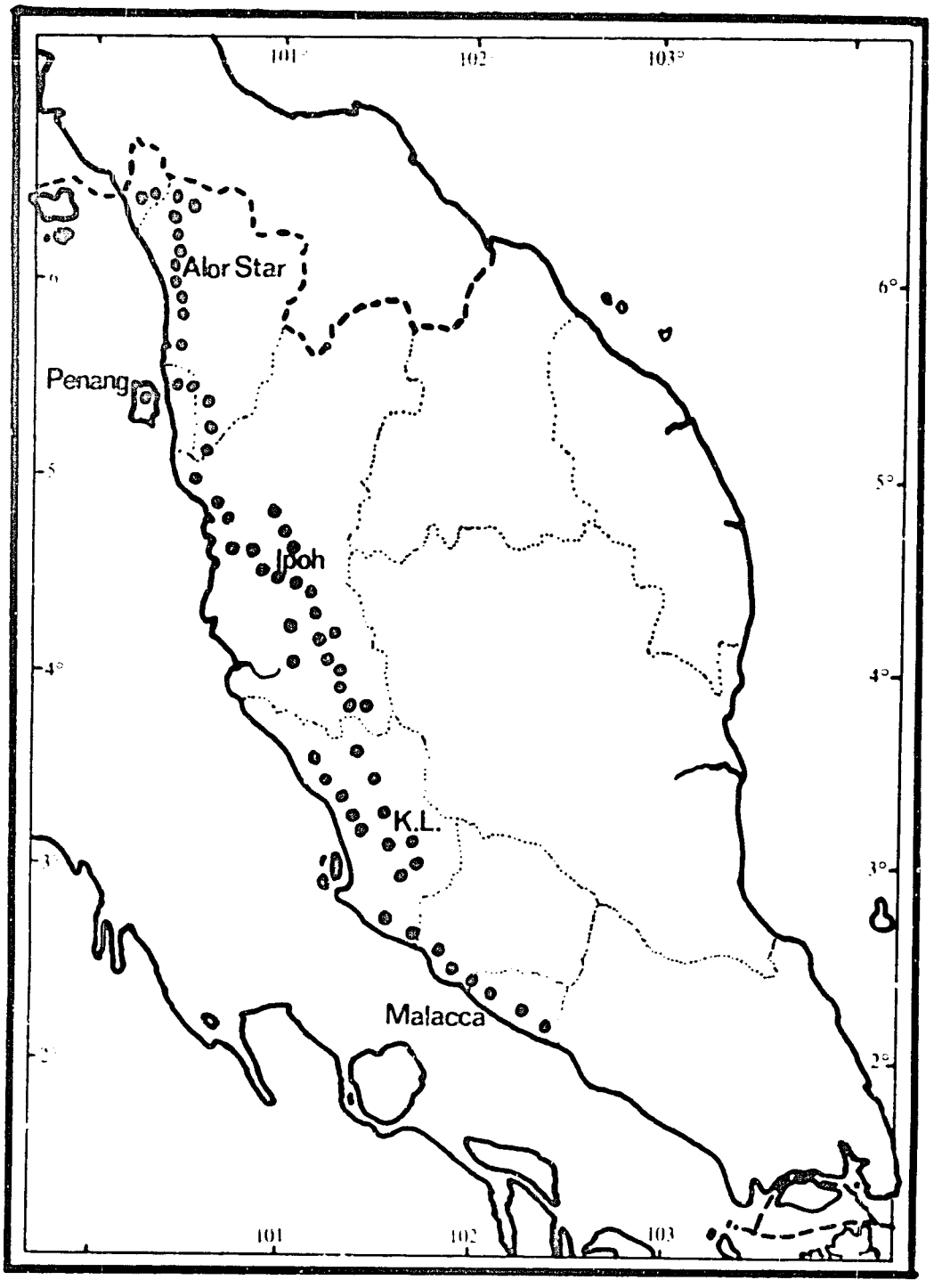


Figure 2. Malaysian winged bean collection location of collection sites.

All lines were grown under glasshouse conditions in 30 cm diameter polythene bags containing unsterilized river loam. Water was given as required. Nutrients were supplied (including nitrogen at levels sufficiently high to suppress natural nitrogen fixation). Plants were supported by two-metre tripods of cut cane.

The number of plants per line (per polybag) varied between one to five. Replication was incomplete and experimental design was inadequate for statistical purposes. Thus, yield information is of little consequence.

## General Performance

Table 2 compares planting and collections within performance categories. Germination took from 8 to 14 days and was poorest in the Malaysian B collection which had never before been planted. Once established, Malaysian lines were more persistent than PNG lines. In planting A, three lines — two from IITA and one from Indonesia — failed to flower. In planting B, 54 per cent of the lines which flowered in winter failed to set pod.

**Table 2. Germplasm screening: performance comparison.**

| Planting | Collection | Performance* (number of lines) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G | Total |
| Planting A Dec. 1976 | PNG | 17 | 9 | 6 | 41 | 30 | — | 2 | 105 |
| | MALAYSIA | 1 | — | — | — | 11 | — | — | 12 |
| | IITA | 2 | — | — | 7 | 4 | 2 | — | 15 |
| | *P. scandens* | — | — | — | — | — | — | 1 | 1 |
| | INDONESIA | — | — | — | — | — | 1 | — | 1 |
| Planting B Dec. 1977 | MALAYSIA | 21 | 3 | 1 | — | 37 | 2 | 29 | 93 |
| Planting C April 1977 | PNG | 11 | — | 8 | 4 | — | 3 | — | 26 |
| | MALAYSIA | 14 | — | 2 | — | 1 | 2 | — | 19 |
| | INDIA | — | — | — | — | — | 2 | — | 2 |
| | INDONESIA | — | — | — | 1 | — | — | — | 1 |

***Performance categories:**
**A — Failed to emerge**
**B — Died in vegetative stage**
**C — Flowered but died subsequently**
**D — Produced mature pods but died subsequently**
**E — Produced mature pods and persister**
**F — Remained in the vegatative phase**
**G — Flowered, persisted but produced no mature pods.**

The single specimen of *P. scandens* proved to be very persistent, flowered profusely, but failed to set a single pod in spite of pollination assistance.

## Germplasm Differences

A comparison of the collections for variation in qualitative characters is listed in Table 3 and for quantitative characters in Table 4. Only plantings A and B are included.

The categories used in Table 5 mask the considerale diversity in the PNG collection to which Khan (1976) has previously referred, but highlight the differences between collections. The Malaysian collection was surprisingly uniform when considering the wide area it represented, while the IITA collection of mixed origins, was intermediate in diversity.

Although there were individual exceptions, the PNG collection proved on average, to be less persistent, less vigorous and smaller in leaves, flowers and seed than the other collections. The small pod size and seed number recorded for the Malaysian lines was very likely an artifact of the particularly late development in the Perth environment. In general, leaf area and pod size were much smaller than recorded in other studies (see for example Khan, 1976; Wong, 1975). This emphasizes the harsher growing conditions in this study.

**Table 3. Comparison of qualitative variation.**

| Character | | Categories | Number of lines per collection PNG | MALAYSIA | IITA |
|---|---|---|---|---|---|
| Leaflet | Shape | Ovate | 88 | 80 | 14 |
| | | Intermediate | — | 1 | — |
| | | Lanceolate | — | 2 | — |
| Stem | Colour | Green | 61 | 82 | 9 |
| | | Part Pigment | 21 | — | 1 |
| | | Full Pigment | 24 | 1 | 4 |
| Calyx | Colour | Green | 29 | 83 | 10 |
| | | Part Pigment | 18 | — | 1 |
| | | Full Pigment | 67 | — | 1 |
| Flower | Colour | Pale Blue | 32 | — | 1 |
| | | Blue | 17 | 81 | 11 |
| | | Intermediate | 15 | — | — |
| | | Purple | 36 | — | — |
| Pod | Colour | Green | 25 | 48 | 7 |
| | | Only Pigmented Wings | 23 | — | 1 |
| | | Pigmented | 25 | — | 1 |
| | Shape | Rectangular | 51 | 48 | 9 |
| | | Semi-flat | 4 | — | — |
| | | Flat | 7 | — | — |
| | Surface | Smooth | 53 | 48 | 9 |
| | | Rough | 10 | — | — |
| Seed | Colour | Tan | 12 | 48 | 8 |
| | | Mottled or Marked | 23 | — | 1 |
| | | Brown | 9 | — | — |
| | | Black | 16 | — | — |

*Categories are arbitrarily defined. Many sub-categories could be used for the PNG collection (see Khan, 1976).

**Table 4: Comparison of Quantitative Variation.**

| Character | Collection | Number of lines | Range | Mean |
|---|---|---|---|---|
| Vigour (subjective score 1-10 during flowering) | PNG | 84 | 1 — 9 | 5.5 ± 0.2 |
| | IITA | 15 | 7 — 10 | 9.2 ± 0.2 |
| | MALAYSIA A | 10 | 8 — 10 | 9.5 ± 0.1 |
| | MALAYSIA B | 72 | 1 — 10 | 8.8 ± 0.2 |
| Single Leaf Area (sq. cm. based on largest leaf) | PNG | 27 | 23 — 135 | 62 ± 5.1 |
| | IITA | 14 | 50 — 138 | 93 ± 7.5 |
| | MALAYSIA A | 10 | 63 — 181 | 102 ±11.1 |
| | MALAYSIA B | 40 | 73 — 194 | 99 ± 4.0 |
| Flower Size (Standard breadth cms. based on 5 flowers per plant) | PNG | 30 | 2.5 — 3.2 | 2.9 ± 0.05 |
| | IITA | 8 | 2.1 — 3.4 | 3.0 ± 0.15 |
| | MALAYSIA A | 5 | 2.7 — 3.6 | 3.3 ± 0.14 |
| Pod Length (cm. based on mean per plant) | PNG | 50 | 6.5 — 22.0 | 13.2 ± 0.5 |
| | IITA | 10 | 8.1 — 26.5 | 14.6 ± 1.3 |
| | MALAYSIA A | 11 | 10.5 — 14.7 | 12.2 ± 0.4 |
| | MALAYSIA B | 36 | 5.9 — 18.8 | 11.9 ± 0.4 |

**Table 4.** *continued.*

| | | | | |
|---|---|---|---|---|
| Seed Weight (mg, based on mean per plant) | PNG | 45 | 69 — 353 | 227 ± 12 |
| | IITA | 12 | 247 — 523 | 375 ± 26 |
| | MALAYSIA-A | 11 | 278 — 534 | 343 ± 26 |
| | MALAYSIA-B | 34 | 128 — 536 | 419 ± 14 |
| Seed Number per Pod (based on mean per plant) | PNG | 45 | 3 — 12 | 6.7 ± 0.1 |
| | IITA | 12 | 1 — 12 | 6.1 ± 1.1 |
| | MALAYSIA-A | 11 | 4 — 8 | 5.7 ± 0.4 |
| | MALAYSIA-B | 34 | 2 — 9 | 4.7 ± 0.3 |

**Table 5. Flowering date.**

| | Number of lines | Mean flowering* date | Number of days from planting date to flowering | Duration of flowering |
|---|---|---|---|---|
| Planting A | | | | |
| IITA | 12 | 23 | 143 ± 3.9 | 41.4 ± 4.5 |
| PNG | 83 | 26 | 146 ± 1.6 | 35.8 ± 2.6 |
| MALAYSIA | 11 | 31 | 151 ± 4.7 | 34.5 ± 5.0 |
| Planting B | | | | |
| MALAYSIA | 69 | 47 | 137 ± 1.4 | 31.2 ± 2.1 |
| Planting C | | | | |
| PNG | 9 | 111 | 113 ± 2.6 | 12.6 ± 3.4 |
| MALAYSIA | 3 | 118 | 120 ± 11.2 | — |

*Recorded in days from the occasion of the first flower on April 13.

## Reproductive Development and Planting Effect

Table 5 summarizes data for flowering time.

In planting A flowering did not commence until 13 April by which time daylengths and temperatures were on the decrease (Figure 1) and plants were already more than 120 days old. This is twice the number of days required for flowering under equatorial conditions.

In the later plantings B and C, time to flowering was progressively reduced. Node of first flower dropped from greater than 15 in planting A to a mean of 7.1 ± 0.4 in planting C, suggesting the beneficial influence of decreasing photoperiod. The negative impact of declining temperature, however, can be judged by the reduction in duration of flowering which was negatively correlated (r = −0.34) with flowering date. As winter progressed an increasing proportion of flowers failed to open and exhibited severe developmental distortion. By mid-July reproductively effective flowering had ceased, although flowers continued to be formed in some lines, until mid-August.

Table 6 records data concerning fruit development. The first fully matured pods began to appear at the beginning of July, a fully 200 days after the first planting date, and continued through well into September for planting B. The impact of the colder months is seen in the percentage of flowers resulting in pods. In planting B, 25.8 per cent of pods contained distorted split seeds.

Although the Malaysian collection in Planting A was significantly slower in coming to flower than the other collections, it produced a greater number of pods per line. This, however, must be regarded with caution because of the compounding effect of different plant numbers per line.

Diversity within collections was observed and in each collection a few lines stood out for their quickness of flowering in comparison with other lines.

The single specimen of *P. scandens* did not begin to flower until July, seven months after planting. Vegetative growth had been vigorous and more than 300 flowers in racemes of up to 26 individual flowers were formed. Flowering was in the morning in contrast to the afternoon flowering of winged bean. No pods were formed in spite of pollination assistance.

**Table 6. Fruiting percentage.**

| | Planting A | | | Planting B |
|---|---|---|---|---|
| | IITA | PNG | MALAYSIA | MALAYSIA |
| Mean number of pods per line | 6.0 ± 1.2 | 4.5 ± 0.4 | 9.2 ± 1.6 | 1.7 ± 0.3 |
| Percentage of flowers resulting in fully matured pods | 21.2 ± 3.8 | 33.4 ± 3.2 | 20.4 ± 2.6 | 10.0 ± 1.6 |

**Tubering, Regeneration and Vegetative Propagation**

Once the reproductive phase was completed, tubers began to fill out the expense of shoots. Tubering was most apparent in those lines which had not set pod.

In order to test the regeneration capacity of the tubers, all surviving lines were cut to three inches above ground level in mid September. At the same time, stem cuttings and partitioned tubers of a few lines were treated with a commercial rooting hormone preparation and planted out in small pots.

Of the original 105 PNG lines, 15 IITA lines and 105 Malaysian lines which had been planted out at the beginning of 1977, 28, 47 and 79 per cent had regenerated by late October. Of these regenerated plants, 31, 29 and 39 per cent had begun to initiate flower buds. An examination of these lines in late December revealed that very few of the buds had persisted through to mature flower. Only two lines, both IITA, were in full flower. Other lines, particularly of the Malaysian collection, were in a vigorous vegetative phase.

Very little success was achieved with the partitioned tubers planted out in pots under glasshouse conditions. Of six PNG lines only one regenerated sufficiently to produce a growing shoot.

On the other hand, propagation by cutting proved particularly successful. Five cuttings each of six lines (one of which was *P. scandens*) were planted in a vermiculite-perlite mixture and then raised under nutrient culture in an incubator held at 27°C. Table 7 summarizes the results. Cuttings of *P. scandens* were the most vigorous while PNG lines were the least.

**Table 7. Propagation from cuttings: performance 35 days after planting.**

| | Lines | | | | | | |
|---|---|---|---|---|---|---|---|
| | *P. scandens* | UPM 80 Malaysia | UPS 47 PNG | UPS 32 PNG | UPS 121 PNG | UPS 909 Indonesia | IPt 1 IITA |
| Cuttings still surviving (per cent) | 80 | 100 | 60 | 80 | 100 | 100 | 100 |
| Mean root (1-5 score) | 4.6 | 3.8 | 2.6 | 2.0 | 3.2 | 4.6 | 4.0 |
| Mean leaf number | 13.6 | 5.0 | 0.6 | 2.5 | 3.0 | 2.6 | 2.0 |

## CONTROLLED ENVIRONMENT ANALYSIS

A factorial experiment involving three temperature regimes combined with three daylengths and distributed across four winged bean lines each with five replicates, was set up in June 1977 in the CSIRO Phytotron at Canberra (see Morse and Evans, 1962). Treatments imposed were temperatures of 21°Cday/16° night, 27°C day/22°C night and 36° day/31° night (later reduced to 33° day/28°C night); photoperiods of 10, 12 and 14 hours comprising eight hour natural daylight supplemented with incandescent bulbs where required; and genotypes MARDI (Malaysia), UPS 121, UPS 32 and UPS 47 (PNG).

Seeds were germinated in petri dishes on moist filter paper at a temperature of 28°C. After one week they were transplanted into 18 cm pots containing a 1:1 vermiculite:perlite mixture. A Hoaglands No. 2

nutrients solution with 200 ppm nitrogen was used; inoculation was not carried out. Plants were staked to provide climbing support.

### Vegetative Growth

Within two weeks of planting in pots it was realized that the top temperature level of 36°/31°C was too extreme. A decision was made to lower the temperature to 33°/28°C. Even so, plants failed to recover and by September only 37 per cent of the original plants were still living. After it became apparent that the remaining plants were not going to flower before November, the treatment was abandoned and plants were harvested.

The intermediate temperature regime 27°/22°C proved to be optimal for vegetative growth. At day 45 the mean plant height across all photoperiod categories was 101.9 cm ± 8.4 whereas in the 21°/16°C treatment the mean plant height was only 15.7 cm ± 2.5.

### Reproductive Development

Information is still coming in, regarding flowering so a full statistical analysis is not possible. *Table 8* summarizes the data at hand as of this time.

It will be noted that the 14-hour photoperiod category does not appear in the table. This is because by December many plants still had not flowered in spite of vigorous vegetative growth in many lines. The effect of short daylength is obvious both for days to flowering and for the node of first flower. Temperature greatly affected time to flowering, but was less important in determining node of flowering.

In all lines the optimum treatment for quick flowering was short daylength (10 hr) and intermediate temperature (27°/22°C).

The Malaysian line, MARDI, was distinctly slower to flower and more severely inhibited by adverse environmental conditions. In the sub-optimal treatment categories flowers were born on primary and secondary branches in the case of MARDI whereas in most plants of the other lines flowers continued to appear first in the nodes of the main stem.

**Table 8. Effect of temperature and photoperiod on days to first flower and number of vegetative nodes formed prior to floral initiation.**

| Genotype | 10-hour Photoperiod 27°/22°C | 10-hour Photoperiod 21°/16°C | 12-hour Photoperiod 27°/22°C | 12-hour Photoperiod 21°/16°C |
|---|---|---|---|---|
| | | Day to First Flower | | |
| UPS 121 | 54.5(5)* ± 0.7 | 87.8(5) ± 4.7 | 71.6(5) ± 3.5 | 108.2(5) ± 2.4 |
| UPS 32 | 54.4(5) ± 2.2 | 69.5(4) ± 0.5 | 63.4(5) ± 1.1 | 130.5(2) ± 8.5 |
| UPS 47 | 55.7(3) ± 2.7 | 78.8(4) ± 3.5 | 98.8(4) ± 11.8 | 89.3(3) ± 1.8 |
| MARDI | 66.2(5) ± 1.8 | 100.4(5) ± 9.8 | 101.0(5) ± 2.8 | 133.8(5) ± 4.5 |
| | | Number of Vegetative Nodes | | |
| UPS 121 | 8.2(5) ± 0.97 | 9.8(5) ± 1.02 | 16.4(5) ± 1.78 | 13.4(5) ± 0.81 |
| UPS 32 | 9.8(5) ± 0.38 | 7.0(4) ± 0.82 | 16.0(5) ± 0.45 | 18.5(2) ± 2.53 |
| UPS 47 | 8.0(5) ± 0.59 | 8.3(4) ± 0.63 | 15.6(3) ± 1.80 | 8.0(3) ± 0.59 |
| MARDI | 10.8(5) ± 0.80 | 7.6(5) ± 2.66** | 18.4(5) ± 1.73** | 12.6(5) ± 1.79** |

*Figures in brackets refer to number of plants included in the mean.
**Flowers formed on side branches in some plants.

## DIALLEL CROSSING PROGRAM

Several lines of contrasting origins and characteristics were chosen for inclusion in a diallel crossing program, which aims to analyse the genetic basis of the winged bean's response to temperature and daylength.

During the flowering months of April through to July 1977, hand cross-pollinations were carried out using a method similar to that of Erskine and Bala (1977).

In mid-October parental and $F^1$ seed was planted out in glasshouse conditions in Perth, Western Australia.

**Crossing Success**

Out of a total of 132 miscellaneous crosses attempted, 34.8 per cent set pod and 20.7 per cent went right through the mature seed. These figures confirm the efficacy of Erskine and Bala's (1977) technique and were surprisingly high in view of the adverse climatic conditions and low natural pod set referred to earlier (Table 6).

Table 9 contains information regarding the success of crosses among parents chosen for the diallel analysis. Approximately half the required crosses have so far been obtained. Some crosses (for example, those using UPS 81 as a female parent) were difficult to achieve. There was, however, no evidence of cross incompatibility between lines of different origins. This was in contrast to the lack of success in the few crosses attempted between *P. scandens* and winged bean lines.

Table 9. Success of crosses between parental lines chosen for inclusion in the diallel analysis.

| Collection | Line | Number of crosses used as female parent | Per cent success | Number of crosses used as male parent | Per cent success |
|---|---|---|---|---|---|
| PNG | UPS 32 | 15 | 33 | 12 | 58 |
| | UPS 34 | 6 | 67 | 7 | 42 |
| | UPS 47 | 3 | 100 | 1 | — |
| | UPS 70 | 13 | 31 | 2 | — |
| | UPS 81 | 20 | 15 | 20 | 50 |
| | UPS 91 | 10 | 40 | 6 | 17 |
| | UPS 121 | 6 | 17 | 8 | 25 |
| IITA | IPt 1 | 6 | 67 | 9 | 33 |
| | UPt 14 | 9 | 67 | 16 | 38 |
| MALAYSIA | M 10/2 | 11 | 36 | 11 | 46 |

**$F_1$ Progress**

By the end of December 1977, $F_1$ hybrid and parental plants had attained the height of six to seven feet and were growing vigorously under Perth's high summer light intensities and temperatures. However, not a single flower bud had formed — testimony again to the inhibitory effect of long days.

No data are available concerning the genetics of particular winged bean characters.

## GENOTYPE-ENVIRONMENT VARIETY TRIALS

The State of Western Australia contains a very large land area with a diversity of environments. In the summer season of 1977/78 variety trials have been set up in three very different locations: Broome in the north-western, semi-arid, tropical belt; Perth in the mediterranean, coastal plains; and Majimup in the temperate, well-watered south-west. Figure 1 summarizes climatic data for these three sites.

At each site a randomised block design involving eight replicate plots of 15 lines has been employed. At the Perth site this design has been repeated on three different planting dates from September to December. The 15 lines include materials from Papua New Guinea, Malaysia, Thailand, Indonesia and Sri Lanka.

The hope is that a daylength insensitive line may be encountered. At the very least this trial should provide valuable information on the winged bean's response to marginal environmental conditions.

## DISCUSSION

Our initial hypothesis that the winged bean is specifically adapted to the environmental condition of the equatorial tropics gains some support from the results reported here. Early indications from the G × E interaction trials, suggest, however, that the responses of varieties from higher latitudes (e.g., Northern Thailand) may lead to a modification of this picture.

Although there were marked differences between the three main collections in many characters, our success with hybridization indicates that the differences do not reach the level of reproductive isolation. The question of whether Malaysian and Papua New Guinea populations should be regarded as distinct taxonomic entities needs debate.

The great diversity of the Papua New Guinea collections could be explained by the multiplicity of growing environments and cultivation practices in the highlands and by the insularity of growing sites. On the other hand it could also reflect a long history of cultivation in the area.

Within the collections sampled in our study, there were individual lines which could be of particular use. For example, amongst the regenerating plants from the germplasm screening, were two lines (IPt 6 and IPt 4) which were flowering in the long days of December. Similarly in the G × E trials there were three lines which gave indications of some degree of daylength neutrality. These lines will have to be examined further to see whether they can be exploited in plant improvement programs.

Three lines, one from Indonesia (Pt 909) and two from IITA (IPt 13 and IPt 16) have not flowered at any time during 1977. Such plants appear to produce larger tubers, presumably because there are no reproductive sinks to compete for nutrients. This is one way in which daylength sensitivity could be used to advantage in subtropical environments.

The question of how the winged bean might fit into subtropical agriculture is not easy. As a backyard or minor market vegetable, it might have a place but only if daylength insensitive lines can be produced to capitalise on high summer temperatures. The perennial and indeterminate character of many lines could be of use in developing the winged bean as a forage or cover crop.

For grain production in the sub tropics, the winged bean would have to be substantially modified. While it just might be possible to cope with the indeterminate growth habit by harvesting methods similar to those in use for field peas, characters like daylength sensitivity and slow maturity would require alteration.

The problems of photoperiod sensitivity and maturity are the central issues of the ongoing studies reported here. Subtropical environments are suitable for screening germplasm for these characters, because of the range of test environments that can be provided. This is one good reason for working on the species *Psophocarpus tetragonolobus* (L) DC. in the location of Perth, Western Australia.

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So many others have helped but none as much as Chai Nyet Fah.

Mrs. Muriel Goodall has given of her holiday time to prepare this script, and Marian Currie typed the final paper.

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# Flowering Behavior of the Winged Bean

*Siti Harti Aminah Lubis*[1]

**Studies on the flowering behavior were conducted using 30 lines of winged bean. The number of days to first flowering of each line varied from 70 to 98 days, but the number of days when 50% of plants in each line were flowering varied from 84 to 144 days. Morphological and anatomical studies were carried out to determine the special characters of flower opening, anther dehiscence, stigma receptivity, anther and stigma position at every stage of flower development, the best time for emasculation, and the critical period for artificial pollination. Pollen germination studies in boric acid and sugar solution were conducted to determine the method of the pollen storage. Insect visitation during the flowering season were observed in order to know its effect on the plant and flower development, flower pollination, and pod setting.**

## INTRODUCTION

In producing high yielding types of winged bean with uniform time of flowering and seed maturation through breeding (NAS, 1975), a knowledge of floral characters and flowering behavior is important. The present study was conducted to generate knowledge towards this end.

## MATERIALS AND METHODS

Thirty lines of winged bean collected from different locations in Java, Bali, Madura and Lesser Sundra Islands were used in this study. Twenty plants of each line were planted in the field, and their plant characters were observed during their development. The number of days to first flowers, the number of days when 50% of plants in each line were in flower, the flower morphology and anatomy during their development, time of anthesis, time of stigma receptivity, time for emasculation and time for artificial pollination were recorded.

Insect visitation and pests and diseases during flowering season were also observed.

## RESULTS AND DISCUSSION

The number of days to first flowers in the lines varied from 70 to 98 days. The first opened flowers usually dropped the following day. The flowering period lasted from 3 to 4 months. To determine the flowering time for breeding purposes, the number of days when 50% of plants in each line were in flower was observed (Cruz & Villareal, 1970). Table 1 shows the variations on the number of days, for first flowers to open and the number of days when 50% of plants in each line were in flower. The earliest flowering time was 84 days as in line C30 and the latest was 144 days as in line C13. By knowing the flowering time of every line, the planting date can be arranged for breeding purposes.

### Inflorescence and Individual Flower Development

The inflorescence is an axillary erect raceme which consists of 3 to 12 individual flowers. Normally only 2 to 4 flowers and only 1 to 2 pods mature in one inflorescence. However, not all inflorescence produce pods, so that on the average, 9 to 11% of the opened flowers produce pods under natural conditions. The number of pods produced may even be reduced by pests and diseases.

Individual flowers need 21 to 25 days to open from buds of 0,2 to 0,3 cm. The flowers open between 09.00 to 11.00 o'clock and close in the late afternoon. The flower colors are white, blue, purple and bluish

[1]National Biological Institute, LIPI, Bogor, Indonesia.

**Table 1. Variation in the number of the days to flowering of 30 lines of winged bean.**

| Collection number | Days to first open flower | Days when 50 line of each were in flower |
|---|---|---|
| C 1 | 77 | 112 |
| C 2 | 95 | 143 |
| C 3 | 84 | 114 |
| C 4 | 86 | 117 |
| C 5 | 88 | 118 |
| C 6 | 75 | 101 |
| C 7 | 82 | 95 |
| C 8 | 77 | 102 |
| C 9 | 84 | 97 |
| C10 | 93 | 135 |
| C11 | 94 | 137 |
| C12 | 80 | 100 |
| C13 | 96 | 144 |
| C14 | 53 | 129 |
| C15 | 80 | 130 |
| C16 | 93 | —* |
| C17 | 97 | 135 |
| C18 | 93 | 115 |
| C19 | 90 | 116 |
| C20 | 98 | 123 |
| C21 | 89 | 115 |
| C22 | 86 | 97 |
| C23 | 91 | 118 |
| C24 | 88 | 112 |
| C25 | 98 | 135 |
| C26 | 86 | 121 |
| C27 | 79 | 119 |
| C28 | 98 | 123 |
| C29 | 87 | 100 |
| C30 | 70 | 84 |

*The plant number C16 was seriously attacked by *Synchytrium psophocarpi*.

purple. Variations in flower color were observed in some samples; they are blue, bluish purple and purple in C26; blue, bluish purple and white in C8 and blue and bluish purple in C1.

In the early stage of flowering style was observed longer than the filament, the stigma curved nodding to the anther side. At the time of flower opening the anthers would approach the stigma which has an abundance of white hairs growing around its neck. The stigma itself is glabrous. These stigmatic hairs perform a special function by catching the spreading pollen from the dehisced anthers, which usually occurs early in the morning.

Anthesis and Stigma Receptivity

The morphological and anatomical characters of the developing flowers were observed by dissecting samples taken at every stage of flower development. It was found out that the anthesis occurred at 01.00 to 02.00 o'clock, i.e. 7 to 8 hours before the flowers opened. Since emasculation must be carried out prior to anthesis, it must be carried out before 01.00 to 02.00 o'clock; which was not within the normal working hours, the emasculation was attempted in the late afternoon at 15.00 to 16.00 o'clock, the day before the flowers were expected to open. At this time, the flowers were reaching the size of 2 to 2.5 cm. This was found to give good results. Stigma receptivity started at a later time after the anthesis began. It could be detected by the brilliant green color of the moist stigma. The spreading pollen from the dehiscing anthers were caught by the stigmatic hairs until the stigma were ready to be pollinated. Pollination took place at 06.00 to 07.00 o'clock as could be detected by fixing the flowers between 05.00 to 08.00 o'clock and processing them with clearing methods.

**Pollen Collection and Pollen Germination**

Pollen grain for artificial pollination were collected in two possible ways: a) anthers were collected during the flower emasculation. This method was useful if reciprocal crosses were to be carried out. The anthers were kept in a clean vial and stored at room temperature until the following day. The pollen coming out from the anthers could then be used for artificial pollination. b) The pollen grains were collected in the early morning at about 06.00 o'clock on the day the flower was expected to open. The pollens were kept in a clean vial and used within the next two hours for artificial pollination.

Under natural conditions pollen grains start to grow 1 to 2 hours after pollination (i.e. at 09.00 to 10.00 o'clock). After 4 to 5 hours of pollination (i.e. at 12.00 to 13.00 o'clock), the length of pollen tube is about 4 to 5 times the pollen diameter. Preliminary observations indicate that the growth of pollen tube in boric and 10% sugar solution were the same as that under natural condition. After 24 to 48 hours of storage at room temperature, the pollen grains could lose their viability. The methods of storing the pollen for breeding purpose need further studies.

**Insect Visitation**

Many insects such as bumble bees, bees, and butterflies visited the winged bean experiment area. These insects sucked the nectar from freshly opened flowers. The butterfly larvae ate some parts of the plants particularly the leaves, buds, flowers and young pods. The larvae of butterfly *Lampides boeticus* L., for example, need 5 to 7 flower buds to grow from egg to maturity. The bumble bee *Xylocopa confusa* was a regular visitor during the flowering period. It had a habit not to visit the same flower twice, as if it knew which flowers had been visited. While the bumble bee sucks the nectar its abdomen touches the keel of the flower forcing it to open, so that the stigma and anther are exposed and the pollen is smeared on the abdomen of the bumble bee. When the bumble bee would visit other flowers, it would contaminate them with the foreign pollen. Since the population in our experiment plot consisted of many different cultivars, hybridization was expected to occur as a result of this bumble bee visitation.

***Synchtrium psophocarpi***

It was mentioned by previous writers that some fungi attacked the winged bean plants (Burkill, 1906; Khan, 1974). In these experiments, some fungi were detected in some lines planted, particularly *Synchytrium psophocarpi*, *Meliola erythryna* var. *psophocarpi*, *Oidium* sp., *Cercospora aranetae* and *Cercospora psophocarpi* (Rifai, M.A., personal communication). *Synchytrium psophocarpi* was found to be the most serious disease attacking the lines which originated outside of Java. Those that were seriously attacked were lines C7, C8, C9 from Bali, C21, C22 and C23 from Madura and C16 from Lombok. No pods were produced from C16 because it was attacked by *Synchytrium psophocarpi* during the flowering period.

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# The Winged Bean (*Psophocarpus tetragonolobus* (L.) DC.)

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## INTRODUCTION

The diet of the populations of developing countries in the moist tropical zone is based primarily on crops with high carbohydrates content, i.e., plaintains, cassava, maize, rice, yams, and to a lesser degree, taro, and sweet potatoes. It is well known that the above crops supply about 70% calories of their daily diet. Unfortunately, they are deficient in vitamins, mineral substances, and particularly proteins. For instance, the plaintains contain some 1.5% proteins, cassava less than 1%, maize 4.9%, rice 7.8%, yams about 2%, taro 2% and sweet potatoes roughly 2%.

This lack of proteins and mineral substances is partly made up for by consumption of a variety of leaf vegetables, of which the most common ones are (the numbers indicate the content of protein (%) in 100g of fresh vegetable leaves): *Acalypha wilkesiana* 6.7%, *Amaranthus* spp. 2.5-6%, *Basella alba* 1.2-8%, *Brassica* spp. 1.4%, *Cassia* spp. 3.6-2%, *Celosia* spp. 2.4%, *Ceratotheca sesamoides* 5.8%, *Colocasia esculenta* 3.5%, *Corchorus* spp. 2.6%, *Cucurbita* spp. 2.6%, *Hibiscus* spp. 1.2-3.2%, *Ipomoea* spp. 1.8-4.6%, *Lagenaria leucantha* 2.3-3.3%, 4.6%, *Leucaena glauca* 6-10%, *Luffa acutangula* about 10%, *Manihot utilissima* 4-10%, *Moringa oleifera* 5-10%, *Phaseolus* spp. 3-8%, *Portulaca* spp. 2-2.5%, *Raphanus sativus* 2-4%, *Rumex* spp. 1.5-3%, *Sechium* edule 4%, *Sesbania grandiflora* 3.9%, *Solanum* spp. 6%, *Spilanthes* spp. 2%, *Talinum triangulare* 1.3-5.8%, *Tamarindus indica* 3.4%, *Tetragonia expansa* 1.5-4%, *Vernonia* spp. some 3%, *Vigna unguiculata* 2.5-3.0%, *Xanthosoma* spp. 2.2-4.1%, and ten other species and genera (Terra, 1966).

Although the leafy vegetables are rich in proteins and particularly vitamin C, they have low caloric value, and because they are eaten well cooked in the tropics, the vitamin C content is very much reduced. For this reason, fresh fruits are of great importance in tropical countries.

Apart from fishes and the increasingly rare meat of domestic animals, there is a good source of protein, namely the seeds of various pulse crops which can also provide vegetable fats and some vitamins. According to research done by FAO in Western Africa (growing region for cacao, robusta coffee, cola, plaintains, oil palm), the caloric value of daily diet is based on the average of starch crops such as cassava, plaintain, yam, etc. (53-81%) fruits and vegetables (1.9-4.4%), oil plants (5.3-18.4%), and animal products (2.9-6.8%). In general, we can say that the foods containing proteins account for less than 10% of the caloric value of African diets. Chronic shortage of proteins in the diets of inhabitants of the humid tropics, particularly of children, is responsible for a number of primary diseases (Kwashiorkor), which lead to weakening and secondary infections.

It is necessary to increase the proportion of proteins in the tropical diet. It can be achieved either by higher livestock production, which is not an easy task with the prevalence of potential animal diseases, or by crop production involving more domestic and introduced pulses. A review of the most common pulses grown in the humid tropics and their chemical composition is given in Table 1.

A very little known pulse species is the "rediscovered" *Psophocarpus tetragonolobus* studied in Ghana. It is now gaining the attention of plant scientists. An international team of research workers was set up (Steering Committee of the Winged Bean, sponsored by the Asia Foundation) and the research institutes of a number of the following countries: Australia, Bangladesh, Belize, Burma, Cameroon, Colombia, Costa Rica, Ecuador, Egypt, Fiji, Ghana, Granada, Honduras, India, Indonesia, Ivory Coast, Jamaica, Malaysia, Nicaragua, Papua New Guinea, South Korea, Sri Lanka, Taiwan, Thailand, and U.S.A. have embarked on research of this promising crop. The problem has been approach seriously by the Medical Section of the Committee for the Developing Countries, Czechoslovakia Academy of Sciences, and it has also become a part of

**Table 1. Chemical composition of major pulse crops grown in humid tropics (per 100 g of seeds)[a].**

| Species | Water ml | Proteins g | Fat g | Glucides g | Fiber g | Mineral Substances Ca mg | Fe mg | Vitamins A I.u. | $B_1$ mg | $B_2$ mg | PP[b] mg | C[c] mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Cajanus cajan* | 10 | 20 | 2.0 | 58 | 7.0 | 100 | 57.0 | 0.140 | 0.50 | 0.15 | 2.3 | + |
| *Canavalia ensiformis* | 8 | 25 | 3.0 | 59 | 1.8 | 100 | 4.0 | + | 0.5 | 0.1 | 1.1 | + |
| *Lablab niger* | 8 | 21 | 1 | 65 | 2 | 80 | 4.5 | 100 | 0.5 | 0.1 | 1.8 | + |
| *Phaseolus vulgaris* | 10 | 24 | 1.7 | 57 | 4 | 110 | 8.0 | + | 0.5 | 0.2 | 2.0 | + |
| *Phaseolus lunatus* | 12 | 20 | 1.5 | 58 | 5 | 90 | 6.0 | + | 0.5 | 0.14 | 1.5 | + |
| *Vicia faba* | 9 | 25 | 1.5 | 57 | 4.5 | 100 | 6.0 | 50 | 0.4 | 0.3 | 2.5 | + |
| *Vigna mungo* | 12 | 22 | 1 | 57 | 4.7 | 100 | 8.0 | 40 | 0.45 | 0.2 | 2.0 | + |
| *Vigna unguiculata* | 10 | 22 | 1.5 | 60 | 4.0 | 90 | 5.0 | 20 | 0.9 | 0.15 | 2.0 | + |
| *Voandzeia subterranea* | 10 | 18 | 6.0 | 60 | 3.3 | 65 | 6.0 | + | 0.3 | 0.1 | 2.0 | + |

[a]Tindall, H.D. (1968).
[b]Vit. pp = Nicotinamide.
[c]traces.

the research project taken up by the Institute of Tropical and Subtropical Agriculture, Agricultural University Prague, Czechoslovakia (which is the co-ordinating basis for the authors).

*Psophocarpus tetragonolobus* (L.) DC is a perennial climbing plant of the family Fabaceae, attaining a height of 3 to 4 m in the tropics, with the leaves similar to the genus *Phaseolus*, with generally blue or whitish flowers, usually 2 to 7 (up to 10) in a raceme (Fig. 1). After about six months, tuber-like, pulpy roots would develop which are very tasty when young. These contain some 17-20% proteins. The plant begins to flower 60 days after sowing in the tropics, and the flowers develop extremely fast. The four-winged, 20-38 cm long (exceptionally 60 cm), slightly bent pods, contain mostly 16 to 12 pea sized, rusty brown and/or brownish black seeds making up 41% of the total weight of dry pods. One hundred air dried seeds weigh about 36 g and ripe seeds contain on the average 33% protein and 16% fat, selected cultivars as much as 39% protein and 17% fat. Seed yield varies from 2200 to 4590 kg/ha (Malaysia) and those of tubers from 2246 to 12,925 kg/ha (Papua New Guinea). Apart from edible tubers and seeds, crusty green pods (7-10 days after flowering) are popular as food and these contain 2.4% protein. The leaves as well as the flowers (3-5% protein) may also be eaten.

The species is considered to be as promising as soybean which has become the major source of plant protein in the last 60 years. Table 2 shows the chemical composition of winged bean in comparison with soybean and groundnuts (Tindall, 1968).

**Table 2. Composition of seeds of the winged bean, in relative comparison with soybean and groundnuts (per 100 g of ripe seeds).**

| Species | Water ml | Proteins g | Fat g | Glucides g | Fiber g | Mineral Substances Ca mg | Fe mg | Vitamins A I.u. | $B_1$ mg | $B_2$ mg | PP[a] mg |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Psophocarpus tetragonolobus* | 14 | 33 | 16 | 32 | 5 | 0 | 0 | 0 | 0.08 | | |
| *Glycine max* | 9 | 35 | 18 | 20 | 4.5 | 200 | 7 | | 1.1 | 0.3 | 2 |
| *Arachis hypogea* | 6 | 27 | 45 | 17 | 3 | 50 | 2.5 | | 0.90 | 0.15 | 17 |

a = nicotinamide
b = traces

There is a general conclusion that *Psophocarpus tetragonolobus* is a very plastic species whose improvement program resembles soybeans. There is a justified assumption that if the winged bean is given concentrated attention by the crop research institutions, it may become the major source of plant protein.

However, there are still a number of unresolved problems associated with this promising pulse crop, and it is therefore necessary to join efforts to learn more about it as soon as possible.

This paper aims to improve knowledge of pollination conditions in Ghana and Czechoslovakia, effect of day length on growth (Czechoslovakia), development of tubers (Czechoslovakia) and growth of pods (Ghana).

## MATERIALS AND METHODS

The seeds of the population of *Psophocarpus tetragonolobus* were obtained from the experiments conducted in 1965 in Ghana by F. Pospisil. By way of positive selection, several productive forms were identified and these were propagated further. Other seeds for experiments carried out at the Institute of Tropical and Subtropical Agriculture, Prague, were kindly supplied in 1975 and 1976 to the author by Dr. Karikari, Head of the Agricultural Research Station, Kade, Ghana. These seeds of cinnamon-brown color were sown in 8-liter cultivation pots (3 seeds per pot), and the plants were provided with 120 cm high supporting sticks. Some of the seedlings were transplanted in the spring of 1977 onto the beds of a tropical greenhouse, and the following data were collected: time of sowing, time of germination, time of flowering, time of pod setting, size of pods, number and contents of seeds, health condition of plants, formation of tubers and their weight. Some seeds were exposed to gamma radiation and/or neutron radiation. This comparative trial has been under way, and its results will be published in the following contribution.

## RESULTS

### Pollination Conditions

The experiments were carried out by the first author in Ghana in the years 1965-1970.[1] The climatological characteristic of the forest zone of Ghana is given in Table 3. The winged bean plants grown at the A.R.S. Kade (University of Ghana, Legon) began to flower 46 to 61 days after sowing of seeds (Table 4).

**Table 3. Climatic conditions in A.R.S. Kade, Ghana (6°06' N.L., 135 altitude)[a]**

| 1964-1974 | J | F | M | A | M | J | J | A | S | O | N | D | Mean of Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean daily temperature (°C) | 25.8 | 27.2 | 27.1 | 26.8 | 26.5 | 25 | 24.7 | 24.2 | 24.9 | 25.3 | 25.7 | 25.5 | 25.8 |
| Mean maximum temperature (°C) | 30.7 | 32.7 | 32.4 | 31.8 | 31.2 | 29.3 | 28.0 | 27.4 | 28.4 | 29.1 | 30.3 | 29.8 | 30.1 |
| Mean minimum temperature (°C) | 20.9 | 21.9 | 21.8 | 21.8 | 22.0 | 21.8 | 21.4 | 21.4 | 21.2 | 21.5 | 21.1 | 21.3 | 21.5 |
| Annual rainfall (mm) | 27 | 60 | 255 | 162 | 227 | 205 | 128 | 129 | 129 | 78 | 151 | 71 | 1622 |
| Mean relative air humidity at 15:00 p.m. | 57 | 60 | 58 | 64 | 68 | 75 | 75 | 76 | 73 | 67 | 65 | 65 | 76.6 |
| Sunshine (h) | 148 | — | 175 | 148 | 151 | 115 | 89 | 67 | 80 | 126 | 160 | 112 | 1371 |
| Mean air temperature (15:00 p.m.) depth 50 cm | 27.7 | 29.4 | 29.7 | 29.5 | 29.3 | 28.3 | 27.3 | 26.9 | 27.2 | 27.1 | 27.4 | 27.4 | 28.1 |

[a]Source: COMBINED ANNUAL REPORT 1971-1975, A.R.S. Kade, University of Ghana.

**Table 4. Length of flowering of winged bean plants.**

| Beginning of flowering (after n days) | Date of sowing | Year |
|---|---|---|
| 46 | June 4 | 1966 |
| 46 | August 25 | 1969 |
| 51 | April 18 | 1968 |
| 58 | May 24 | 1967 |
| 60 | July 3 | 1967 |
| 61 | May 11 | 1965 |
| 61 | May 18 | 1968 |

[1]In cooperation with K. Cerny, S. Karikari and F. Mensah.

In 100 inflorescences selected at random, 11 contained one flower only, 30 of them 2 flowers, 22 three flowers, 12 four flowers, 12 five flowers, 6 six flowers, 1 seven flowers, and 4 eight flowers. The incidence of nine flowers was not observed but in 2 inflorescences 10 flower were found. It is interesting that in most inflorescences having two or more flowers, the development was gradual so that only the oldest was open while the others were in different developmental stages. Only 16% of inflorescences under study had two flowers open at the same time, and only 9% of opened flower pairs were in the inflorescences containing more than two flowers.

The winged bean flowers in Ghana were visited frequently by large bumble-bees (black, black and white, and rust coloured), mainly between 8 and 10 o'clock a.m. This has led to an assumption that the bumble-bees are the main pollinating agents. One hundred flowers isolated at random without emasculation bore pods in 18.6% cases only. However, the experiments conducted in the greenhouses of the Institute of Tropical and Subtropical Agriculture (ITSA), Prague, in 1975-1977 showed that the winged bean plant would bear pods even when not pollinated by insects, i.e. it is a self-pollinating plant. Some flowers had even set pods without any completed flower opening. The temperature in the experimental greenhouse at the time of flowering ranged from 16 to 24°C. Our results in this aspect were confirmed by the investigations described by Dr. Karikari in the Combined Annual Report A.R.S. Kade, for 1971-1975.

### The Effect of Daylength on Time of Flowering

Our experiments done in the greenhouse of the Institute of Tropical and Subtropical Agriculture, Prague (50° N.L.) showed that the plants of winged bean would begin to flower usually from March to May, and if we take into consideration the effect of geographical latitude in hours and minutes:

| | | | |
|---|---|---|---|
| January | 08.09 | July | 16.19 |
| February | 09.17 | September | 13.32 |
| March | 10.55 | August | 15.16 |
| April | 12.52 | October | 11.44 |
| May | 14.9 | November | 09.51 |
| June | 16.04 | December | 08.27 |

It is evident that the flowering of *Psophocarpus* is related to an 11 to 14-hour day. Hildebrand (1977) reported that experimental plants in a greenhouse in Maryland (USA), 38°N.L., began to flower in the month of September, i.e., on a 14 hour day.

Length of day is however of particular importance with respect to longitudinal growth of the winged bean stalks. Test plants grown on beds in a tropical greenhouse in Prague (mean temperature 24-26°C) were about 110 cm high in the early June, 1977. By the end of September, 1977, i.e. 4 mo. after transplanting, they attained heights of about 700-800 cm, and developed an abnormally dense mass of foliage and lateral shoots, (Fig. 2) a circumstance that might be important economically when the winged bean is grown for the purpose of producing green matter as an annual plant in regions of suitable climate featuring day lengths over 14 hours at least for four months.

### Development of Tubers

The experimental plants in containers grown in greenhouses of the Institute in Prague developed numerous nodules on the roots even without artificial inoculation, when cultivated in the soil mixture consisting of 2 parts compost, 1 part peat, and 1 part sand (Figs. 3-5). After 190 days, they developed pulpy, fairly tough, and fibrous roots (tubers) whose average weight is 60 g.

### Growth of Pods

The development of pods upon termination of flowering in climatically favorable conditions is very fast (A.R.S. Kade, Ghana). We studied the growth in length of 10 pods selected at random between flowering to full length (maximum, ultimate length) under irregular irrigation (Table 5). The longitudinal growth lasted 16 days, in the course of which the pods attained their full length. The first green pods may be harvested 6-9 days after termination of flowering, and these may be used for the same purpose as the "French beans". Fig. 6 represents the development of pods throughout 16 days, and the drawing was always done consistently at the same time of the day. The scale indicates a 10 cm length. Fig. 7-16 depict this development on each odd day up to the 17th day since the flower bud stage, and the respective scale shows the respective length to the nearest 0.5 cm. It follows that since the harvest of the first tender pods which can be used as a vegetable, an

additional 1.5 months is necessary for the seeds to ripen and to change their colour from green to yellowish and finally to brown. Thus, in the tropical climate of Ghana, 4 months are necessary to harvest the first day pods since the time of sowing. The development of winged bean pods between flowering and ripening in a greenhouse of the ITSA-Prague is almost identical to that taking place in the tropics, i.e. 65 days.

**Table 5. Mean winged bean pod length (mm) from the first day after termination of flowering.**

| Days after termination of flowering | Mean pod length (mm) | Mean growth in length (mm) |
|---|---|---|
| 1 | 38 | — |
| 2 | 42 | 4 |
| 3 | 46 | 4 |
| 4 | 62 | 16 |
| 5 | 73 | 11 |
| 6 | 102 | 29 |
| 7 | 114 | 12 |
| 8 | 162 | 48 |
| 9 | 206 | 44 |
| 10 | 245 | 39 |
| 11 | 263 | 18 |
| 12 | 272 | 9 |
| 13 | 311 | 39 |
| 14 | 352 | 41 |
| 15 | 363 | 11 |
| 16 | 364 | 1 |
| 17 | 364 | — |
| 18 | 364 | — |

**The length growth (mm) is better represented in Fig. 17.**

## CONCLUSIONS

The experiments carried out in the greenhouses of the Institute of Tropical and Subtropical Agriculture, Prague, Czechoslovakia, in 1975 to 1977 have shown that *Psophocarpus tetragonolobus*, the seeds of which originated from Ghana, are self pollinating. The species began to flower at 50° NL during the 11 to 14 hour days, i.e. in the months of March to May, when pods develop fairly well. Less flowering may also occur during the fall months (October and November) which however is an unfavorable period with regards to geographical latitude for the development of green pods. The development of tubers begins after 190 days, and the nodules on roots grow nicely even without artificial inoculation. Development of pods is fast and their longitudinal growth is completed within 16 days. The time between flowering and pod ripening was found to be the same in the tropics and at a 50° northern latitude (under green house conditions), i.e. some 65 days.

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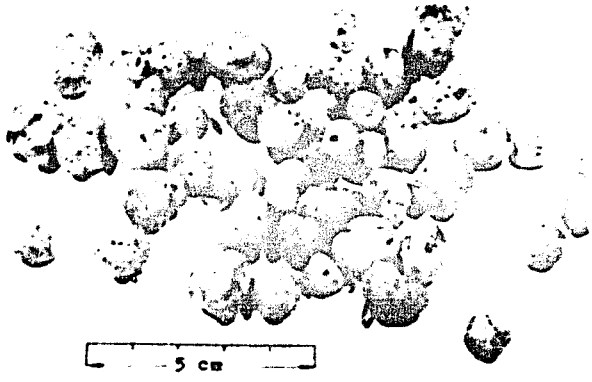
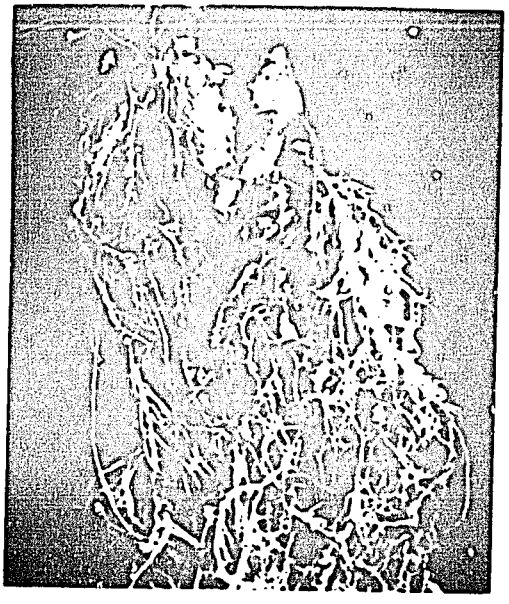
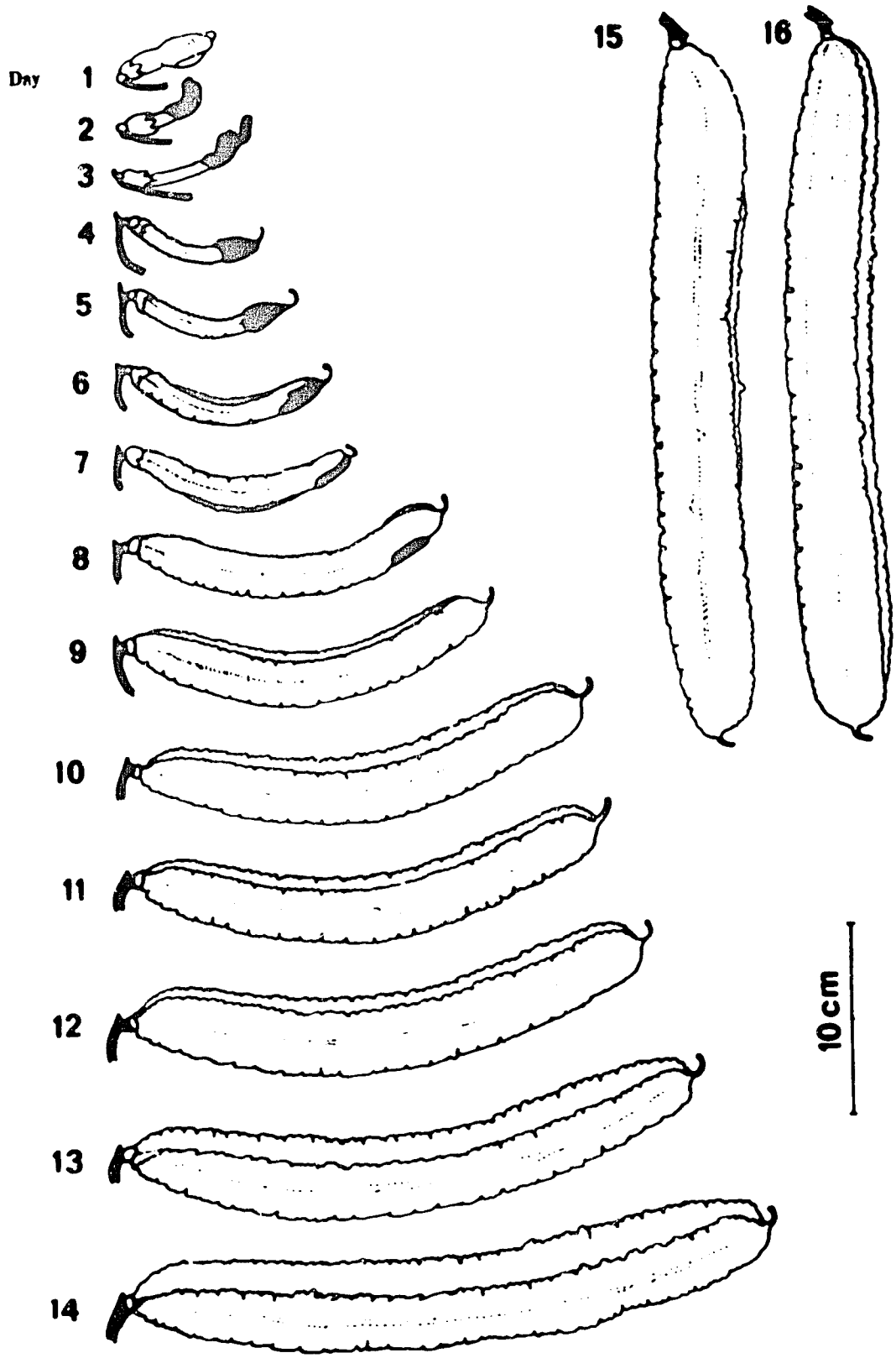



*1. Young pods of green house grown plant, ITSA, Prague. 2. At transplanting time, the height of this plant was only 100 cm. Four months later, it was 700-800 cm. 3. Root system of a winged bean plant. 4. Nodules (slightly enlarged). 5. Root system showing tubers and nodules.*

5.

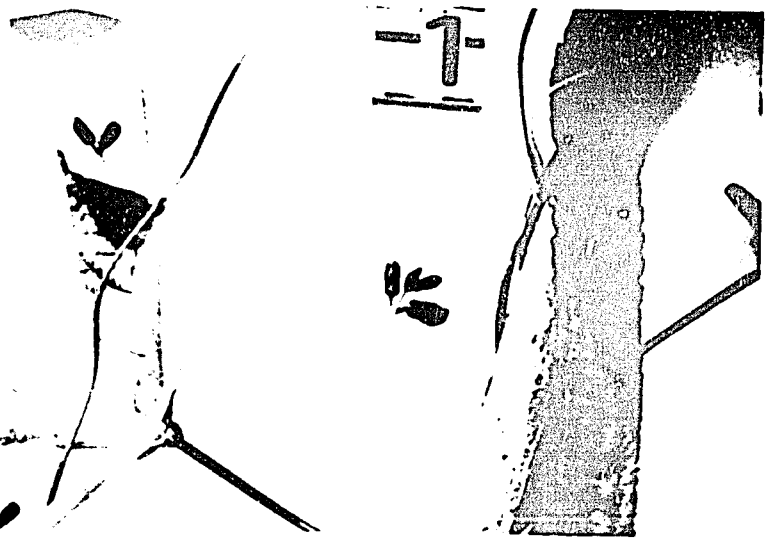


6. *Development of winged bean pod throughout 16 days.*



7.

*7-16 (pp. 131-134) The development of the pod on each odd day from the flower bud stage.*

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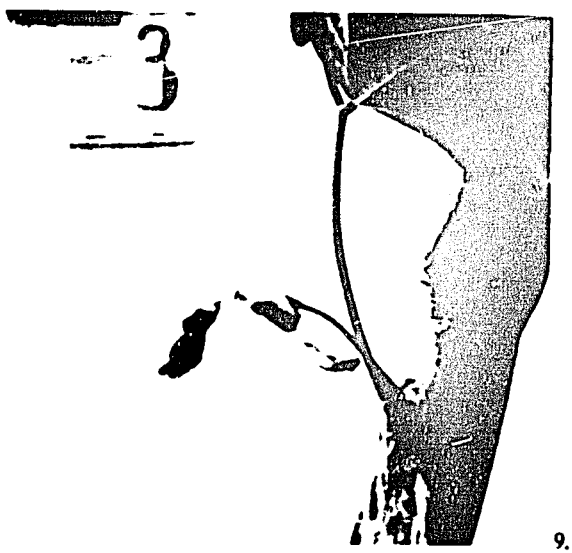


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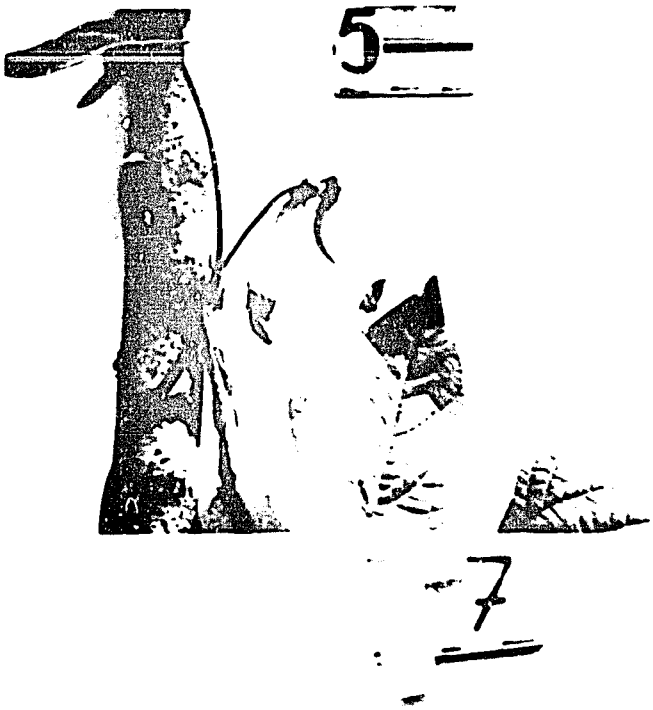


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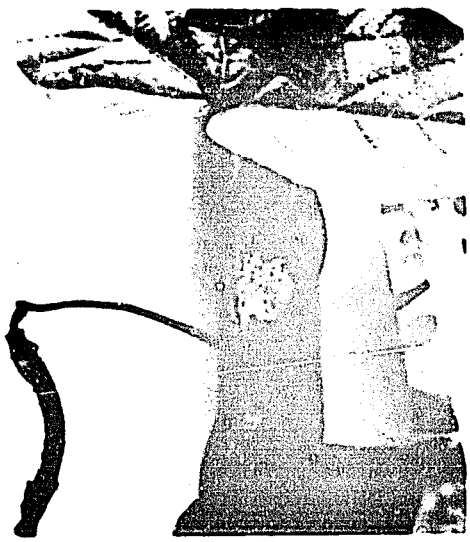

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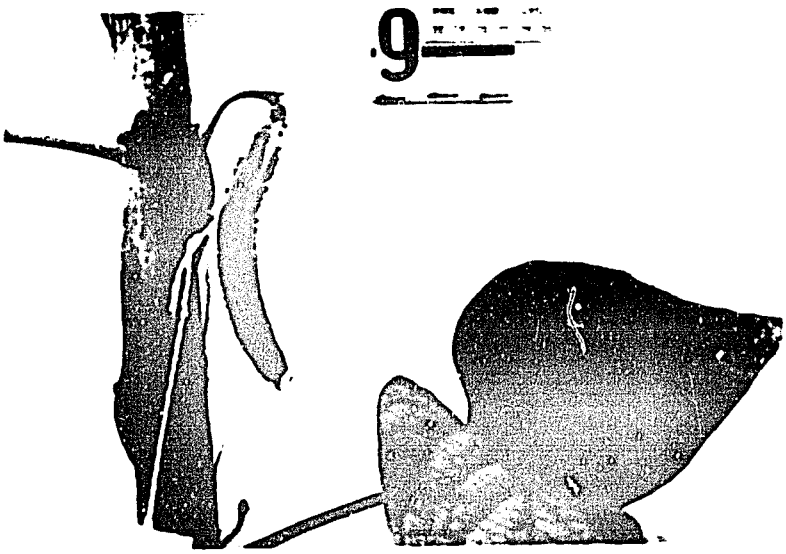


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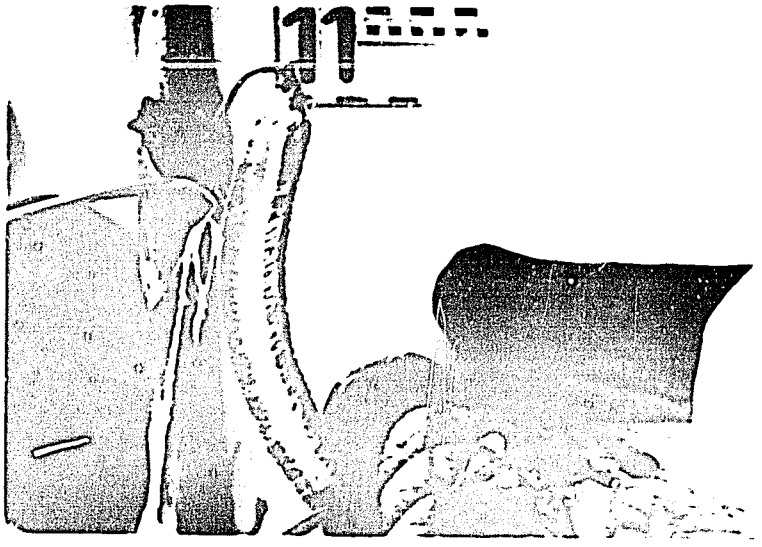


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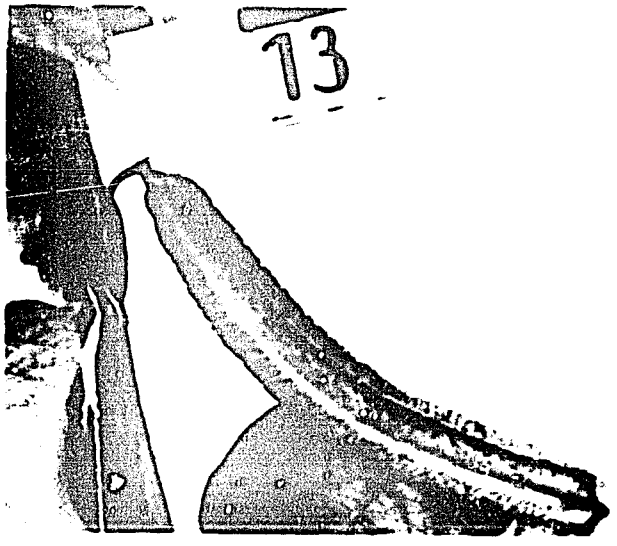


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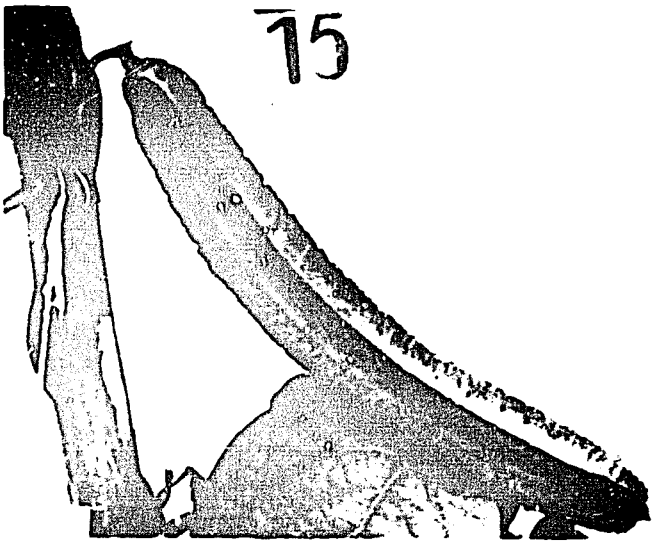

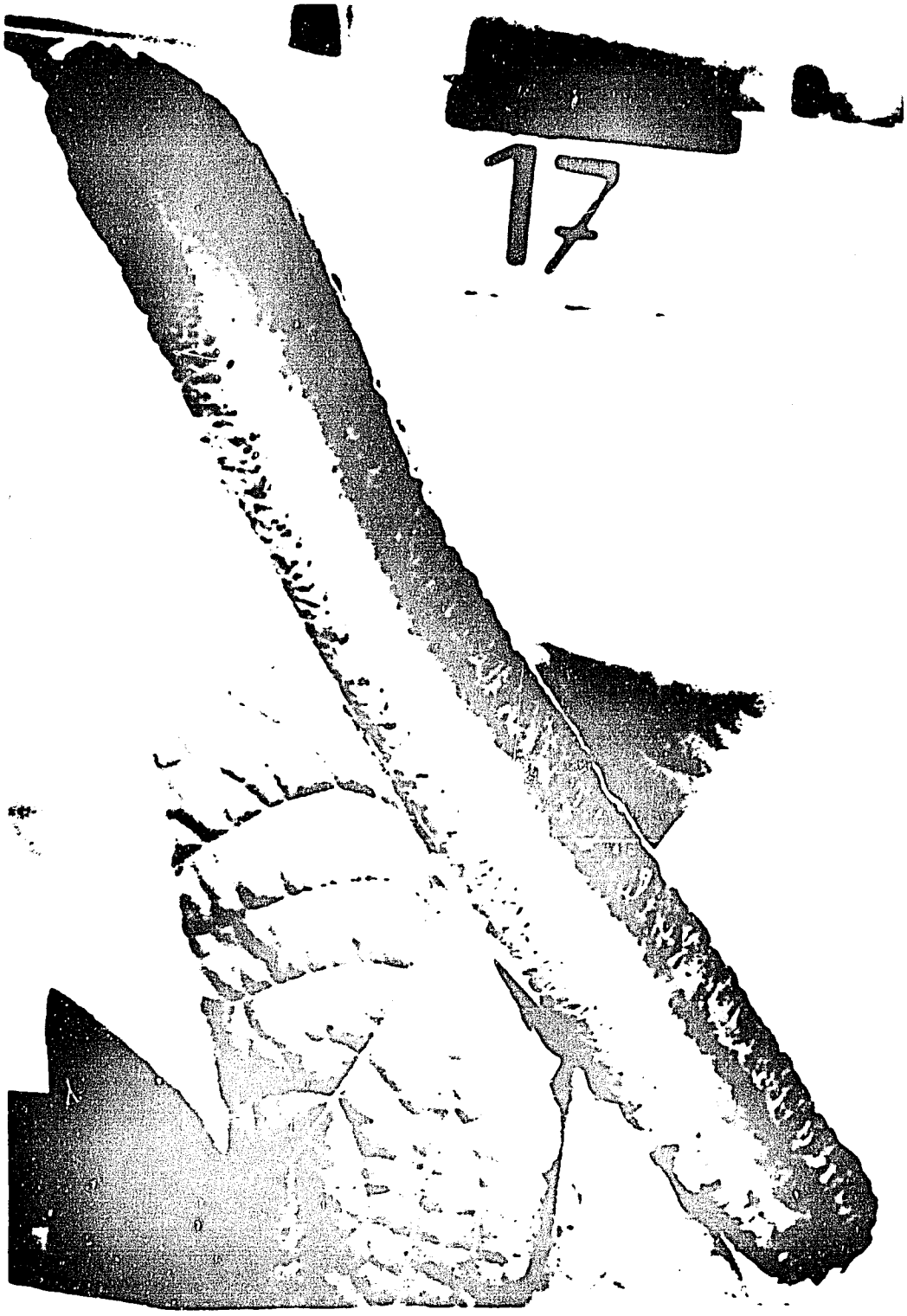
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# A Study of the Effects of Gamma-Irradiation on Growth and Productivity of Winged Bean

*B. S. Jalani*[1]

## INTRODUCTION

The potential of the winged bean or the four-angled bean (*Psophocarpus tetragonolobus*) as a multipurpose crop has recently attracted worldwide attention (Anonymous, 1975 a, b). Although the crop has been known for 300 to 400 years, it is still being cultivated mainly in backyard gardens as a domestic vegetable. However, studies are now underway in many countries to develop and upgrade this crop from its "backyard" status to a commercial one.

There have been extensive germplasm collections in many parts of the world, especially in Papua New Guinea, Indonesia, and Malaysia. All these materials have indeterminate growth habits and need supports for growing. No determinate or bush-type erect mutants have been reported or known. Khan (1974) suggested an international program for research with a number of priorities. One of these areas is mutation breeding, a method to develop determinate or bush-type erect mutants have been reported or known. Khan (1974) suggested an international program for research with a number of priorities. One of these areas is mutation breeding, a method to develop determinate or bush-type mutants and other desirable characters. This paper, therefore, presents a preliminary report on induced mutation breeding with special reference to effects of gamma-irradiation on a number of traits of the winged bean.

## MATERIALS AND METHODS

Seeds from one accession (IKM/WIL-9) of winged bean were used. The seeds (with water content of 9.73%) were irradiated by gamma-rays from a 17458.9-Ci array of $^{60}Co$ source in a "Gammacell 220" irradiation unit made by the Atomic Energy of Canada Limited, Ottawa. Irradiation doses were 0 (control), 10, 20 and 30 krads at a rate of 395.5 krads/sec. The seeds were then scarified with concentrated $H_2SO_4$ for 10 minutes, washed thoroughly in running water for about 4 hours and sown at an average depth of 20 mm in soil in plastic bags.

To allow for destructive samplings, six plants from each treatment were chosen at random. Plants chosen were removed carefully from the bags by cutting the bag and washing it with water to remove any soil particles adhering to the roots. Samplings were done at two-week intervals.

## RESULTS

The irradiated seeds had a lower rate of germination than the control. Germination increased as the level of irradiation dose was decreased. The control had the highest percentage germination. There were significant differences (Table 1) among responses to different levels of irradiation dose.

Irradiation can also affect seedling growth, i.e., plant height (Table 1). Plant height decreased with an increase in irradiation dose. There were significant differences (Table 1) among the responses to various irradiation doses given.

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**Table 1. Effects of different levels of gamma-irradiation dose on seed germination, plant height, number of branches and internode of winged bean.**

| Dose (Krads) | Percentage of seed germination[a] at 2 weeks* | Plant height cm at 4 weeks* | Number of branches[a] at 12 weeks* | Length of 10 internodes cm[a] at 12 weeks* |
|---|---|---|---|---|
| 0 | 77.0 a | 13.7 a | 2.8 a | 17.6 a |
| 10 | 68.4 ab | 12.4 a | 3.7 a | 24.5 a |
| 20 | 66.7 bc | 12.3 a | 3.8 a | 18.8 a |
| 30 | 50.7 c | 9.8 b | 4.2 a | 15.8 a |

[a]Means in the same column followed by the same letters are not statistically different at the 5% level of probability.
* Means after sowing.

Table 1 also shows various dose response with respect to the mean number of branches of one or more nodes originating from the main stem. Although there were no significant differences, plants with the highest dose had more branches than those receiving lower doses or none at all.

The length of ten internodes are shown in Table 1. Irradiation had a stimulatory effect on the length of the internode, but the length decreased as irradiation dose was increased.

Root nodulation also appeared to be affected by irradiation doses (Table 2 and Fig. 1). In all cases, no nodules were evident in two week old seedlings. High irradiation doses reduced as well as delayed nodulation, e.g., plants with an irradiation dose of 30 krads formed no nodules even at the age of four weeks. They also formed the least number of nodules, compared to plants receiving lower and no dosage at all. However, nodulation seemed to reach its maximum when the plants were around 6 to 10 weeks old (Table 2, Fig. 1). Analyses of variance showed that there were significant differences (Table 2), with regard to the number of nodules, among the various plant ages as well as among the various levels of irradiation dose.

**Table 2. Effect of different levels of gamma-irradiation dose on the number of nodules of winged bean.**

| Dose (krads) | Weeks after sowing[a] 2 | 4 | 6 | 9 | 10 | 12 | Mean no. of nodules per plant[a] (4-12 weeks) | (6-12 weeks) |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 2.2 | 31.3 | 27.3 | 22.3 | 24.0 | 21.4 a | 26.2 a |
| 10 | 0 | 0.8 | 17.8 | 18.3 | 21.0 | 21.2 | 15.8 ab | 19.6 b |
| 20 | 0 | 1.5 | 14.8 | 17.0 | 21.8 | 19.8 | 15.0 ab | 18.3 b |
| 30 | 0 | 0 | 13.3 | 12.0 | 15.5 | 18.5 | 11.9 b | 14.8 b |
| Mean | | 1.1 a | 19.3 b | 18.7 b | 20.2 b | 20.9 b | | |

[a]Means in the same column followed by the same letters are not statistically different at the 5% level of probability.

From Fig. 2 it is very difficult to observe any clear cut effect of irradiation dose of 10 krads on total dry weight. However, at six weeks and succeeding weeks thereof, plants pre-treated with 20 krads always had higher total dry weights than the control. On the other hand, those pre-treated with 30 krads always had lower total dry weight than the control.

Table 3 shows various dose response with respect to the mean number of pods per plant. The number of pods increased as the level of irradiation dose was decreased. The control plants had the highest number of pods per plant.

The mean pod lengths are shown in Table 3. It seemed that pod length was inhibited as the irradiation was increased.

Irradiation can also affect the number of seeds per pod (Table 3). The number of seeds per pod decreased with an increase in irradiation dose.

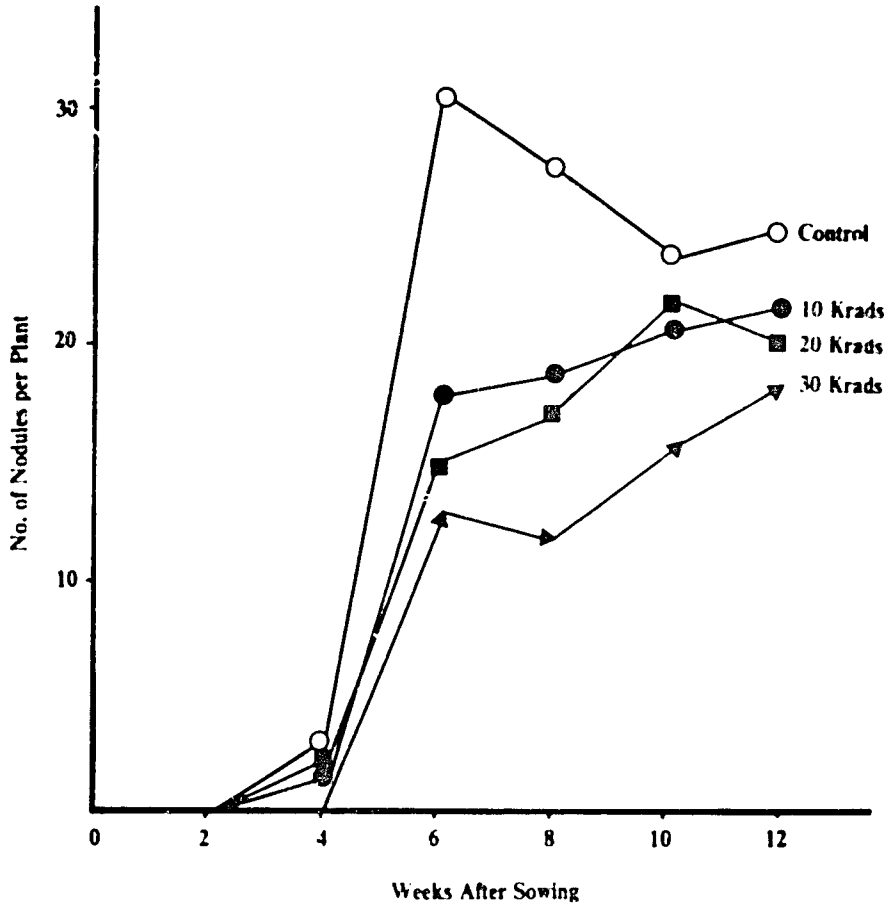


Fig. 1. Effect of different levels of gamma irradiation dose on nodulation of winged bean.

Both fresh and dry weight of tubers were affected by irradiation doses (Table 3). There was a stimulatory effect on the fresh and dry weight of the tubers, but the weight decreased as the irradiation dose was increased.

## DISCUSSION

The results presented above reveal that seeds with pre-sowing gamma-irradiation treatments showed different response at different growth and reproductive stages. The effects of irradiation can either be inhibitory

Table 3 Effects of different levels of gamma-irradiation dose on number of pods, pod length, number of seeds, fresh and dry weights of tubers.

| Dose (krads) | Number of pods per plant | | Pod length (cm) | | Number of seeds per pod | | Fresh weight of tuber per plant (gm) | | Dry weight of tuber per plant (gm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| 0 | 22.4 | 16-32 | 17.1 | 10.0-23.5 | 9.2 | 4-14 | 45.9 | 11.2-120.0 | 12.8 | 1.5-24.6 |
| 10 | 21.8 | 12-29 | 16.1 | 6.0-21.7 | 8.7 | 2-13 | 56.2 | 23.9-111.9 | 13.4 | 2.7-27.9 |
| 20 | 19.4 | 11-25 | 15.7 | 10.0-22.0 | 6.9 | 1-12 | 37.7 | 6.8-110.8 | 10.4 | 1.6-42.0 |
| 30 | 14.6 | 8-22 | 15.4 | 6.5-23.0 | 6.3 | 2-13 | 28.1 | 11.8-72.0 | 8.9 | 3.9-24.1 |

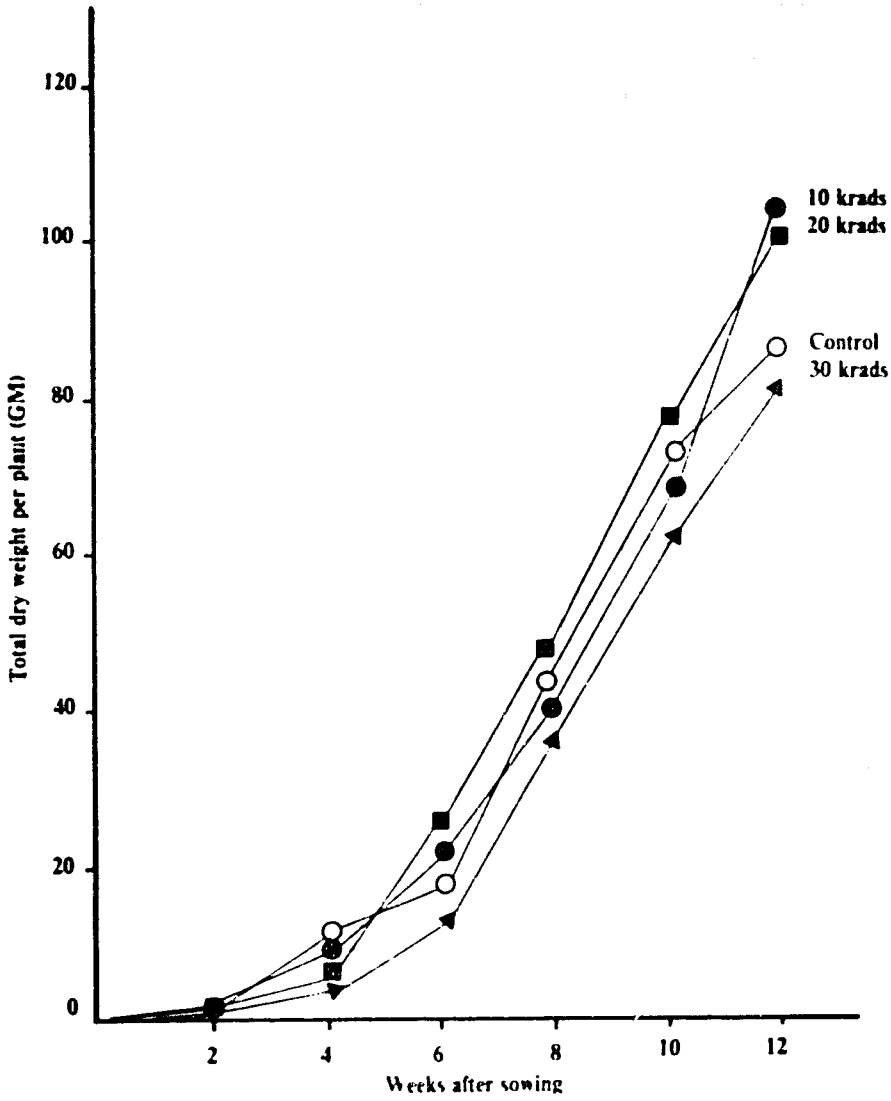


**Fig. 2. Effect of different levels of gamma irradiation dose on total dry weight of winged bean.**

or stimulatory (Sax, 1963; Casarett, 1968). Germination, for example, was decreased as the level of irradiation dose was increased (Table 1). Similar results, showing inhibition of germination by high doses of $^{60}Co$ gamma irradiation were reported by Khan and Brock (1975) and Jalani (1976). Other inhibitory effects were also shown with respect to plant height (Table 1), nodulation (Table 2, Fig. 1), total dry weight (Fig. 2), number of pods per plant (Table 3), pod length and number of seeds per pod (Table 3) for those which were pre-treated with high irradiation dose. Irradiation-induced reduction of growth in plants is generally considered to be due primarily to nuclear damage and environmental conditions. It is a parameter which has been extensively used in radiobiological investigations (Davis, 1962).

The stimulatory effects of irradiation were also revealed in this experiment. For example, at 10 krads, the plants had heavier fresh and dry weights than those of the controls and those exposed to higher irradiation doses (Table 3). Another example is that the plants, at 10 and 20 krads, also had longer internodes than those of the control and those exposed to 30 krads. Similarly, the number of branches was increased with an

increase in irradiation dose (Table 1). No consistent pattern of response was shown for total dry weight. Different tissues, organs, doses and especially time of determination offer irradiation influence the kind and degree of response observed (Constantin and Love, 1967). However, there are indications of growth stimulation. For instance, the 20 krad irradiated seeds grew more vigorously and always had higher total dry weight than those of the control, especially from the sixth week onwards (Fig. 2). The stimulation of plant growth by exposing seeds to low doses of ionizing radiation has been reported by many investigators. Although, in most cases, the reported stimulations have been small and not always reproducible, Sax (1963) concluded in his review that documentation is sufficient to establish growth stimulation by small doses of irradiation. In the present studies, where stimulation caused by the pre sowing irradiation treatments occurred (e.g., number of branches, total dry weight, fresh and dry weight of tubers), these were likewise small and not always statistically significant. It is hoped that some of these stimulatory as well as inhibitory effects (e.g., in order to get bush type erect mutants, the plants must have short internodes) can be directed towards the use of irradiation in winged bean improvement.

## SUMMARY

Seeds of one accession of winged bean were given 0 (control), 10, 20, and 30 krads using $^{60}$Co as a source of radiation. Seed germination, plant height, nodulation, number of pod per plant, pod length and number of seeds per pod were reduced with an increase of irradiation dose. Irradiation at low doses apparently stimulated the number of branches, internode length, fresh and dry weight of tubers, but these stimulations were decreased as the level of irradiation dose was increased. The response of total dry weight (vegetative) was inconsistent. It is hoped that some of these effects can be directed towards the use of irradiation in winged bean improvement.

## ACKNOWLEDGEMENTS

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# Correlation and Path Coefficient Analysis of Components of Green Pod Yield in Winged Bean

*A. Satyanarayana, R. Rajendran* and *S. R. Biswas*[1]

## INTRODUCTION

The winged bean (*Psophocarpus tetragonolobus* (L.) DC.), a tropical legume, has a potential for improving human diets. It produces edible seeds, pods, leaves and tubers with unusually high protein levels. Despite these qualities, little is known about its genetic improvement. In any breeding programme for high yields, information on the nature and magnitude of variation in the available material, association of characters with yield and among themselves and the extent of environmental influence on these aspects is required. Furthermore, knowledge about the direct and indirect causitive factors on yield through path analysis permit critical examination of specific forces acting to produce a given correlation. Such work has been reported in many grain legumes viz., cowpea (Singh and Mehndiratta, 1969); moth bean (Tikka *et al.* 1976), horsegram (Aggarwal and Kang, 1976); French beans (Benett, J.P. and Adams, 1977). However, no such information is available for winged bean. The present studies were carried out to estimate relationships between yield and other agronomic characters and to analyse path coefficients to evaluate the relative contributions of each character, both direct and indirect to green pod yield.

## MATERIALS AND METHODS

Twenty-five varieties collected from different parts of the world were used in this study. These varieties were planted in single row plots of 5 m long in a randomized block design with 2 replications at the Indian Institute of Horticultural Research, Bangalore, India in 1976. The distance between row to row was 1.5 m and 25 cm between plant to plant. Five plants per plot were randomly selected and data were obtained on all growth and morphological characters viz., (i) number of leaves per plant, (ii) number of primary branches or leaves per plant, (iii) number of pods per plant, (iv) length of the pod, (v) weight of the pod and (vi) green pod yield per plant, were subjected to analysis of variance using plot means. Heritability and correlations (both genotypes and phenotypic) as well as the genetic advance of direct selection were calculated using the method suggested by Goulden (1959).

## RESULTS AND DISCUSSION

Yield being a complex entity, the morphology of the entire plant needs understanding regarding variability, and inter relationships of various components in determining the yield. Range, mean, phenotypic and genotypic variance, genetic coefficient of variability, heritability and genetic advance are given in Table 1. Considerable variability was present for the characters studied. The coefficient of genetic variability, and heritability estimates were calculated from the phenotypic and genotypic variances which is also presented in Table 2. The coefficient of genetic variation was lowest for the number of pods per plant and highest for the number of primary branches (24.07). Length of the pod showed highest heritability estimate (69.60) followed by the weight of the pod (46.96). Genetic gain for the number of leaves (9.55) and length of the pod (3.08) are fairly high.

[1]**Indian Institute of Horticultural Research, Bangalore — 560006. (Contribution No. 613.)**

**Table 1. Phenotypic variability in winged bean for various traits.**

| Sl. No. | Character | Range | Mean | Phenotypic variance | Genotypic variance | Coefficient of Genetic Variation | Heritability (%) | Genetic Advance (% of mean) |
|---|---|---|---|---|---|---|---|---|
| 1 | Number of leaves per plant | 124.2-31.00 | 66.09 | 1297.0335 | 167.0887 | 19.56 | 14.78 | 14.45 |
| 2 | Number of primary branches per plant | 2.6-1.00 | 3.94 | 4.5681 | 0.8987 | 24.07 | 24.49 | 22.08 |
| 3 | Number of green pods per plant | 27.0-6.00 | 11.62 | 20.1574 | very low | — | — | — |
| 4 | Length of pod | 1.62-9.99 | 15.67 | 13.2621 | 5.4423 | 14.89 | 69.60 | 19.66 |
| 5 | Weight of the pod | 18.94-7.66 | 12.32 | 11.9831 | 3.8289 | 15.88 | 46.96 | 18.51 |
| 6 | Green pod yield per plant | 317.80-49.97 | 141.17 | 2935.8234 | very low | — | — | — |

Heritability and genetic advance for different characters varied considerably. High heritability indicates that the effectiveness of selection for phenotypic performance is good, but it does not mean a high genetic gain for a particular character. However, high heritability estimates associated with genetic gain are more useful than heritability alone. In the present study, high heritability for the length of the pod was associated with a fairly high genetic gain indicating the presence of additive gene effect. However, the number of leaves per plant showed highest genetic gain but heritability was low.

Selection is usually concerned with changing two or more characters simultaneously; the understanding of correlation is therefore of interest to the plant breeder. Correlation coefficients among different traits are given in Table 2. Green pod yield was significantly and positively correlated with the number of pods (0.7169) per plant and length of the pod (0.4205). Significant positive correlations were also found between length of the pod and weight of the pod (0.7807), number of leaves and number of pods (0.7655), number of pods and number of primary branches (0.6937), and number of leaves and number of branches (0.7340). This clearly indicates that the number of pods which showed a high positive correlation with the number of branches and leaves per plant. The length of the pod was negatively correlated with these two characters but positively correlated to the weight of the pod. The correlation between the length and the number of pods is negative but not significant, indicating that a selection procedure aimed at increasing the length of the pod will not significantly reduce the number of pods. The path coefficients (standardized partial regressions) proposed by Wright (1921) permits the separation of correlation coefficients into direct and indirect effects of the

**Table 2. Phenotypic correlation coefficients among different traits.**

| | Number of primary branches per plant | Number of pods per plant | Length of the pod | Weight of the pod | Green pod yield per plant |
|---|---|---|---|---|---|
| Number of leaves per plant | 0.7340* | 0.7655** | — 0.2916 | — 0.5536** | 0.3626* |
| Number of primary branches per plant | | 0.6937** | — 0.3838* | — 0.4568* | 0.3396 |
| Number of pods per plant | | | — 0.1735 | — 0.3205 | 0.7169** |
| Length of the pod | | | | — 0.7807** | 0.4205* |
| Weight of the pod | | | | | 0.3926* |

*Significant 5% level.
**Significant at 1% level.

characters contributing to yield. The direct and indirect effects of different characters on yield are shown in Table 3. The number of pods per plant (0.8860) and weight of the pod (0.6368) were direct effects of the length of the pod (0.0981) which was quite low in comparison to its phenotypic correlation with green pod yield, because of high indirect effect via weight of the pod (0.49722). The number of branches and number of leaves showed high indirect effects on yield via number of pods, although their correlations and direct effects were low.

**Table 3. Direct and indirect effects of various agronomic characters on green pod yield per plant.**

| Character | No. of leaves per plant | No. of primary branches plant | No. of pods per plant | Length of pod | Weight of pod | Total indirect effect |
|---|---|---|---|---|---|---|
| Number of leaves plant | (0.05660) | 0.0085 | 0.6787 | −0.0286 | −0.3525 | 0.3060 |
| Number of primary branches per plant | 0.0416 | (0.01160) | 0.6150 | −0.0376 | 0.2909 | 0.3280 |
| Number of pods per plant | 0.0433 | 0.0080 | (0.8860) | −0.0170 | −0.2041 | −0.1691 |
| Length of the pod | −0.0165 | −0.0045 | −0.1538 | −(0.0981) | 0.49722 | 0.3224 |
| Weight of the pod | −0.0313 | −0.0055 | −0.2841 | 0.766 | −(0.6368) | −0.2442 |

Values given within parentheses are direct effects.

An overall examination of the results presented above indicates that there may be two ways to improve green pod yield. One is by increasing the number of pods because of its highest direct effect and also by increasing the number of leaves and branches because of their indirect effect on yield via number of pods. The second way to improve the yield is by increasing the length and weight of the pod, because weight has a high direct effect and length has a high indirect effect via weight and these two characters have a negative correlation with the number of leaves and branches. In the absence of a bushy plant for winged bean, an ideal plant will be of the second type, i.e., a plant preferably with a single leader having 40 to 50 nodes with flowering starting as low a node as possible with 2 or more longer pods per branch. With such a plant type, more plants are accommodated per unit area, and they can be turned easily on a thread over trellises.

## ACKNOWLEDGEMENTS

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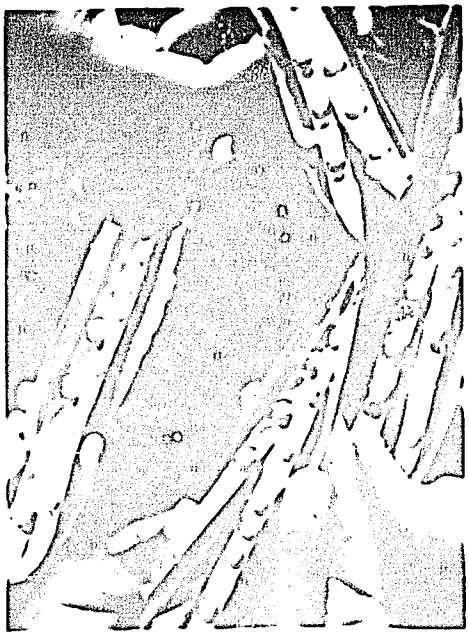
2.

*1. Winged bean roots showing prolific nodulation. 2. An early drawing of the winged bean abovegrouna morphology. 3. A regular size winged bean tuber*



2

3

*1. Four angled winged bean pods split to show seeds. 2. A long podded Indonesian cultivar. 3. Winged bean flower*

# Agronomy

- *Feasibility of Winged Bean in Venezuela*
- *An Integrated Approach Toward Agronomic and other Research Needs on Winged Bean: A Case Study of Winged Bean Collaborative Program in Ghana*
- *Effect of Cultural Practices on the Yield of Seed and Tubers in Winged Bean*
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- *Support Systems for Climbing Food Crops*
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- *Winged Bean Investigations at Niftal: Observational Garden. Rhizobium Strain Testing and Response Across a Liming Gradient*
- *Rhizobia in Tropical Legumes.*
- *The Potential for Green Pod Production in Winged Bean*
- *Effect of Lime and Inoculum on Nodulation and Growth of Psophocarpus tetragonolobus and Arachis hypogaea*
- *Agronomy of the Winged Bean in Malaysia*

# Feasibility of Winged Bean in Venezuela

*Dario R. Boscan Odor*[1]

**Studies to explore the possibility of growing winged bean in Venezuela were carried out at the Cagua Experiment Station, 10°11'N.67°30'W444 m above sea level, in a silty loam soil with pH 8, phosphorus (Olsem), 18 ppm, and exchangeable potassium, 71 ppm.**

**Preliminary results with material from I.I.T.A. Ibadan-Nigeria have shown very good yields and high protein content in green pods, leaves and dry seeds.**

**The protein content of six Tpt lines fluctuated between 36.3% as in Tpt-1 and 34.3% as in Tpt-14 in dry seed; between 31.4% as in Tpt-3 and 20.5% as in Tpt-6 in green pods, and between 35.3% as in Tpt-14 and 32.5% as in Tpt-4 in the leaf. The amount of calcium was also high in all the 6 lines fluctuating from 2.34% as in Tpt-14 and 2.19% as in Tpt-6.**

**The high amount of protein in green pods in Tpt-3, makes this line suitable for production in home gardens. However its climbing habit, makes this crop impractical and uneconomical for commercial production. The knowledge contained herein should be useful in the near future for its development of the winged bean as a subsistence crop or cash crop for small local markets in El Salvador.**

## ESTUDIO SOBRE LA POSIBILIDAD DEL CULTIVO DEL FRIJOL ALADO
*(Psophocarpus tetragonolobus)*

## INTRODUCTION

El frijol alado (*Psophocarpus tetragonolobus*) es un cultivo poco conocido hasta el presente. Se le cultiva principalmente en algunas partes de Africa, Sur este Asiatico y en mayor contidad en Papua Nueva Guinea, donde forma parte de la dieta del pueblo. Es una leguminosa trepadora tropical con un ulto valor nutritive tanto en las hojas, flores, vainitas, tuberculos y semillas. En estas ultimas el valor proteinico se compara con el de la soya, tanto por la calidad como por la cantidad de aminoacidos esenciales. Generalmente, las vainitas son consumidas cuando estan verdes y tiernas, o las semillas semi maduras; las hojas son consumidos como un hortializa, al igual que la espinaca. En alguna areas de Papua Nueva Guinea, los tuberculos son consumidos como un alimento de subsistencia, sin embargo, en la mayoria de las areas de esa region se consumen solos durante pocas semanas al año. No obstante el tremendo valor proteinico de esta leguminosa y su caracter tropical, es un cultivo desconocido en Venezuela, donde es ahora cuando se inician trabajos para estudiar su comportamiento y perpiedades nutritivas, considerando que en este aspecto aventaja a la soya, puesto que, todas las partes del vegetal son comestibles a diferencia de aquwllas donde solo las semillas son consumidas.

El presente estudio fue diseñado para conocer las bondades del frijol alado, sus caracteristicas agronomicas y posibilidades de desarrollo en el pais, dado su alto valor nutritive, que lo podria convertir en un cultivo de subsistencia y mercadeo local en algunas zones del pais.

## MATERIALES Y METODOS

Con semillas de 6 lineas de frijol alaso provenientes del I.I.T.A., Ibadan-Nigeria, identificadas como Tpt-1, Tpt-2, Tpt-3, Tpt-4, Tpt-6 y Tpt-14, enviadas por el Dr. Luse, Jefe del Programa de Leguminosas de eses instituto, fueron sembradas en la Estacion Experimental de Cagua, Lat. 10°11'N. Lon. 67°30'W altitud 444 mts. en suelos de la serie Maracay, de textura franco-limosa con un pH de 8, un contenido de carbono organico de 1125%, fosforo (Olsem) 18 ppm y potasio cambiable de 71 ppm. La siembra se efectuo el 21 de deciembre de 1976, en 6 parcelas de observacion para su evaluacion perliminar sobre comportamiento y adatacion, y observacion de algunas caracteristicas agronomicas. De sus vainitas y semillas se tomaron muestras para analisis quimicos re realizados por el Dr. Fritz Warner Romero, del Instituto Nacional de

[1] **Fundacion Servicio para el Agricultor, Estacion Experimental de Cagua.**

Nutricion. Durante el desarrollo del cultivo se aplicaron 15 riegos cada 8 dias para un total de agua aplicada de 480 mm., la siembra fue hecha sobre camellones, con un metro de separacion entre ellos, con un area por parcela de 11.50 m², la siembra fue realizada a mano, plantado una semilla cada 30 cm, la germinacion se inicio 10 dias despues de la siembra, 16 dias mas tarde todo el material mostraba plenitud de germinacion, no se aplico ningun tipo de fertilizantes, no se observaron plagas ni enfermedades de importancia, sin embargo, se pudo observar al final del ciclo del cultivo alguna colonias de acaros sin llegar a producir daño de importancia. Las plantas fueron empaladas utilizando palos de bambu y alambre liso para el sosten de las plantas.

## RESULTADOS Y DISCUSION

En el cuadro No. 1, se destacan algunas caracteristicas agronomicas observadas durante el desarrollo del cultivo.

**Cuadro No. 1. Caracteristicas y rendimientos obtenidos en 6 lineas de Frijol Alado *Psophocarpus tetragonolobus***

| Cultivar | Dias a plenitud de floracion | Dias a inicio cosecha | Dias a final cosecha | Rendimiento semillas kg. ha. |
|---|---|---|---|---|
| Tpt 1 | 72 | 120 | 160 | 2.073 |
| Tpt 2 | 68 | 120 | 160 | 1.826 |
| Tpt 3 | 68 | 120 | 160 | 1.587 |
| Tpt 4 | 68 | 120 | 160 | 1.370 |
| Tpt 6 | 68 | 120 | 160 | 1.152 |
| Tpt 14 | 74 | 120 | 160 | 1.348 |

**Se aprecia que la floracion alcanzo su plenitud entre 68 y 74 dias. El periodo de maduracion (cosecha de frutos secos) se inicio a los 4 meses. Prolongandose hasta los 5 meses y 10 dias; los rendimientos en semilla son bastante halagadores si consideramos que ciertos rendimientos reportados en Papua Nueva Guinea y Nigeria, a traves de various años de experimentacion, estan en el orden de 1.2 a 1.4 t ha.; aunque tambien se conocen rendimientos de 2.4 t ha. logrados en el I.I.T.A. (1).**

En los cuadros 2, 3 y 4, se destacan las caracteristicas quimicas de las hojas de vainitas y semillas de las 6 lineas probadas, en ellas se observan:

1. Que los valores de proteina en las vainitas y semillas son bastante diferentes en las 6 lineas, destacandose valores mayores para la semilla en estado seco, la cual era de esperarse. Se observa, asimismo, que los valores de proteina en la semilla estan todos por encima del 30%, con un maximo para la Tpt-1 de 36.3%, y minimo para la Tpt 14 de 34.3%. En las vainitas por el contrario, estos valores estan por debajo del 26.3%, con excepcion deila linea Tpt-3 con 31.4%, lo cual convertiria a esta en la mas apropriada para la produccion de vainita para consumo fresco, en comparacion con los cultivares Tpt-1 y Tpt-6 que, a pesar de sus altos contenidos de proteina en la semilla, poseen los valores mas bajos en las vainitas, con 22.2 y 20.5% respectavamente. Los valores de proteina en las hojas son bastante elevados. Se podria decir que muy proximo a los encontrados en la semilla, destacandose en este aspecto la linea Tpt-14 por 35.4%, aunque los valores de 32.5 para la Tpt-4, el mas bajo del grupo, no se podrian descartar.
2. Contenido de grasa en la semilla: las lineas Tpt-4, Tpt-6 y Tpt-14 muestran los valores mas altos del grupo, estos podrian ser comparados por los citados por (1) del 13% de grasa en alguna lineas. Los valores de grasa en la hoja parecen ser igualmente elevados, aunque no se pudo establecer comparaciones con otros trabajos. Igual consideracion se podria hacer del porcentaje de grada encontrada en las vainas.
3. Los valores de calcio y fosforo en las hojas son bastante elevados, especialmente el primero, si se compara con los encontrados en vainas y semillas.

No obstante la importancia del conocimiento de los parametros descritos desde el punto de vista nutricional, su habito de crecimiento lo descarta de toda posible produccion agricola en gran escala en Venezuela, hasta tanto no se logre la obtencion de plantas capaces de altos rendimientos y facilmente mecanizables. Si consideramos que ha sido en los ultimos 4 años, cuando verdaderamente ha habido una motivacion mumdial por el desarrollo y mejoramiento del cultivo, y la contribucion que este puede hacer para cubrir en parte la

escasez de proteinas en muchas regiones tropicales, no hay duda de que la obtencion de una planta de esas caracteristicas no llevara mucho tiempo.

Mientras esto sucede, todo conocimiento que se obtenga sobre el comportamiento del frijol alado en Venezuela, sera de mucha importancia para su desarrollo como cultivo, sin descartar que los materiales actuales y otros por consequir. Pueden ser utilizados en siembras familiares en los patios de las casas donde el consumo de proteina sea bajo.

**Cuadro No. 2. Caracteristicas quimicas de las vainas de 6 Lineas de Frijol Alado procedentes del I.I.T.A. sembradas en la Estacion Experimental de Cagua, 10° 11 N. 67° 30' W.**

| % Cultivar | % Humedad | % Proteina | % Grasa | % Fibra | % Extra. Libre de N. | % Ceniza | % Calcio | % Fosforo | % Total Humedad |
|---|---|---|---|---|---|---|---|---|---|
| Tpt 1 | 4.3 | 22.2 | 1.2 | 24.4 | 41.9 | 6.0 | 0.55 | 0.32 | 89.4 |
| Tpt 2 | 4.2 | 23.6 | 1.1 | 17.2 | 47.5 | 6.4 | 0.91 | 0.38 | 89.0 |
| Tpt 3 | 5.7 | 31.4 | 1.4 | 20.3 | 34.0 | 7.2 | 0.61 | 0.44 | 88.7 |
| Tpt 4 | 5.6 | 26.3 | 1.6 | 21.2 | 38.4 | 6.9 | 0.79 | 0.46 | 87.9 |
| Tpt 6 | 4.0 | 20.5 | 1.9 | 17.5 | 50.3 | 5.8 | 0.79 | 0.34 | 86.2 |
| Tpt 14 | 3.9 | 25.6 | 2.6 | 22.4 | 39.4 | 6.5 | 0.73 | 0.39 | 88.2 |

**Cuadro No. 3. Caracteristicas quimicas de las semillas de 6 lineas de Frijol Alado procedentes del I.I.T.A. sembradas en la Estacion Experimental de Cagua, 10°11 N. 67° 30'W.**

| Cultivar | Humedad | Proteina | Grasa | Fibra | Extra Libre de N. | Ceniza | Calcio | Fosforo |
|---|---|---|---|---|---|---|---|---|
| Tpt 1 | 10.5 | 36.3 | 12.8 | 9.1 | 26.9 | 4.4 | 0.47 | 0.45 |
| Tpt 2 | 10.5 | 35.0 | 12.4 | 9.8 | 27.8 | 4.5 | 0.51 | 0.45 |
| Tpt 3 | 10.8 | 34.5 | 13.6 | 9.2 | 27.0 | 4.9 | 0.42 | 0.44 |
| Tpt 4 | 10.1 | 34.6 | 14.6 | 8.8 | 27.5 | 4.4 | 0.48 | 0.45 |
| Tpt 6 | 9.9 | 35.1 | 14.2 | 9.0 | 27.6 | 4.2 | 0.48 | 0.42 |
| Tpt 14 | 9.7 | 34.3 | 14.9 | 8.3 | 28.4 | 4.4 | 0.42 | 0.45 |

**Cuadro No. 4. Caracteristicas quimicas de las hojas de 6 lineas de Frijol Alado procedentes del I.I.T.A. sembradas en la Estacion Experimental de Cagua, 10° 11'N. 67° 30' W.**

| Cultivar | % Humedad | % Proteina | % Grasa | % Fibra | % Extra Libre de N | % Ceniza | % Calcio | % Fosforo | % Total Humedad |
|---|---|---|---|---|---|---|---|---|---|
| Tpt 1 | 4.3 | 32.9 | 4.1 | 16.2 | 32.6 | 9.9 | 2.30 | 0.36 | 80.6 |
| Tpt 2 | 4.5 | 34.1 | 5.0 | 19.1 | 27.8 | 9.5 | 2.25 | 0.35 | 79.1 |
| Tpt 3 | 5.0 | 33.6 | 4.5 | 16.7 | 30.4 | 9.8 | 2.26 | 0.36 | 80.3 |
| Tpt 4 | 4.2 | 32.5 | 4.0 | 18.4 | 31.0 | 9.9 | 2.30 | 0.34 | 80.3 |
| Tpt 6 | 3.8 | 32.7 | 4.4 | 18.6 | 31.1 | 9.4 | 2.30 | 0.34 | 79.3 |
| Tpt 14 | 3.6 | 35.4 | 4.7 | 15.6 | 30.9 | 9.8 | 2.34 | 0.39 | 80.9 |

# An Integrated Approach Toward Agronomic and Other Research Needs on Winged Bean — A Case Study of Winged Bean Collaborative Programme in Ghana

*S. K. Karikari*[1]

**Several varieties of the winged bean have been studied at the University Research Station at Kade. The aim of our research has been to exploit the full potential of the crop as: green vegetable; seed for human and livestock consumption; fallow restorative cover crop in tree crop plantation; and as root crop.**

**The plant appears to have critical harvesting stages as a green vegetable and such early harvests appear to stimulate greater pod formation. Mature seeds are best processed industrially. The high profit realized in winged bean cultivation serves as incentive for wider cultivation.**

**In cover cropping areas, winged bean appears to be the multipurpose legume required to restore fertility, raise additional income and provide forage for the integrated livestock.**

**Tuberization of the plant appears to benefit from increasing support length up to 240 cm as well as good soil preparation and the absence of the seed sink.**

**Varieties have been selected or developed to meet the needs of utilization of the crop. The best varieties for green pod production were 1/26, 4/24, 5/12 and 6/16 while varieties 24/3, 2/10, 15/6 and 11/6 were suitable for seed production. For cover cropping, varieties 27/4, 26/6 and 10/6 appeared to serve well and varieties suited for production of tubers were 10/6, 27/4, 6/16 and 1/2. It is envisaged that the new drought tolerant variety Kade 6/16 could help spread the cultivation of the winged bean to even drier areas.**

## INTRODUCTION

Since 1968 the University of Ghana Agricultural Research Station at Kade (6°N 1°E) has carried out agronomic investigation on the winged bean and has found basic information on the cultural practices and nutritive values of the crop. The results of these works, have been published in the Station's annual reports and scientific journals. Some findings have also been discussed at symposia, conferences and seminars. References to these works can be cited as follows: Anon. 1966/67, 1967/68, 1968/69; Pospisil; Karikari and Boama-Mensah: 1970; Karikari: 1972; and Boateng: 1976; Karikari and Asiedu: 1976; Karikari and Oteng: 1977 and Karikari: 1977.

These investigations have contributed to our knowledge on how to cultivate the crop and have also unearthed the potential of the crop for improving human and livestock diets. The investigations have been carried out mainly on the species *P. tetragonolobus* which have appeared to have an apparent merit over other species, especially in terms of seed yield.

The winged bean has received much international recognition and research attention since the National Academy of Sciences, U.S.A. ad hoc panel on the crop met in Washington in 1974 and since the publication of the booklet "The Winged Bean — A High Protein Crop for the Tropics."

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Since 1974 research on the crop in Ghana has been carried out in an integrated approach, and within the framework of information available from Kade. In order to integrate work on the crop, a careful analysis was made in which utilization of the crop was defined. This became necessary because, it appeared that wide variations existed and a "multi purpose" variety which produces tubers, seeds and foliage was difficult to come by. Also, such characters could not be incorporated easily into a single crop. There was also a problem with growing the crop in areas of low rainfall [76.2 cm (30 inches) per year] and so a need was felt to select and breed a type which could tolerate drought conditions.

Under the integrated programme, priorities have been defined with regard to utilization of the crop as a green vegetable, as seed for human consumption and feed for livestock, as a fallow restorative cover crop in the culture of perennial tree crops especially cocoa, oil palm and citrus and as a root crop.

Figure 1 shows areas in Ghana involved in winged bean research and seed multiplication trial programme. The organization is evolving as new seeds become apparent, but its present stage is summarized in Table 1a. Table 1b shows the range of disciplines concerned.

**Table 1a. Organization of the Ghana winged bean program.**

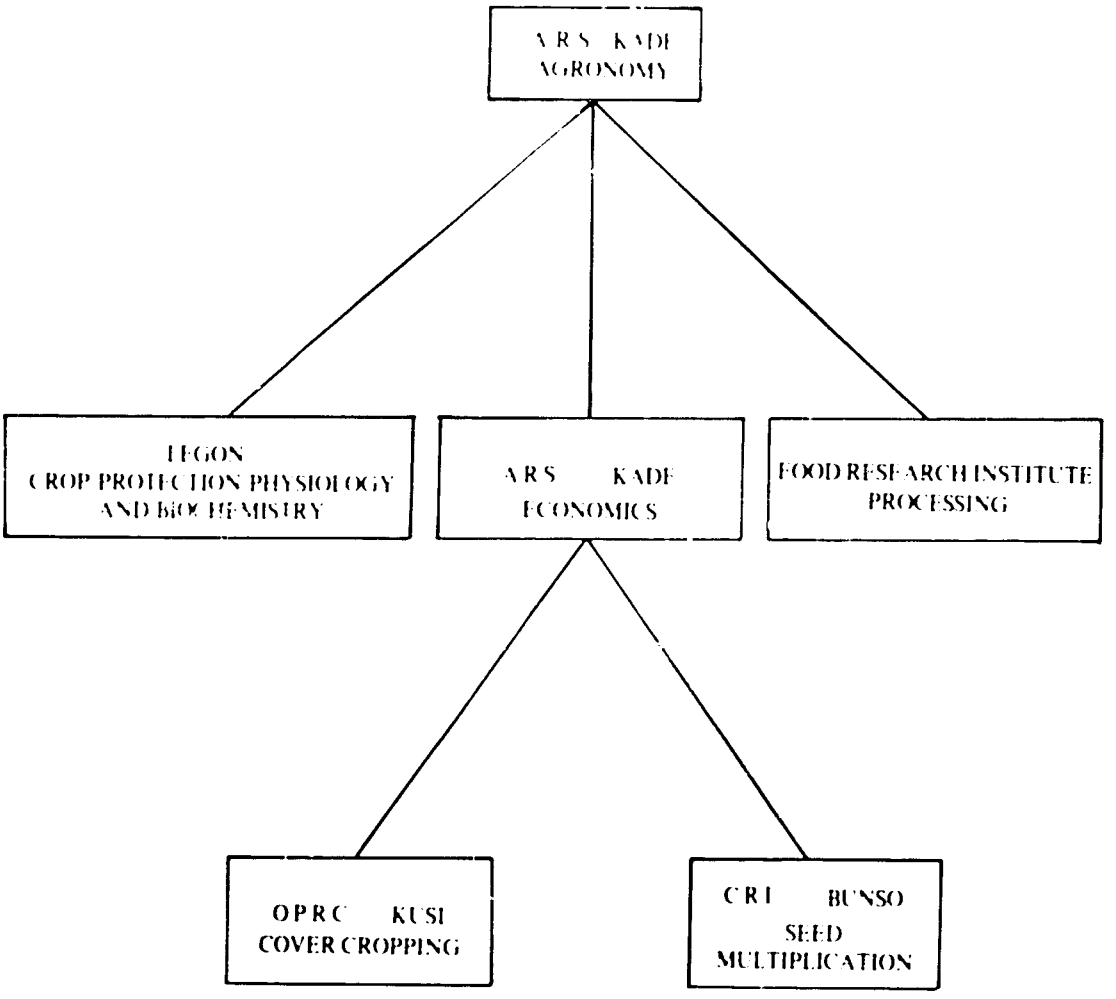

**Table 1b. An integrated research program on the winged bean in Ghana.**

| Agronomy | Crop Protection | Physiology Biochemistry | Economics | Processing |
|---|---|---|---|---|
| 1 Germplasm collection (120 varieties) | 1 Crop tolerance to competition and weeds | 1 Photoperiodic response | 1 Supply and demand | 1 Utilization for food and feed |
| 2 Selection for<br>A Green vegetables<br>B Seed<br>C Cover cropping<br>D Root crop | 2 Insects and diseases that attack crop during growth and storage | 2 Chemical analysis of pods, sheds and tubers | 2 Local trends and demand | 2 Cooking methods |
| 3 Breeding<br>A For drought tolerance | | 3 Photosynthesis efficiency | 3 Cost of production and returns | 3 Food preparations and infant weaning foods |
| 4 Yield Studies<br>A Variability in yield<br>B Planting methods | | | 4 Farming systems | |
| 5 Seed multiplication | | | | |

## THE WINGED BEAN AS A GREEN VEGETABLE

A cosmopolitan collection of winged beans has been investigated at Kade during the past years as a source of green beans. Preliminary investigations revealed that some varieties provided a continuous crop of edible immature pods if harvested regularly.

The phenology of the crop revealed that 21 days after fertilization was the best period to harvest the crop as green beans. Pod production started 12 weeks after planting, producing between 6 to 10% of total number of pods between 12 to 16 weeks. Pod production reached a peak of 30% during the 18th week dropping to as low as 1% during the 30th week by which time the dry season would have started. Pods are normally succulent and brittle up to 21 days after fertilization, and during the rainy season. However, some pods produced prior to the dry season, were stringy after 16 days.

Eighteen days from fertilization was therefore taken as the best time to harvest pods for green vegetable during the rainy season; during the dry season this period was reduced to 14 days. The best varieties for green pod production were 1/26, 4/24, 5/12 and 6/16. As compared with Kade Prolific (one of the early selections suitable mainly for foliage) these had long thin pods (16 cm × 2 cm) weighing 18 to 20 g each, reduced wings, thick flesh and tiny seeds. Each plant produced 2 to 3 green pods for 9 to 12 weeks. At the end of the season green pod production per plant was 25 to 36 and weighed 0.5 to 0.7 kg. At a spacing of 60 cm × 60 cm (27,777 plants/ha) the expected total number and weight of green pods ranged from 69,000 to 1 million and 13,888 to 19,443 kg, respectively. At the current price of 44 pesewas per kilogram, 610 to 855 Cedis per hectare could be realized from growing the bean solely for green vegetable. This could be very valuable in view of the fact that plants tended to produce more pods as young pods were plucked off at 18 days of age. Prices could be higher in urban markets in view of the high demand for fresh vegetables.

## PRODUCTION OF THE WINGED BEAN FOR SEED

Preliminary investigations on seed production has been undertaken and reported (Pospisil, Karikari and Boamah Mensah, 1971). For best seed production, a spacing of 60 × 60 cm with 3 seeds per hole has been recommended in Ghana. The plants should be staked since allowing them, to ramble over the soil surface reduces pod formation and subsequent seed production. The hedge staking method is better than pole staking. Seed yields ranging from 820 to 1,380 kg/ha have been obtained in experiments specially designed for seed production in which all pods were allowed to mature before harvesting.

The cooperating farmers and the institutions were supplied with seeds of 24/3, 2/10, 15/6 and 11/6 on credit. These varieties have been found to yield 2,010, 2,000, 1,886 and 1,725 kg of air dried seeds per hectare (Karikari and Boateng, 1975). Extension services were provided from planting to harvesting and each farmer institution had a schedule of work which enabled the planning of the programme. This schedule took into consideration timing which enabled consecutive operations to be carried out at about the same time. The schedule of operations is shown in Table 2.

**Table 2. Work schedule for winged bean operations, farmers institutions, 1976.**

| Time | Operation |
|---|---|
| April 1-20 | Selection of farmers and schools, orientation, extension education in nutritional problems and importance of winged beans. Distribution of seeds, preparing land |
| April 21-30 | Open day show of University of Ghana, Agricultural Research Station, Kade Experimental Farms of winged beans. Demonstration to farmers and schools on aspects of winged bean cultivation including phenology, spraying, weed control, harvesting, shelling and bagging |
| May 1-7 | Fixing of stakes and sowing of seeds. Training vines on to stakes by raffia palm leaves, plaintain twine, etc |
| June 15-Aug. 31 | Field maintenance and spraying once a week by extension staff of the station |
| September 1-10 | Supply of bags and measuring cans to farmers |
| September 10-20 | Harvesting, shelling and drying |
| September 21-30 | Sale of seed and payment in the field |

At the end of the season when all seeds produced by farmers and institutions had been gathered, about 1½ tons of seed was produced. Four bags (100 kg or 220 lb each) were produced at the Research station and six bags produced from other individuals and school project. A total of 174 man days (8 hours of work) at a cost of ₵348.00 were required to raise a hectare of winged beans from secondary forest. At an average production level of 700 kg air dried seeds per hectare, 15 pesewas per cigarette tin (200 g) was accepted as a fair price. This realized a new profit of ₵175.00 as compared with a net profit of ₵26.02 realized when grown for green vegetables. Table 3 shows the operations and costs involved.

**Table 3. Operations and costs of producing seeds from a hectare of winged bean.**

| Operation | Man-days/ha[a] | Cost/ha (₵)[b] |
|---|---|---|
| Bush clearing | 5 | 10.00 |
| Lining and pegging | 4 | 8.00 |
| Cutting stakes and staking | 42 | 84.00 |
| Holing and planting | 31 | 62.00 |
| Cultural operations | 36 | 72.00 |
| Harvesting and shelling | 56 | 112.00 |
| TOTAL | 174 | 348.00 |

[a] A man day is the equivalent of a man working for 1 day (8 hours).
[b] A minimum daily wage of ₵2.00 was used.
[c] ₵1.00 = 0.50 = US $0.87.

## THE WINGED BEAN AS A RESTORATIVE COVER CROP

The use of cover crops in the culture of perennial tree crops has long been recognized for its role in soil amelioration, suppression of weeds and conservation of moisture. In the establishment of young cocoa, oil palm and citrus, in Ghana for example, leguminous cover crops have played significant roles in this respect. Such legumes include *Pueraria* spp., *Centrosema* spp. and *Mimosa* spp. Although these legumes nodulate well, and provide good cover, they are not utilizable by human beings but by stock only, and therefore do not appear to be popular in areas where livestock is not kept. Attempts to substitute these short term fallows of quick growing pasture type legumes for traditional cover cropping have therefore not been successful in areas where livestock is not kept.

References to winged beans as a cover in *Hevea* rubber in Malaysia was reported by Paul (1951). In Ghana, Karikari (1968/69) compared the yield of cocoyams (*Xanthosoma* spp.) as affected by *Psophocarpus tetragonolobus*, *Centrosema pubescens*, *Pueraria* spp., *Mimosa* spp. and natural regeneration, as soil covers, and found out that the yield of cocoyams under *Psophocarpus tetragonolobus* was higher than under other cover crops and natural regeneration. Because cocoyams are annual crops, the long term effects of these covers could not be realized. When used as cover crop, the legumes were not staked. The winged bean yielded 400 kg of air dry seeds per hectare. This preliminary work unearthed the potential of the winged bean as a cover crop, and this study was therefore incorporated in the winged bean collaborative programme.

In the selection work at Kade, certain varieties of winged bean appeared to produce more vegetative material, and had higher leaf weight ratios. These plants also had longer growing periods. They seeded fairly well when allowed to ramble over the ground. Although the tops died off during the dry season, the plants were very fast in picking up foliage as soon as the rains started. These features gave these varieties an apparent merit for use as cover crops and were therefore chosen as such. Varieties which appeared to serve this purpose were 27/4, 26/6 and 10/6.

In 1975 seeds of these 3 varieties were given to the Oil Palm Research Centre of the CSIR for trial as a cover crop under oil palm and after a year's trials they were found to be meritorious. The seeds were multiplied at Kade at the same time and used as trial cover cropping in 14 selected farms, 4 each of newly established private cocoa, citrus and oil palm plantations and 2 in a food crop farm.

In each experiment, soon after clearing of land for crop planting a hectare of field was chosen and then divided into four quarters. Each quarter was alloted one cover crop of *Pueraria*, *Centrosema*, *Psophocarpus* and natural regeneration. Periodically, measurements were taken of ground cover, using the line quadrat system, and early growth of crop using the height of seedling/budding. At the same time, seeds were allowed to mature and harvested for sale.

All the cover crops were planted in April, 1976 and planting of actual tree crops done in June 1976. Harvesting of pods of *P. tetragonolobus* was completed at the end of November, 1976 and by January 1977 all the tops of *P. tetragonolobus* had died off. The vegetative matter of the other cover crops were still green throughout the dry period. The highest quantity of seed provided per hectare was 516 kg for 27/4 and 400 kg for 26/6; and poorest seed yielder was 10/6, producing only 212 kg/ha. With the rains in March 1977 all the varieties started sprouting. Variety 27/4 formed a poor cover, only a few vines developed but these were floating on top of the weeds (grasses). Variety 10/6 which seeded poorly in the first season, sprouted well, formed a good cover and competed satisfactorily with the weeds. The total quantity of seeds per hectare that was obtained during the second ratoon crop in October, 1977 were as follows: 27/4 = 200 kg, 26/6 = 312 kg and 10/6 = 254 kg.

Samples of tuber dug out to study formation showed that 10/6 had well developed tubers producing 34.9 g/plant while 26/6 had 22.9 g/plant and 27/4 had 4.5 g/plant.

At the end of the harvesting season, livestock (sheep and cattle) were turned into the field, and it was always interesting to watch how these animals grazed on the leaves of the winged beans. A feeding trial using winged bean foliage, has been started by the Department of Animal Science, Legon, but the results were not ready for presentation into this report. However local farmers have started feeding poultry with a feed mixture of one part of winged bean seeds to three parts of maize and reported that birds fed on winged bean feed mixture, produce more and bigger-sized eggs than birds fed on other meals (Antwi, private communication).

## THE WINGED BEAN AS A ROOT CROP

An interesting aspect of the winged bean is that it provides edible roots which contain high protein. In our work at Kade certain varieties have shown promise for high tuber formation. Tuber development is fully attained at 10 to 13 months of growth. The tubers at this stage have brown fibrous skin and white solid flesh. If allowed to grow beyond one year and are harvested from ratoon crops tubers become stringy and insipid. Normally the seeds have the consistency of an apple and taste slightly sweet. In the North, the tubers are eaten but only as "famine crop." When they are uprooted from the ground, they are baked in fire, and eaten like cassava. Local people complain that when cooked they do not taste as good as when baked in fire.

In the screening trial at Kade it was found that certain varieties do not form tubers at all. Some varieties produced heavy tubers, and varieties producing both tubers and seeds were very rare. In the tuber producing varieties, tuber formation was enhanced when pods were harvested as green vegetable, and also when flowers were plucked off. Among the Kade varieties the following were found to produce sizeable tubers of the following average:

| Variety | Weight | Range |
|---|---|---|
| 10/6 | 34.9 g | (30—39.8) g |
| 27/4 | 30.0 g | (27.1—35.9) g |
| 1/2 | 24.8 g | (22.5—27.1) g |

At University Research Station, Kade, three experiments were carried out to investigate some agronomic methods that enhance tuber formation. The three varieties 10/6, 27/4 and 6/16 were studied for tuber yield under the following treatments:

1. Effect of vine support length on tuber yield.
2. Planting on mounds, ridges and flat effect on tuber yield.
3. Flowering and deflowering effect on tuber yield.

In experiment 1 stakes of varying lengths 120, 150, 180, 210, 240, and 270 cm were used to support the vines as against the control of "no staking." Tables 4 and 5 show the mean yields of tuber and vegetative matter 12 months after planting.

**Table 4. Effect of staking on yield of tuber (g/plant).**

| Stakes Lengths (cm) | Varieties | | | Mean for Stakes Lengths |
|---|---|---|---|---|
| | 10/6 | 27/4 | 6/16 | |
| 0 | 4.5 | 3.8 | 4.0 | 4.1 |
| 120 | 15.3 | 16.5 | 17.1 | 16.3 |
| 150 | 22.9 | 20.2 | 18.6 | 20.6 |
| 180 | 31.6 | 30.4 | 28.4 | 30.1 |
| 210 | 33.4 | 32.1 | 30.3 | 31.9 |
| 240 | 34.9 | 35.1 | 32.1 | 34.0 |
| 270 | 6.4 | 7.7 | 21.4 | 11.8 |
| Mean for varieties | 21.3 | 20.8 | 21.7 | 148.8 |

LSD (5%) for stake length = 2.14
LSD (5%) for varieties = 1.03

The second experiment, involved three different kinds of soil preparation. The land was ploughed and planting was done on mounds, ridges and flat (control). Table 6 shows the effect of soil preparation on mean yield of tubers, 12 months after planting.

**Table 5. Effect of staking length on mean yield of vegetative matter (kg/plant).**

| Stakes Lengths (cm) | Varieties | | | Mean for Stakes Lengths |
|---|---|---|---|---|
| | 10/6 | 27/4 | 1/2 | |
| 0 | 6.21 | 5.60 | 4.85 | 5.56 |
| 120 | 6.96 | 7.35 | 7.02 | 7.11 |
| 150 | 7.55 | 7.65 | 7.71 | 7.64 |
| 180 | 7.93 | 8.08 | 8.31 | 8.11 |
| 210 | 8.62 | 8.88 | 8.57 | 8.69 |
| 240 | 8.75 | 8.90 | 8.88 | 8.54 |
| 270 | 8.82 | 8.90 | 9.22 | 8.98 |
| Mean for varieties | 7.83 | 7.91 | 7.79 | 164.76 |

**LSD (5%) stakes lengths = 1.6**
**LSD (5%) varieties = 1.2**

**Table 6. Effect of soil preparation on the mean yield of tuber (g/plant).**

| Soil Preparation | Varieties | | | Mean for Planting Method |
|---|---|---|---|---|
| | 10/6 | 27/4 | 1/2 | |
| Flat | 32.3 | 34.6 | 29.5 | 32.1 |
| Mounds | 38.4 | 41.3 | 33.6 | 37.8 |
| Ridges | 42.5 | 46.1 | 33.0 | 40.5 |
| Mean for varieties | 37.7 | 40.8 | 32.0 | 36.8 |

**LSD (5%) planting methods = 3.0**
**LSD (5%) varieties = 6.9**

In the third experiment, the effect of flower removal comprising removal of 50% of flowers (i.e. plucking off every other flower), 100% flower removal, and control (no flower removal), on tuber yield was studied. Tubers were harvested 12 months after planting. Table 7 shows the results obtained.

**Table 7. Effect of deflowering on mean yield of tuber (g/plant).**

| Flowering Treatment | Varieties | | | Mean for Flowering Treatment |
|---|---|---|---|---|
| | 10/6 | 27/4 | 1/2 | |
| No picking of flowers | 33.6 | 41.2 | 38.9 | 37.9 |
| 50% picking of flowers | 44.7 | 46.5 | 38.1 | 43.1 |
| 100% picking of flowers | 52.3 | 56.1 | 37.1 | 48.6 |
| Mean for varieties | 43.5 | 47.9 | 38.1 | 43.2 |

**LSD (5%) varieties = 5.6**
**LSD (5%) flower treatment = 5.0**

## THE WINGED BEAN AS A SAVANNA CROP

The climatic requirements of the winged bean have not been critically studied. The plant study only cultivated within the tropics. The crop has always been grown in regions of very high rainfall and attempts to establish economic cultivation in the dry tropics, except with irrigation, seem likely to lead to disappointing results. From a consideration of the existing areas of cultivation, one may correctly say that the plant may not be capable of giving its maximum yield with an annual rainfall of less that about 112.4 cm (60 inches) per annum.

The plants' inability to tolerate drought therefore appeared to be a serious barrier to its large scale cultivation and rational development in Ghana and other places with similar climate. This problem has been looked into at Kade. One hundred and twenty varieties have so far been assembled at Kade. A number of these showed promise for drought tolerance and characters that appeared to enhance drought tolerance have been described in detail by Karikari (1977)

Of these 120 varieties, seven showed promise for drought tolerance. These were local 12, Damongo, Brown Mottled, Kade Red, Bunso 12, A R S 87 and 36/15. Out of these varieties has been derived Kade 6/16 from crosses of both wild and selected hybrids. A schematic plan is illustrated in Fig. 1.

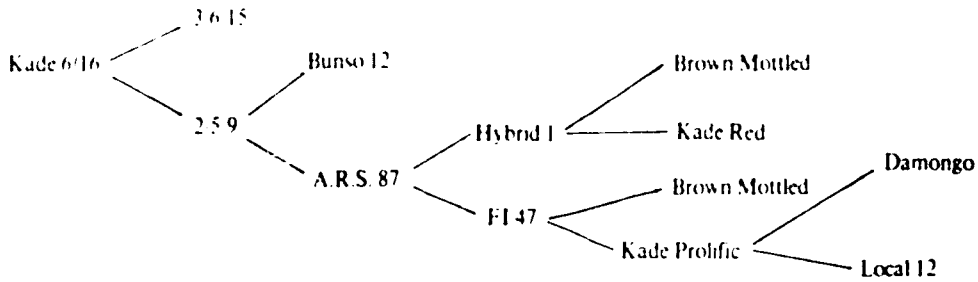


**Fig. 1. A schematic pedigree plan of Kade 6 16 variety of winged bean.**

When 6/16 was compared with known varieties that were unable to tolerate drought the following characters in Table 8 appeared distinct.

**Table 8. Ten distinct characters between variety 6 16, a drought tolerant variety and variety 11 6, a non-drought tolerant variety.**

| Character | Variety 6 16 Drought Tolerant | Variety 11 6 Non-Drought Tolerant |
|---|---|---|
| Leaf weight ratio | 1/16 -- 1/20 | 1/18 — 1/24 |
| Stem thickness (cm) | 0.4 -- 0.6 | 0.3 — 0.4 |
| Pulvinus thickness (cm) | 0.2 -- 0 3 | 0.2 — 0.4 |
| Trifoliate leaf (sq cm) | 80 — 100 | 100 — 136 |
| Internode length (cm) | 10 — 12 | 6 — 10 |
| Petiole length (cm) | 16 | 16 |
| Petiole internode ratio | 1.45 | 2.13 |
| Phyllotaxy | 2/5 | 2/7 |
| Seed yield (g/ha) | 700 | 1,725 |
| Tuber yield (t/ha) | 0 9 — 2.4 | 0 9 — 1 0 |

## DISCUSSION AND CONCLUSIONS

The Ad Hoc Panel on the winged bean at its meeting in Washington, U.S.A., in October 1974 recommended among other things that agronomic research on the winged bean (*Psophocarpus* spp.) be initiated in areas where lack of knowledge consitutes barrier to the rational development of the winged bean. Among the areas where such needs are barriers, are germplasm collection and distribution, vegetable uses, cover cropping, tuber development and crop adaptation to suit adverse environments. It is in these areas that research attention has been focused at Kade and other areas in Ghana in an integrated research programme

In subsistent cultivation of the winged bean the best stage to harvest the pod as green vegetable is when it is soft and brittle. This stage is attained about 18 and 14 days after flowering during rainy and dry seasons, respectively. The long flowering period of about a month gives steady supply of the green vegetable over longer period than determinate crops. This indeterminate habit enables the plant to respond to the harvest of immature pods since the nutrients that would have been utilized for pod filling becomes available for more

pod formation. The best varieties for use as green vegetables should be those with high response to increase the pod number when they are harvested in the immature stages. Such plastic response enables the farmer to choose between seed and vegetable production. For green vegetable the emphasis is on the thick fleshy pods as exemplified in 1/26, 4/24, 5/12 and 6/16 varieties.

However, to cultivate for seeds, the pods must be allowed to mature and dry. At this stage the seed is not popularly used for domestic consumption and are more suitable for processing and storage. In such cases where a farmer is cultivating purposely for sale of the seed, cost analysis and profit maximization become relevant. At a price of ten pesewas (10 P) per cigarette tin of dry seeds, the marginal cost equals the marginal returns and at a price of fifteen pesewas (15 P) the farmer realizes ₵175.00 per hectare i.e. half the cost of production as profit.

In Ghana such a revenue from an annual crop is appreciable. Further research into the economics of production is necessary especially in finding more efficient stakes and staking method to reduce the number of man days involved. Staking cost alone forms about 24% of the total cost. Any reduction in this aspect will increase the farmers' revenue without increasing the cost of inputs to the processing industries.

### The Winged Bean as a Restorative Crop

Perennial crops by their long standing on the land demand conservation of moisture, suppression of weeds and restoration of the ever depleting minerals. Leguminous covers have been successfully used especially *Centrosoma* and *Pueraria*. If winged bean can substitute, the nitrogen restoration can be quicker and the farmer could also derive extra revenue. The successful variety must be able to produce heavy vegetative matter and grow vigorously to compete with weeds. Characters of some Kade selections have been appraised and types like 27/4, 10/6 show vigorous growth, high leaf ratio and shoot to root ratio. Cocoyam as test crop gave higher yield in association with these varieties as cover crops than with the traditional cover crops in Ghana. The additional yield from the winged bean could earn the farmer about ₵62.00 per hectare. It appears that its role as cover crop is also excellent in integrated farming in livestock and tree plantation, since the grazing animals can later be turned on this cover crop after harvesting the seeds. The exceptionally high protein in the leaves makes it excellent forage. Thus the use of winged bean as cover crop appears to answer the search for a multi purpose legume, which is semi perennial in habit to perform the role of cover cropping in the tropics.

### The Winged Bean as a Root Crop

The tubers of winged bean contain higher protein than that of other root crops. Whereas such tuberization is reliable in many tuber crops, they are less in winged bean and certain varieties do not appear to tuberize at all. In the above mentioned screening trial about three varieties gave consistent and reliable tuber yield averaging about 830 kg per hectare. Similar records have been reported in the IITA Annual Report 1974 (p. 86) that in 1974 no tubers were produced in contrast with tuber yields between 572 to 1288 kg/ha obtained in 1973. So far the response to tuber yield stimulation has been very encouraging. The varieties show varying response in tuber yield to various support lengths of the vines. Generally as staking height increases from 0 to 240 cm the tuber yield increased at a decreasing rate, attaining maximum of 240 cm and then declining sharply with further increase of 30 cm in the staking length. The increase in tuber yield is associated with increase in yield of vegetative matter in similar manner (Tables 6 and 7). The association of the two could stem from the fact that expansion in tuber size results from storage of excess photosynthate. Since there was tuberization in the control, it appears that the initiation of tubers, being an endogenous process, does not derive any stimulus from staking. Increasing staking height appears to expose greater photosynthetic area to the sun resulting in higher photosynthesis. Since the vegetative matter increased at decreasing rate with increasing mutual shading, the increase in excess photosynthate production reduced accordingly. It appears that beyond 240 cm of support length, excessive mutual shading reduced the photosynthesis of many surfaces to below compensation point, resulting in deficit in yield.

In the second experiment (Table 8), not all the varieties responded in similar manner but generally tuber yields were highest for ridges and lowest for flat planting. This low yield might be due to the poor structure and absence of root room resulting in suppression of tuber expansion. Thus ridging and mounding breaks loose and hardened soil to allow room for tuber expansion. Such soil is improved in drainage, depth, structure and organic matter from scraping the top soil together. In dual purpose winged bean plant, three sinks may be identified — the various seeds, pods and the tubers. Their functions appear to be competitive in storing the

excess photosynthate. The removal of flowers could result in translocation of all the excess photosynthate into the tubers whereas partial removal could enhance the yields of the remaining seeds and the tubers. Table 7 shows the general increase in tuber yield with increasing deflowering. Results were very remarkable for variety 27/4.

**The Winged Bean as Savanna Crop**

The inability of the winged bean to tolerate drought restricts its cultivation to the high rainfall areas with minimum successes in the savanna areas.

The seven varieties which were screened out of 120 varieties for drought tolerance were systematically combined. The characters which adapt variety 6/16 to drought have been presented. The higher tuber yields of 6/16 appear to serve as high water reserve to survive the plant through drought. Some anatomical adaptations of possible advantage include fewer number of leaves, low leaf area of the terminal trifoliate layer, leaf and stem thickness as well as high pulvinus thickness. All these factors combine to decrease the total surface area of the drought tolerant 6/16 thus reducing its transpiration surface to save the plant from excessive water losses.

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Appendix I. Areas in Ghana involved in winged bean research and seed multiplication.

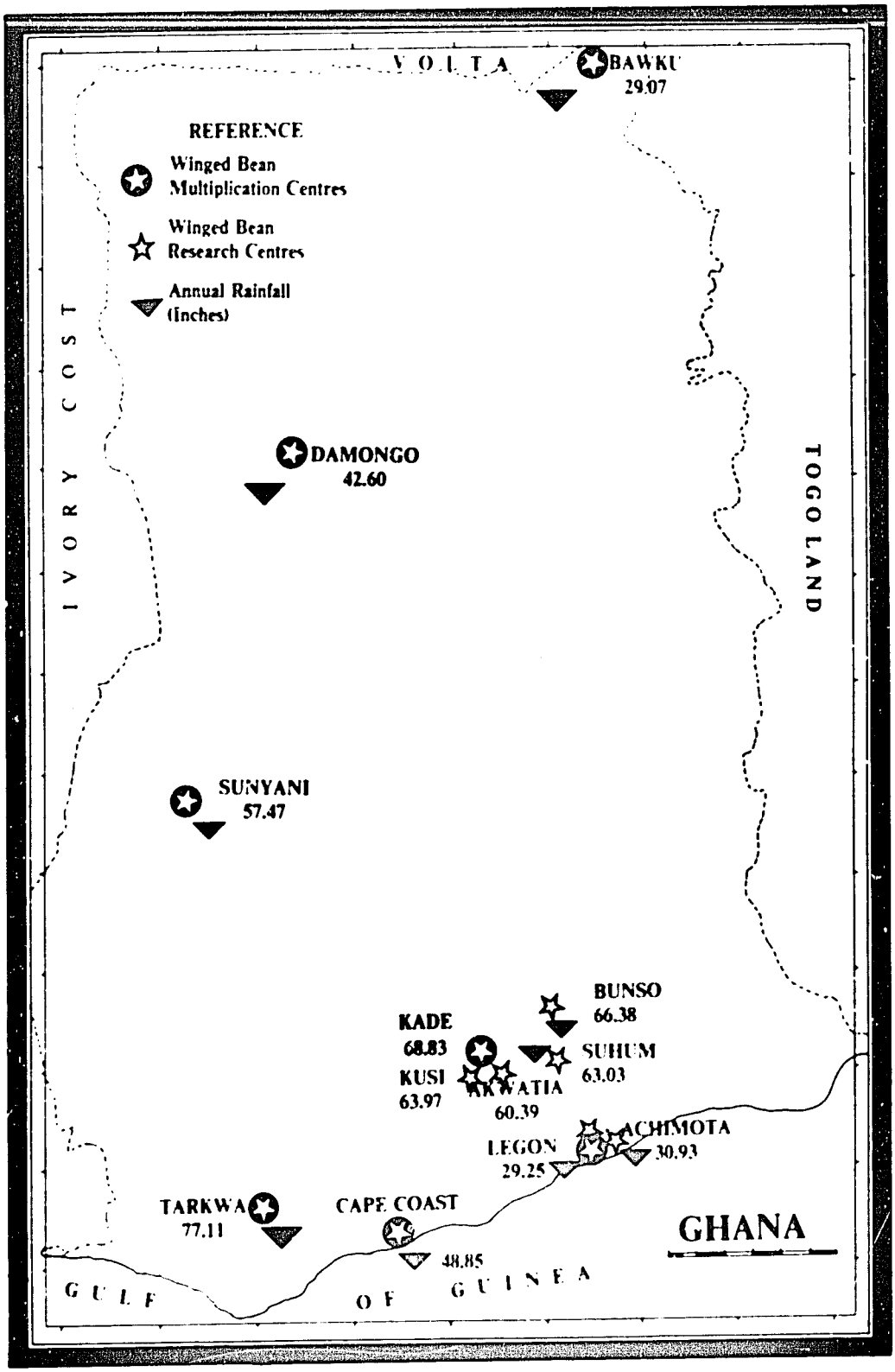


Figure 1. Centres in Ghana for research and multiplication of winged beans.

# Effect of Cultural Practices on the Yield of Seed and Tubers in Winged Beans

*H.M.W. Herath* and *G.C.J. Fernandez*[1]

**The effects of cultural practices on the yield of seed and tubers in four local selections of winged bean (*Psophocarpus tetragonolobus* (L) DC) were studied in Sri Lanka. Removal of flowers increased vegetative growth and flower production while vegetative pruning reduced the rate of growth and the flower production. Tuber yield increased significantly upon the removal of flowers. On the other hand vegetative pruning reduced tuber production. Staking did not have a significant effect on tuber yield and mature pod production, although the peak time of this production was advanced by one month in staked plants. Of the four selections tested $V_3$ and $V_4$ recovered faster after vegetative pruning being more vigorous in growth and drought tolerant. $V_1$ yielded more tubers with flower removal than the other three selections. $V_3$ yielded more seeds and it was considered as a dual purpose type since it produced both seeds and tubers more than the estimated yields of Papua New Guinea selections. $V_4$ recorded higher seed yield than $V_1$. Low seed and tuber yield was recorded in $V_2$. The genetic variability among these selections could be usefully employed for plant improvement in Sri Lanka.**

## INTRODUCTION

The distribution of winged bean in Sri Lanka is mainly confined to the wet and the intermediate agroclimatic zones. Preliminary studies indicate the availability of several selections which are morphologically (Herath *et al.*, 1977) and physiologically different (Herath and Ormrod, unpublished).

The winged bean is commonly trained on to supports such as stakes, trellises and fences. Green pods are used as fresh vegetable. In certain areas the leaves are also used as vegetable. But no attempt has been made to utilize the tubers or to determine the potential for tuber production among the local selections. Hitherto no effect has been made in Sri Lanka to select high yielding varieties and to increase yields by adopting various cultural practices.

The objective of this investigation is to compare the effect of various cultural practices on the growth and yield characteristics of four local selections.

## MATERIALS AND METHODS

This experiment was carried out at the University Farm, Peradeniya from September 1976 to May 1977. The soil was sandy loam, low in available nitrogen and moderate in available phosphate. The pH was 6.1 (Singh and Gunasena, 1975).

The experimental design was split plot with three replicates. Each block was divided into five main plots. A plot measured 126 sq.m. Five main treatments were randomly distributed in each of the main plots. These five main treatments were:

$T_1$ — Vegetative and reproductive pruning (removal of vegetative shoots, flowers and tender pods)

$T_2$ — Vegetative pruning only

$T_3$ — Reproductive pruning only

$T_4$ — No vegetative and no reproductive pruning

$T_5$ — Plants not staked, no vegetative and no reproductive pruning

A main plot was divided into 4 sub-plots, each measuring 27 sq. m. Four winged bean selections collected from different parts of Sri Lanka were grown at random in the four plots. The four selections of winged bean used were:

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$V_1$ — Puttalam — (Acc No. 1)
$V_2$ — Warakapola — (Acc No. 6)
$V_3$ — Colombo — (Acc No. 7)
$V_4$ — Karaliyadde — (Acc No. 8)

Plants in the sub-plots were grown in five rows spaced 92 cm apart and 61 cm within rows. Two seeds were planted per hill and after germination, one seedling was allowed to grow. Plants in treatments 1, 2, 3 and 4 were supported by 2 m high bamboo stakes with 10 to 15 cm long side stumps. In treatment 5, the plants were allowed to ramble over the ground and form a vegetative cover. A mixture of 66 kg urea (46% N), 125 kg super phosphate (42% $P_2O_5$) and 66 kg muriate of potash (60% $K_2O$) per hectare were applied at the final stage of land preparation. During the first three months of growth the plants were maintained free of weeds. They were rainfed and no irrigation was provided.

In treatments 1 and 3, all the flowers and tender pods were plucked at weekly intervals. The number of flowers and pods per plant and the fresh and dry weights were recorded.

In treatments 1 and 2, the height of the plants was controlled by pruning at a height of 1.25 m from the ground once every two weeks. The mean fresh and dry weight of the pruned plant parts per plant in each sub-plot were recorded separately.

In $T_2$, $T_4$, and $T_5$, pods were allowed to mature. These pods were harvested from each sub-plot. The number of dry pods, and number and weight of seeds per plant were recorded.

From each sub plot, three randomly selected plants from the three inner rows were uprooted at 5, 7, and 9 month intervals respectively after planting. The fresh and dry weight of shoots were recorded. The number of fresh and dry weight of tubers of the three uprooted plants were also recorded.

## RESULTS

### Reproductive Pruning

Three to five months (November 1976 — January 1977) after planting, the production of flowers and tender pods was high in treatments 1 and 3. However, in treatment 1 (Fig. 1b), flower production declined steadily after 6 months (February 1977). In treatment 3, flower production increased again after 7 months (March 1977, Fig. 1a).

Total production of flowers and pods was significantly lower in treatment 1 than in treatment 3 (Table 1). No significant differences were observed among the four local selections in the total number of flowers and tender pods produced per plant. In selection $V_1$ flower production was low when the plants were vegetatively pruned as in treatment 1 (Table 1). Generally, $V_3$ produced the largest number of flowers and tender pods compared to the other selections.

**Table 1.** Number of flowers and tender pods per plant plucked during 9 months (mean of 30 plants).[a]

| Main treatment (cultivation practices) | Sub-treatments (local selections of winged bean) | | | | Main treatment mean* |
|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | L S D (p = 0.05) = 1.64 |
| $T_1$ — Vegetative and reproductive pruning in staked plants | 13.46 (181.17) | 17.08 (291.72) | 16.11 (259.53) | 15.21 (231.34) | 15.47 (239.32) |
| $T_3$ — Reproductive pruning only in staked plants | 19.98 (399.20) | 17.60 (309.76) | 21.16 (447.74) | 19.19 (368.25) | 19.48 (379.47) |
| Sub T mean (L S D, p = 0.05) = 1.37 | 16.72 (279.55) | 17.34 (300.67) | 18.64 (347.44) | 17.20 (295.84) | |

[a]Figures in parentheses indicate back transformed numbers +
* Significant at 5% level.
+ Analyses done × $\sqrt{N}$ transformed data.

Significant difference was observed in the fresh weight of flowers per plant (Sub-treatment mean) in $V_3$ over the other three selections (Table 2).

**Table 2. Fresh weight (gm) of flowers and tender pods per plant plucked during 9 months (means of 30 plants).**

| Main treatments (cultivation practices) | Sub-treatments (local selections of winged bean) | | | | Main treatment mean * |
|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | L.S.D. (p = 0.05) = 28.18 |
| $T_1$ — Vegetative and reproductive pruning in staked plants | 119.37 | 181.43 | 161.19 | 150.60 | 153.13 |
| $T_3$ — Reproductive pruning only in staked plants | 263.81 | 192.77 | 302.19 | 222.18 | 245.14 |
| Sub T mean (L.S.D. p = 0.05) = 35.19 | 191.57 | 187.08 | 231.69 | 186.39 | |

*Significant at 5% level

## Vegetative Pruning

In treatments 1 and 2, the dry weight of pruned shoots per plant was recorded once in two weeks. Three to four months after planting, the growth of the plant was at its peak and the dry weight of pruned vines was the highest in both treatments (Fig. 2 a,b). The dry weight of the plant was lowest during the 6th and 7th month was slightly increasing during the 8th and 9th month in all the selections. This fluctuation could be attributed to the rainfall pattern (Table 8). In treatments 1 and 2, selections $V_3$ and $V_4$ recovered quickly after pruning and the amount of pruned vine was high when compared with $V_1$ and $V_2$. Selections $V_3$ and $V_4$ were also superior to $V_1$ and $V_2$ in the total amount of vine pruned per plant (Table 3). The dry weight of pruned vine was significantly higher in $T_1$, where reproductive pruning was done, than in $T_2$, where no reproductive pruning was done (Table 3).

**Table 3. Dry weight (gm) of vines per plant pruned during 9 months (mean of 30 plants).**

| Main treatment (cultivation practices) | Sub-treatments (local selections of winged bean) | | | | Main treatment mean* |
|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | L.S.D. (p = 0.05) = 2.05 |
| $T_1$ — Vegetative and reproductive pruning in staked plants | 11.20 | 11.54 | 16.26 | 15.24 | 13.54 |
| $T_2$ — Vegetative pruning only in staked plants | 6.93 | 8.63 | 10.85 | 9.75 | 9.04 |
| Sub treatment (mean)* L.S.D. (p = 0.05) = 2.42 | 9.02 | 10.06 | 13.56 | 12.50 | |

*Significant at 5% level.

## Dry Pod Yields

Dry pods were harvested four months after planting in treatments 2, 4 and 5 where reproductive pruning was not carried out.

Dry pod yield was high up to the 7th month and decreased during the last two months (Fig. 3 a,b,c). Production of dry pods per plant was highest in February in treatment 5 and in January in treatment 4. Dry pod production was uniformly spread during the first three months of harvest (January-March) in treatment 2 (Fig. 3 b).

In treatments 2 and 5, $V_3$ yielded more dry pods at the 6th and 7th month harvest. The dry pod yield in treatment 4 was high in $V_4$ between the 5th and 7th month harvest. $V_2$ yielded the lowest number of dry pods in staked plants while $V_1$ yielded the lowest number of dry pods in unstaked plants.

There was no significant difference at 5% level in the mean number of dry pods harvested per plant in all three main treatments.

Significant differences were observed in the mean of sub-treatments (Table 4). Mean total dry pod yield was higher in $V_3$ and $V_4$ and $V_3$ and $V_2$ in the total harvest.

**Table 4. Number of dry pods harvested per plant during 9 months (mean of 30 plants)[a]**

| Main treatment (cultivation practices) | Sub-treatments (local selections of winged bean) | | | | Main treatment mean |
|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | L.S.D (p = 0.05) = 0.49 |
| $T_2$ — Vegetative pruning only in staked plants | 5.36 (28.72) | 5.29 (27.98) | 5.86 (34.33) | 5.61 (31.47) | 5.53 (30.58) |
| $T_4$ — No vegetative and no reproductive pruning in staked plants | 5.58 (31.13) | 5.21 (27.14) | 5.80 (33.64) | 6.26 (39.18) | 5.71 (32.60) |
| $T_5$ — No vegetative and no reproductive pruning in unstaked plants | 5.09 (25.90) | 5.94 (35.28) | 6.91 (47.74) | 6.31 (39.81) | 6.06 (37.72) |
| Sub-treatment (mean)* L.S.D (p = 0.05) = 0.43 | 5.34 (28.51) | 5.48 (30.03) | 6.18 (38.19) | 6.06 (36.72) | |

[a] Back transformed number in parentheses
* Significant at 5% level.
+ Analyses done $\sqrt{N}$ transformed data.

## Seed Yield

Seed yield was recorded as weight of seeds harvested per plant. There were no significant differences among the three main treatment mean (Table 5).

The seed yield of selection $V_3$ was significantly higher than the other three selections. $V_2$ recorded the lowest seed yield.

The mean 100 yield of selections were: $V_1$ = 37.24g, $V_2$ = 24.40g, $V_3$ = 38.39g, and $V_4$ = 32.26g.

The mean seed yield of selection $V_3$ was 150.26 g/plant (Table 5), which is equal to 2678 kg/ha when planted at a spacing of 0.92 m x 0.61 m.

**Table 5. Weight (g) of seeds per plant harvested during 9 months (mean of 30 plants).**

| Main treatment (cultivation practices) | Sub-treatments (local selections of winged bean) | | | | Main treatment mean |
|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | L.S.D. (p = 0.05) = 16.43 |
| $T_2$ — Vegetative pruning only in staked plants | 101.31 | 63.55 | 133.12 | 107.05 | 101.26 |
| $T_4$ — No vegetative and no reproductive pruning in staked plants | 117.79 | 64.93 | 128.05 | 125.00 | 108.84 |
| $T_5$ — No vegetative and no reproductive pruning in unstaked plants | 97.67 | 87.66 | 189.61 | 127.32 | 124.32 |
| Sub treatments* L.S.D (p = 0.05) = 14.22 | 105.42 | 70.94 | 150.26 | 119.79 | |

*Significant at 5% level.

## Tuber Yield

1. **Main treatment effects.** When the plants were allowed to set seeds in treatments 2,4 and 5, the tuber yield was lower than treatments 1 and 2 where all the flowers and tender pods were removed (Table 6 a,b,c). Significant differences were not observed in the mean dry weight of tuber per plant among the main treatments 2,4 and 5.

**Table 6a.** Dry weight (g) of tubers plants, uprooted at 5th month after planting (mean of 9 plants).

| Main treatment (cultivation practices) | Sub-treatments (selections) | | | | Main treatment mean* |
|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | L.S.D (p = 0.05) = 1.79 |
| $T_1$ – Vegetative and reproductive pruning in staked plants | 25.24 | 7.32 | 15.96 | 15.52 | 16.01 |
| $T_2$ – Vegetative pruning only in staked plants | 5.37 | 2.86 | 9.12 | 6.05 | 5.85 |
| $T_3$ – Reproductive pruning only in staked plants | 6.73 | 2.91 | 10.72 | 4.45 | 6.20 |
| $T_4$ – No vegetative and no reproductive pruning in staked plants | 34.61 | 3.96 | 26.74 | 9.35 | 18.66 |
| $T_5$ – No vegetative and no reproductive pruning in unstaked plants | 7.76 | 3.18 | 10.85 | 7.97 | 7.44 |
| Sub-treatment mean* L.S.D (p = 0.05) = 3.61 | 15.63 | 4.02 | 14.68 | 8.57 | |

* Significant at 5% level.

**Table 6b.** Dry weight (g) of tubers per plant, uprooted at 7th month after planting (Mean of 9 plants).

| Main treatment (cultivation practices) | Sub-treatments (local selections) | | | | Main treatment mean* |
|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | L.S.D. (p = 0.05) = 5.98 |
| $T_1$ – Vegetative and reproductive pruning in staked plants | 24.51 | 9.46 | 19.58 | 17.36 | 17.72 |
| $T_2$ – Vegetative pruning only in staked plants | 6.08 | 2.75 | 7.82 | 5.64 | 5.57 |
| $T_3$ – Reproductive pruning only in staked plants | 38.64 | 4.51 | 24.67 | 11.06 | 19.72 |
| $T_4$ – No vegetative and no reproductive pruning in staked plants | 8.74 | 2.96 | 8.93 | 5.47 | 6.55 |
| $T_5$ – No vegetative and no reproductive pruning in unstaked plants | 8.45 | 3.13 | 10.87 | 7.94 | 7.59 |
| Sub-treatment mean* L.S.D (p = 0.05) = 5.21 | 17.23 | 4.63 | 14.79 | 9.56 | |

* Significant at 5% level

**Table 6c. Dry weight(g) of tubers per plant uprooted at 9th month after planting (mean of 9 plants).**

| Main treatment (cultivation practices) | Sub-treatments (local selection) | | | | Main treatment mean* |
|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | L.S.D ($p = 0.05$) = 7.32 |
| $T_1$ — Vegetative and reproductive pruning in staked plants | 25.68 | 9.37 | 22.87 | 19.76 | 19.42 |
| $T_2$ — Vegetative pruning only in staked plants | 6.14 | 2.36 | 6.17 | 3.78 | 4.61 |
| $T_3$ — Reproductive pruning only in staked plants | 62.24 | 7.71 | 27.64 | 17.47 | 28.78 |
| $T_4$ — No vegetative and no reproductive pruning in staked plants | 6.76 | 2.98 | 10.73 | 4.48 | 6.24 |
| $T_5$ — No vegetative and no reproductive pruning in unstaked plants | 9.46 | 4.25 | 12.47 | 8.18 | 8.59 |
| Sub-treatment mean* L.S.D ($p = 0.05$) = 6.17 | 22.25 | 5.33 | 15.97 | 10.79 | |

*Significant at 5% level

In treatments where reproductive pruning was done in staked plants, the mean dry weight of tubers per plant was significantly higher than $T_4$ where reproductive pruning was not done. Even though the plants were vegetatively pruned under treatments 1 and 2 tuber yield was high in treatment 1 where all the flower and tender pods were removed. Mean dry weight of tubers per plant was higher in treatment 3 than in treatment 1. Significant differences were observed among these two main treatments in the harvests made at the 5th and 9th month intervals after planting. At the 7th month after planting, no significant differences were noted between these two treatments.

2. **Sub-treatments effects.** There was a significant difference between selections in tuber yield at three stages of harvest (Table 6 a, b, c). Selection $V_3$ produced the lowest tuber yield under the five main treatments at all three stages of harvest. The mean dry weight of tubers per plant was significantly higher in $V_1$ and $V_3$ than $V_2$ and $V_4$. However, at 5 months after planting, $V_2$ and $V_4$ also had significant differences in the mean dry weight of tubers per plant. There was no significant difference in the mean dry weight of tubers per plant among $V_1$ and $V_3$ at any of the intervals of harvesting. Selections $V_2$ and $V_4$ were most affected by vegetative pruning ($T_2$). Selection $V_3$ produced higher tuber yield than $V_1$ when reproductive pruning was not carried out in $T_2$, $T_4$ and $T_5$. But $V_1$ yielded more than $V_3$ when reproductive pruning was carried out ($T_1$ and $T_3$).

   In treatments 1, 3 and 5, the mean dry weight of tubers per plant slightly increased from the 5th to the 7th month and the 9th month after planting (Table 6 a, b, c). In treatment 4 the mean dry weight of tubers slightly increased from the 5th month to the 7th month and declined at the 9th month after planting.

**Dry Weight of Shoots**

The mean dry weight of shoots per plant was recorded at the time of uprooting in the five main treatments. These main treatments had significant differences on dry matter in shoots at all three stages of harvesting (Table 7 a, b, c).

Dry matter in shoots was very high in treatment 3. A comparison in dry matter in shoots between treatments 3 and 4, showed that reproductive pruning increased vegetative growth thereby resulting in higher tuber yields. Even though the plants in treatments 1 and 2 were vegetatively pruned, dry matter was much

**Table 7a. Dry weight (g) of shoots per plant uprooted at 5th month after planting (mean of 9 months).**

| Main treatment (cultivation practices) | Sub-treatments (local selections) | | | | Main treatment mean* |
|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | L.S.D. (p = 0.05) = 4.85 |
| $T_1$ — Vegetative and reproductive pruning in staked plants | 45.83 | 81.93 | 61.43 | 74.44 | 63.47 |
| $T_2$ — Vegetative pruning only in staked plants | 18.90 | 27.37 | 29.47 | 33.57 | 27.32 |
| $T_3$ — Reproductive pruning only in staked plants | 56.75 | 82.84 | 87.64 | 120.30 | 86.88 |
| $T_4$ — No vegetative and no reproductive pruning in staked plants | 55.64 | 57.40 | 83.03 | 61.10 | 64.24 |
| $T_5$ — No vegetative and no reproductive pruning in unstaked plants | 12.13 | 34.87 | 23.02 | 30.79 | 25.20 |
| Sub treatment mean* L.S.D. (p = 0.05) = 12.42 | 37.83 | 58.15 | 54.96 | 63.03 | |

*Significant at 5% level.

**Table 7b. Dry weight(g) of shoots/plant uprooted at 7th month after planting (mean of 9 plants).**

| Main treatment (cultivation practices) | Sub-treatments (local selections) | | | | Main treatment mean* |
|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | L.S.D. (p = 0.05) = 14.42 |
| $T_1$ — Vegetative and reproductive pruning in staked plants | 13.70 | 29.84 | 15.33 | 26.52 | 21.33 |
| $T_2$ — Vegetative pruning only in staked plants | 2.15 | 6.84 | 3.94 | 5.86 | 4.68 |
| $T_3$ — Reproductive pruning only in staked plants | 24.44 | 46.32 | 21.24 | 55.14 | 36.74 |
| $T_4$ — No vegetative and no reproductive pruning in staked plants | 6.63 | 18.62 | 8.43 | 17.55 | 12.78 |
| $T_5$ — No vegetative and no reproductive pruning in unstaked plants | 1.74 | 4.27 | 2.50 | 11.78 | 5.06 |
| Sub treatment mean* L.S.D. (p = 0.05) = 14.31 | 9.51 | 21.25 | 10.28 | 18.12 | |

*Significant at 5% level.

higher in treatment 1 where all the flowers and tender pods were removed. Dry matter in shoots of unstaked plants was low in treatment 5. Plants in treatment 2 which were pruned vegetatively had lower dry matter in shoots than unpruned plants in treatment 4.

The difference in dry matter among the four selections was significant only at the 5th month after planting (Table 7 a, b, c). $V_1$ recorded the lowest dry matter in all five main treatments.

**Table 7c. Dry weight (g) of shoots per plant uprooted at 9th month after planting (mean of 9 plants).**

| Main treatment (cultivation practices) | Sub-treatments (local selections) | | | | Main treatments mean |
|---|---|---|---|---|---|
| | $V_1$ | $V_2$ | $V_3$ | $V_4$ | L.S.D. (p=0.05)=18.34 |
| $T_1$ — Vegetative and reproductive pruning in staked plants | 7.67 | 20.53 | 14.94 | 32.24 | 18.84 |
| $T_2$ — Vegetative pruning only in staked plants | 4.93 | 8.24 | 4.54 | 7.32 | 6.26 |
| $T_3$ — Reproductive pruning only in staked plants | 25.37 | 51.82 | 51.63 | 56.25 | 46.26 |
| $T_4$ — No vegetative and no reproductive pruning in staked plants | 17.62 | 23.97 | 19.73 | 21.62 | 20.73 |
| $T_5$ — No vegetative and no reproductive pruning in unstaked plants | 3.38 | 4.15 | 2.37 | 4.67 | 3.64 |
| Sub-treatment mean L.S.D. (p=0.05)=15.32 | 11.79 | 21.74 | 18.64 | 24.42 | |

*Significant at 5% level.

Dry matter in shoots increased during the first five months of growth and decreased after that. This decrease could be attributed partly to the severe drought conditions that prevailed during the month of January to March 1977.

## DISCUSSION

The winged bean has an indeterminate growth habit (Khan 1974) and an extended period of flowering. However, the period of flowering is further extended when flowers and pods are removed at weekly intervals. Salisbury and Ross (1969) suggested that a flowering hormone "florigen" which is synthesized in the leaves of plants is necessary for flower induction. Thus, the increased vegetative growth and flower production upon the removal of flowers may be attributed to a continued hormone production. It is also possible that such increase may be due to the low mobilization of nutrients. Both these factors might have been operative either independently or dependently. In treatments 1 and 2, vegetative pruning reduced the capacity of flowering probably due to the reduction in the number of flowering nodes and also the low levels of synthesis of the flowering hormone. Vegetative pruning seemed to reduce the rate of growth and the recovery of the four selections. This effect was more evident in selection $V_1$ and least evident in selection $V_3$.

The tuber production of the four selections was also affected by reproductive pruning. Similar to the total flower production, this treatment increased the yield of tubers in all four selections. This increase was four-fold over the control wherein the flowers were not removed. Watson and Petrie (1940) showed that nutrient accumulation in the roots of the tobacco plant increased when the flowers were topped. Thus, the general increase in the tuber production may be attributed to the greater translocation and accumulation of photosynthates in the roots, in the absence of sink effect in the pods. Vegetative pruning reduced the yield of tubers since the source of carbohydrate synthesis was removed. It was also found that staking did not have any effect on tuber yields.

Increased yields of pods were obtained by staking the winged bean in Nigeria (Rachie, 1974). However, when Sri Lankan selections were grown with stakes and without stakes, it was observed that the total mature pod yield was not significantly different, although there was a difference in the peak time of production bet-

ween staked and unstaked plants. The peak production occurred in staked plants during January, the 5th month after planting and in unstaked plants in February, the 6th month after planting. Haupt (quoted by Leopold, 1964) showed that when *Pisum sativum* plants were exposed to high light intensity, flower production was advanced. Thus, one could assume that since the staked plants were more exposed to light, the reproductive phase may have been advanced. However, further studies on light intensities and staking are necessary to support this assumption. A peak period of pod production was not evident in vegetatively pruned plants which were maintained at a height of 1.5 m. However, the level of pod production was uniform for three months from January to March.

Similar to findings of Rachie(1974), the yield of mature pods in selection $V_1$ was low in unstaked plants. The other three selections yielded more pods when unstaked. This variability could be attributed to the differences in the growth habit of the selections.

In Sri Lanka, the winged bean is generally grown in areas with sufficient rainfall during the growing season. In other countries, it is cultivated under irrigation (National Academy of Sciences.1975). It was observed that when there was adequate moisture in the soil, the dry weight of pruned vines was greater. The low production during dry season could be attributed to this seasonal effect.

Of the four selections tested in this investigation, $V_3$ and $V_4$ were able to recover much faster after pruning than the other two selections during both seasons. This indicates that they were more vigorous in growth and were drought tolerant. $V_1$ and $V_3$ yielded more tubers than the other two selections with flower removal. The former had higher yields than the latter. When pods were allowed to mature, $V_3$ yielded the highest amount of tubers.

It was also found that selection $V_3$ was a particularly dual purpose type since it produced both seeds and tubers more than the estimated yields of Papua New Guinea selections. It has a potential seed production of 2678 kg/ha and tuber production of 535 kg/ha in comparison to the yield of Papua New Guinea selections which are 1,946 kg/ha and 450 kg/ha,respectively, (Khan, 1974). The weight of seed was also highest in selection $V_3$, indicating that the largest seeds were produced by this selection. Selection $V_1$ and $V_4$ behaved differently in tuber and seed production. The former produced higher tuber yields while the latter produced higher seed yields. Selection $V_2$, on the other hand, produced the lowest tuber and seed yields. The genetic variability among the selections studied could be useful in the improvement of the winged bean in Sri Lanka.

**Table 8. Rainfall data from July 1976 to May 1977 at Peradeniya. (Meteorological observations at Gannoruwa).**

| Months | July | August | September | October | November | December | January | February | March | April | May |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total R.F. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

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APPENDIX I: Fig. 1—3

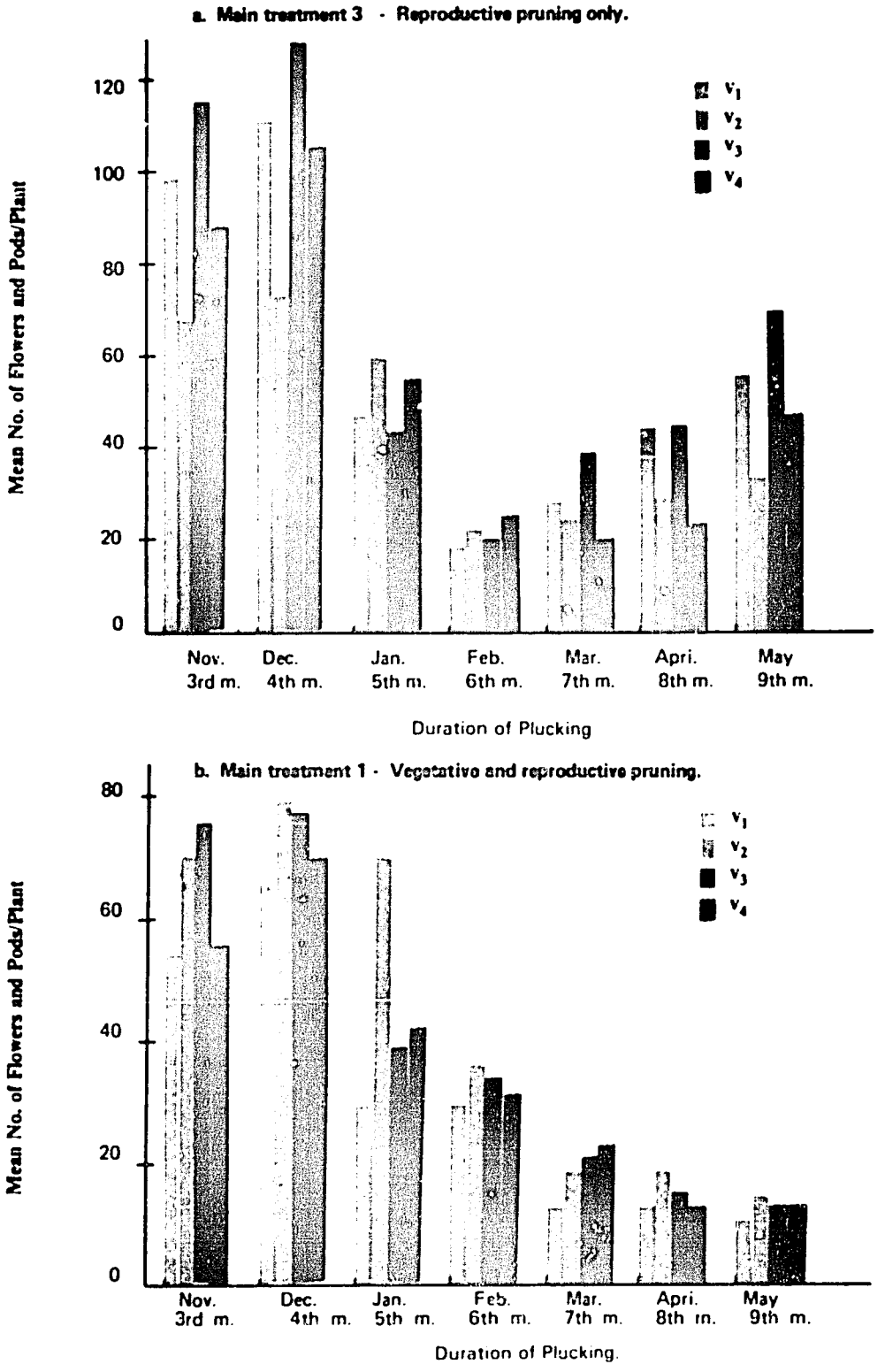
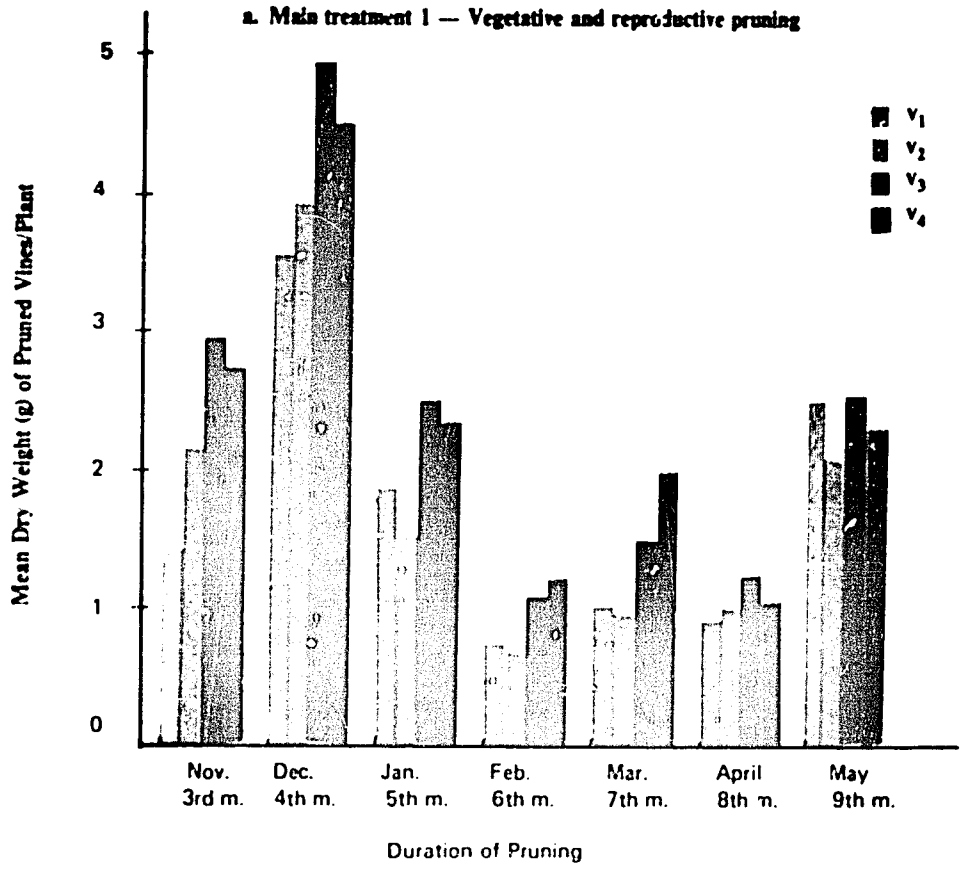



**Fig. 1a, b. Mean number of flowers and tender pods per plant during 9 months.**



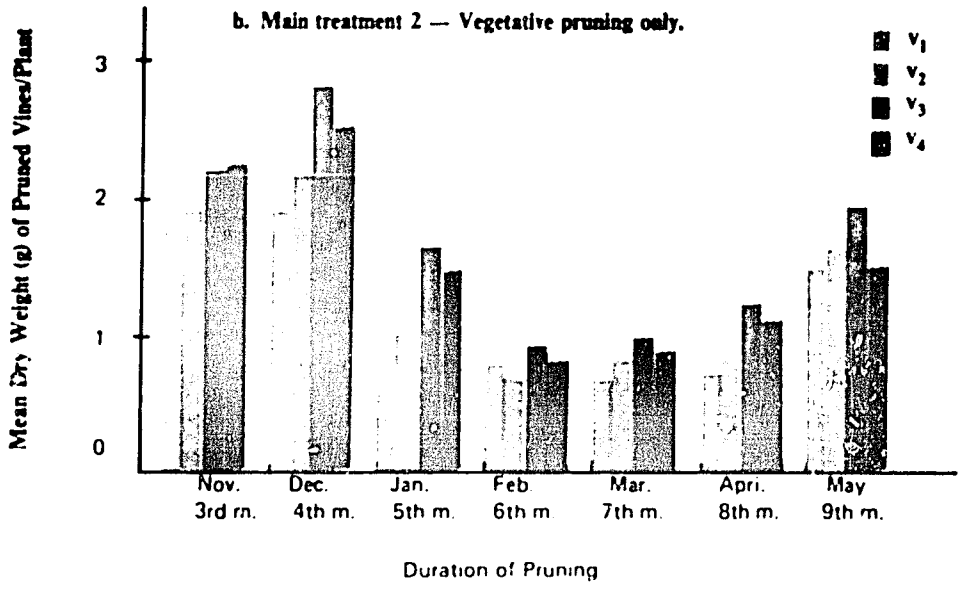




**Fig. 2a, b. Mean dry weight (g) of pruned vines per plant during 9 months.**

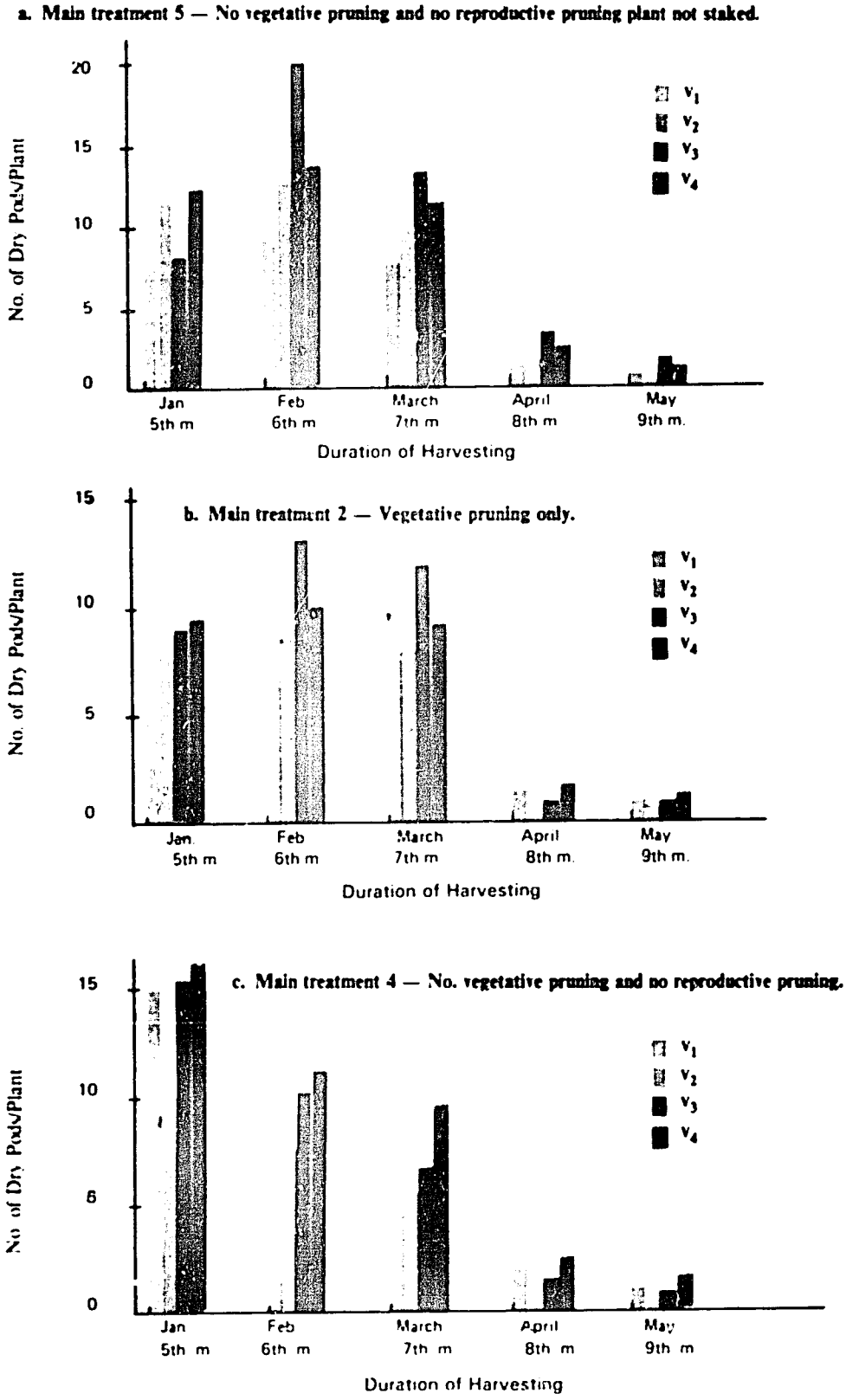



**Fig. 3a, b, c. Mean number of dry pods harvested per plant during 9 months.**

# An Examination on the Growth of Winged Bean During the Wet Season at Kununurra

*G. A. Robertson, J. Warren*[1] and *T. N. Khan*[2]

Winged bean *(Psophocarpus tetragonolobus)* was grown during the wet season in 1976 to 1977 as three series of observation plots under irrigation. The general aim was to examine the potential of the winged bean as a cover crop during the wet season, providing additional nitrogen for the dry season irrigated crops.

## CLIMATE

The Ord area has a normal southern tropical climate except that the average annual rainfall of 740 mm is lower and the temperature is higher than most monsoonal areas. Table 1 gives monthly temperatures in terms of average daily maxima, average daily minima, average monthly rainfall, relative humidity and evaporation for the period of the experiments.

## SOILS

The soils in the irrigation area were derived from alluvial materials deposited by the Ord and Keep Rivers. Winged bean was planted on Kununurra clay which makes up the bulk of the irrigable soils. It is a tough highly alkaline clay soil which cracks into large irregular blocks on drying: the cracks are up to 25 mm wide and can penetrate 60-100 cm into the soil. When wet, the surface clay swells, the cracks close and the soil becomes very sticky and highly impervious to water.

## EXPERIMENT 1: AN EVALUATION OF 6 VARIETIES OF WINGED BEAN FROM NEW GUINEA

The following varieties were evaluated: UPS 62, UPS 45, UPS 99, UPS 102, UPS 121 and UPS 61. These varieties were manually planted into plots four rows wide and 30 m in length. The soil was ridged and furrowed on a row spacing of 91 cm. Treflan (trifluralin) was incorporated for weed control at 3 litres/ha prior to seeding. The plant stand aimed was 75,000 plants per hectare. Seeding depth was 5 cm and the plants were watered on December 15, 1976. The plants were grown without trellising and allowed to trail over the area of the plots. (3.64 m x 10 m). Irrigation was forthnightly until the 'wet' started and again fortnightly from April 11, 1977.

**Table 1. Average temperature, rainfall, evaporation, and relative humidity in Ord from 1976 to 1977.**

| | 1976 | 1977 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG |
| Av. max. °C | 38.1 | 36.6 | 35.3 | 33.9 | 33.9 | 32.2 | 28.5 | 28.7 | 32.7 |
| Av. min °C | 25.0 | 25.3 | 24.9 | 24.5 | 21.8 | 17.7 | 13.5 | 13.0 | 13.7 |
| Total rainfall (mm) | 92.5 | 145.4 | 163.8 | 153.8 | 18.7 | — | — | — | — |
| Mean daily evaporation (mm) | 9.3 | 8.3 | 6.9 | 5.3 | 7.3 | 6.5 | 6.6 | 7.0 | 7.6 |
| Av. relative humidity 0900% | 54.0 | 65.0 | 69.0 | 72.0 | 44.0 | 42.0 | 30.0 | 26.0 | 30.0 |

[1]Department of Agriculture, Kununurra, Western Australia.
[2]Department of Agriculture, Perth, Western Australia.

**Table 2. Kununurra annual average climatic statistics.**

| | |
|---|---|
| Mean max °C | 35.00 |
| Mean min. °C | 20.61 |
| Relative humidity (9.00 am) | 44.00 |
| Rainfall | 740.70 |
| Evaporation (mm) | 2,592.60 |

## Plant Establishment

Establishment was between 40% to 50% on all plots by January 6, 1977. Gaps were filled in by replanting on January 7, to 10, 1977. Overall plant population was in the order of 60,000 per hectare by January 17, 1977. The low initial establishment was probably related to the high soil temperatures and the rapid crusting of the soil surface. Trifluralin provided good weed control and did not appear to have any deleterious effect on seeds that germinated.

## Vegetative Growth

Initial vegetative growth was satisfactory until the rainy season commenced on February 6, 1977. From there on until the middle of April (the end of the wet) growth was obviously affected by the waterlogged conditions of the soil. Many plants died during this period resulting in a reduction in the area of ground covered from March 21, 1977 to April 7, 1977 in some varieties (Table 3). There were significant differences between the ability of the different varieties to withstand waterlogging, UPS 99 being relatively unaffected by waterlogging conditions and it continued to grow well, while UPS 62 was very susceptible to waterelogging.

**Table 3. Estimated % soil surface covered by vegetative material.**

| Variety | % Soil Surface Covered | |
|---|---|---|
| | 21.3.77 | 7.4.77 |
| UPS 62 | 45 | 15 |
| UPS 121 | 75 | 65 |
| UPS 45 | 70 | 85 |
| UPS 61 | 70 | 75 |
| UPS 99 | 85 | 95 |
| UPS 102 | 85 | 75 |

## Flowering

There was very little difference between the dates of appearance of first flowers in the six varieties (Table 4). Some grasshoppers damage to early buds could have extended the time to first flower.

**Table 4. Number of days for the appearance of first flowers in different varieties.**

| Variety | Days of appearance of first flower |
|---|---|
| UPS 62 | 82 |
| UPS 121 | 89 |
| UPS 45 | 77 |
| UPS 61 | 85 |
| UPS 99 | 77 |
| UPS 102 | 89 |

**Pod Set**

The degree of pod setting was rated (maximum of 5) on two dates, 21st March and 31st March. There was a large difference between varieties (Table 5) which suggested that in particular, UPS 45 was able to produce more seeds under the prevailing conditions.

**Table 5. Degree of pod setting in different varieties.**

| Variety | Pod Set Rating 21/3 | 7/4 | Date of 1st pod reaching maturity |
|---|---|---|---|
| UPS 62 | 2 | 3 | 20/4 |
| UPS 121 | 0 | 1 | 23/4 |
| UPS 45 | 3 | 5 | 20/4 |
| UPS 61 | 0 | 2 | 20/4 |
| UPS 99 | 3 | 3 | 20/4 |
| UPS 102 | 0 | 2 | 28/4 |

**Insect Damage**

There was little insect damage before flowering with the exception of minor leaf damage caused by grasshoppers. Grasshoppers did cause some damage by eating flowers and chewing through stems adjacent to pods. Aphid infestation was high at times as were numbers of the green vegetable bug *(Nezara viridula)*. Damage by these insects however did not appear to be important.

**Harvest**

Quadrats one meter square were pegged in each plot and yields were determined by picking pods as soon as they matured (Table 6). Pod shattering was a serious problem if the plots were not examined daily. This problem would have been accentuated by the low humidity from April and by the large diurnal range in temperatures.

An attempt was made to harvest the plots using a mechanical harvester. While the plots were still green and actively growing and fruiting, it was necessary to dessicate the crop before attempting to harvest. On July 7, 1977, all plots were sprayed with diquat (Reglone*) at 250 ml. A.I. per 100 liters of water. The plants dried off quickly and seed shattering became a serious problem. On November 7, 1977, the plots were harvested using a self-propelled harvester with a 1.5 m cut. Machine harvested yields are shown in Table 6.

Losses due to mechanization were considerable. Most of these losses however were the result of the shattering, not inefficiencies during actual harvesting. Seed yield of hand-picked quadrats were substantial with UPS 45 producing 3.62 ton/ha (Table 6).

Tuber production in these lines was minimal under these conditions. The plants all appeared to produce nodules well with the native rhizobial strains.

**Table 6. Yields of clean seed (ton/ha).**

| Variety | Quadrat (hand picked) | Machine harvested |
|---|---|---|
| UPS 62 | 1.87 | 0.05 |
| UPS 121 | 3.11 | 0.20 |
| UPS 45 | 3.62 | 0.46 |
| UPS 61 | 1.61 | 0.31 |
| UPS 99 | 2.23 | 0.39 |
| UPS 102 | 2.69 | 0.61 |

*Trademark.

## EXPERIMENT 2: AN EVALUATION OF A COLLECTION OF WINGED BEAN FROM PAPUA NEW GUINEA

A collection of 107 varieties from the University of Papua New Guinea were planted on December 15, 1976. Three seeds of each variety were planted on a meter of ridge with a meter buffer between each variety. When the plants were well established, they were thinned to one plant per variety.

### Plant Establishment

The viability of some seeds was low, and by January 6, 1977 many of the varieties still had not germinated. A second planting was made on January 10, 1977. The varieties that did not germinate after the second planting were: UPS 2, UPS 21, UPS 69, and UPS 70.

No further plantings of these varieties were done. All other varieties had at least one established plant.

By March 22, 1977 the following varieties did not survive: UPS 15, UPS 22, UPS 40, UPS 55, UPS 62, UPS 71, UPS 96, UPS 109, and UPS 59.

UPS 90 died by April 7. When the final harvest took place on July 7, 1977 the following varieties had also died: UPS 13, UPS 16, UPS 26, UPS 46, UPS 65, UPS 67, UPS 88, UPS 91, UPS 98, UPS 112, and UPS 113.

The main cause of death of the plants was apparently related to the waterlogged conditions in the heavy soil during the late wet season.

### Vegetative Growth

All varieties were rated maximum of 5 for vegetative growth on March 22 to July 7, 1977 (Table 7). Factors regulating vegetative growth were tolerance to climate, waterlogging, and tolerance to insect damage.

**Table 7. Vegetative growth and pod set rating for the world collection of winged bean (rating out of 5):**

| Variety | Vegetative Growth | | Pod Set |
|---|---|---|---|
| | 22.03.77 | 07.04.77 | 07.04.77 |
| UPS 2 | — | — | — |
| UPS 4 | 5 | 4 | 5 |
| UPS 5 | 4 | 5 | 5 |
| UPS 6 | 3 | 4 | 3 |
| UPS 7 | 3 | 3 | 3 |
| UPS 8 | 3 | 4 | 3 |
| UPS 9 | 4 | 4 | 4 |
| UPS 10 | 5 | 5 | 5 |
| UPS 11 | 2 | 1 | 1 |
| UPS 12 | 3 | 3 | 2 |
| UPS 13 | 3 | — | — |
| UPS 14 | 4 | 5 | 3 |
| UPS 15 | — | — | — |
| UPS 16 | 3 | — | — |
| UPS 17 | 4 | 3 | 3 |
| UPS 18 | 3 | 1 | 1 |
| UPS 19 | 5 | 5 | 5 |
| UPS 20 | 3 | 2 | 2 |
| UPS 21 | — | — | — |
| UPS 22 | — | — | — |
| UPS 47 | 3 | 3 | 2 |
| UPS 48 | 4 | 2 | 2 |
| UPS 49 | 3 | 3 | 3 |
| UPS 50 | 4 | 1 | 1 |
| UPS 51 | 3 | 2 | 3 |
| UPS 52 | 3 | 1 | 2 |
| UPS 53 | 3 | 1 | 1 |
| UPS 54 | 2 | 3 | 3 |

**Table 7.** *continued . .*

| Variety | Vegetative Growth | | Pod Set |
|---|---|---|---|
| | 22.03.77 | 07.04.77 | 07.04.77 |
| UPS 56 | 5 | 2 | 3 |
| UPS 57 | 3 | 1 | 2 |
| UPS 58 | 4 | 2 | 2 |
| UPS 60 | 3 | 3 | 3 |
| UPS 61 | 4 | 3 | 3 |
| UPS 63 | 3 | 3 | 3 |
| UPS 64 | 3 | 1 | 1 |
| UPS 65 | 3 | — | |
| UPS 66 | 2 | 1 | 2 |
| UPS 67 | 1 | — | — |
| UPS 68 | 3 | 5 | 5 |
| UPS 69 | — | — | — |
| UPS 70 | — | — | — |
| UPS 72 | 5 | 5 | 5 |
| UPS 73 | 4 | 1 | 1 |
| UPS 74 | 3 | 2 | 2 |
| UPS 75 | 3 | 2 | 2 |
| UPS 76 | 4 | 2 | 3 |
| UPS 77 | 3 | 2 | 2 |
| UPS 78 | 2 | 2 | 2 |
| UPS 79 | 3 | 5• | 5• |
| UPS 80 | 2 | 2 | 2 |
| UPS 81 | 4 | 2 | 2 |
| UPS 82 | 1 | 1 | 2 |
| UPS 83 | 2 | 1 | 1 |
| UPS 84 | 3 | 2 | 2 |
| UPS 85 | 3 | 4 | 4 |
| UPS 87 | 3 | 3 | 3 |
| UPS 88 | 2 | — | — |
| UPS 89 | 4 | 3 | 2 |
| UPS 90 | 4 | — | — |
| UPS 91 | 3 | — | — |
| UPS 92 | 4 | 1 | 1 |
| UPS 93 | 3 | 1 | 1 |
| UPS 95 | 3 | 1 | 2 |
| UPS 97 | 4 | 2 | 2 |
| UPS 98 | 1 | — | — |
| UPS 99 | 5 | 3 | 4 |
| UPS 100 | 5 | 5 | 5 |
| UPS 101 | 3 | 3 | 3 |

**Flowering**

Appearance of the first flower ranged from 63 days (UPS 34) to 124 days (UPS, 24, 37, 64, 65, 90, 98 and 102) (Table 8). Some of the large ranges can be attributed to grasshopper damage at the terminal growth points which delayed the formation of flowers. This can be seen by comparing the flowering time of the six varieties in the first trial with the time taken by the same varieties in the single plant observations (Table 9).

**Pod Set**

The degree of pod set was rated (maximum of 5) at harvest (Table 7). There were large differences between varieties and in most cases, the degree of pod set was related to vegetative growth. Vigorous varieties produced more pods than the less vigorous ones, suggesting that the harvest index did not vary significantly.

The reason for the better growth of the Indonesian cultivars as compared to New Guinea cultivars is not clear. The Indonesian lines were planted four weeks after the New Guinea collection. Temperature during initial establishment may have been more favorable. However, it is surprising that from a later planting, the growth of the Indonesian lines quickly surpassed the New Guinea cultivars. It seems likely that the Indonesian lines were suited to the Ord river environment, either due to either or both the soil type and temperature.

**Table 8. Appearance of first flowers.**

| Variety | Date of Planting | Days of Flowering |
|---|---|---|
| UPS 4 | 15.12.76 | 83 |
| UPS 5 | 15.12.76 | 109 |
| UPS 6 | 15.12.76 | 117 |
| UPS 7 | 15.12.76 | 117 |
| UPS 8 | 10.01.77 | 90 |
| UPS 9 | 15.12.76 | 117 |
| UPS 10 | 15.12.76 | 117 |
| UPS 11 | 15.12.76 | 114 |
| UPS 12 | 15.12.76 | 117 |
| UPS 13 | 10.01.77 | 100 |
| UPS 14 | 10.01.77 | 90 |
| UPS 16 | 15.12.76 | 117 |
| UPS 17 | 15.12.76 | 117 |
| UPS 18 | 10.01.77 | 90 |
| UPS 19 | 15.12.76 | 114 |
| UPS 20 | 10.01.77 | 90 |
| UPS 23 | 15.12.76 | 117 |
| UPS 24 | 15.12.76 | 124 |
| UPS 25 | 10.01.77 | 117 |
| UPS 26 | 15.12.76 | 117 |
| UPS 27 | 15.12.76 | 109 |
| UPS 28 | 15.12.76 | 117 |
| UPS 29 | 10.01.77 | 87 |
| UPS 30 | 10.01.77 | 90 |
| UPS 31 | 15.12.76 | 109 |
| UPS 32 | 15.12.76 | 109 |
| UPS 33 | 15.12.76 | 117 |
| UPS 34 | 10.01.77 | 63 |
| UPS 35 | 15.12.77 | 97 |
| UPS 36 | 15.12.76 | 83 |
| UPS 37 | 15.12.76 | 124 |
| UPS 38 | 15.12.76 | 90 |
| UPS 39 | 15.12.76 | 109 |
| UPS 41 | 10.01.77 | 97 |
| UPS 42 | 15.12.76 | 83 |
| UPS 43 | 10.01.77 | 87 |
| UPS 44 | 15.01.77 | 109 |
| UPS 45 | 10.01.77 | 97 |
| UPS 46 | 10.01.77 | 90 |
| UPS 47 | 10.01.77 | 90 |
| UPS 48 | 15.12.77 | 112 |
| UPS 49 | 15.12.77 | 109 |
| UPS 50 | 15.12.76 | 90 |
| UPS 51 | 10.01.77 | 97 |
| UPS 52 | 10.01.77 | 90 |
| UPS 53 | 15.12.76 | 109 |
| UPS 54 | 10.01.77 | 90 |
| UPS 56 | 10.01.77 | 90 |
| UPS 57 | 10.01.77 | 97 |

**Table 8.** *continued...*

| Variety | Date of Planting | Days of Flowering |
|---|---|---|
| UPS 58 | 10.01.77 | 90 |
| UPS 60 | 10.01.77 | 90 |
| UPS 61 | 15.12.76 | 117 |
| UPS 63 | 01.01.77 | 90 |
| UPS 64 | 15.12.76 | 124 |
| UPS 65 | 15.12.76 | 124 |
| UPS 66 | 10.01.77 | 80 |
| UPS 67 | 10.01.77 | 85 |
| UPS 68 | 15.12.76 | 83 |
| UPS 72 | 15.12.72 | 83 |
| UPS 73 | 15.12.76 | 83 |
| UPS 74 | 15.12.76 | 117 |
| UPS 75 | 15.12.76 | 117 |
| UPS 76 | 10.01.77 | 90 |
| UPS 77 | 15.12.76 | 117 |
| UPS 78 | 10.01.77 | 97 |
| UPS 79 | 15.12.76 | 117 |
| UPS 80 | 15.12.76 | 117 |
| UPS 81 | 10.01.77 | 90 |
| UPS 82 | 15.12.76 | 97 |
| UPS 83 | 10.01.77 | 97 |
| UPS 84 | 10.01.77 | 90 |
| UPS 85 | 10.01.77 | 87 |
| UPS 87 | 15.12.76 | 83 |
| UPS 88 | 10.01.77 | 97 |
| UPS 89 | 15.12.76 | 97 |
| UPS 90 | 15.12.76 | 124 |
| UPS 91 | 10.01.77 | 97 |
| UPS 92 | 15.12.76 | 124 |
| UPS 93 | 15.12.76 | 114 |
| UPS 94 | 15.12.76 | 124 |
| UPS 95 | 15.12.76 | 114 |
| UPS 97 | 15.12.76 | 114 |
| UPS 98 | 15.12.76 | 124 |
| UPS 100 | 10.01.77 | 97 |
| UPS 101 | 15.12.76 | 114 |
| UPS 102 | 15.12.76 | 124 |
| UPS 103 | 10.01.77 | 97 |
| UPS 104 | 15.12.76 | 117 |
| UPS 105 | 15.12.76 | 117 |
| UPS 106 | 10.01.77 | 117 |
| UPS 107 | 10.01.77 | 97 |
| UPS 108 | 10.01.77 | 90 |
| UPS 110 | 10.01.77 | 83 |
| UPS 111 | 10.01.77 | 97 |
| UPS 112 | 15.12.76 | 83 |
| UPS 113 | 10.01.77 | 97 |
| UPS 115 | 15.12.76 | 117 |
| UPS 121 | 15.12.76 | 83 |
| UPS 122 | 10.01.77 | 124 |

**Table 9. Comparison of days to first flowering between varieties in the first and second plantings.**

| Variety | Evaluation 1st Planting | New Guinea Plantings |
|---|---|---|
| | (days) | (days) |
| UPS 45 | 77 | 97 |
| UPS 51 | 85 | 117 |
| UPS 59 | 77 | 114 |
| UPS 102 | 89 | 124 |
| UPS 121 | 89 | 83 |

**Table 10. Ratings for vegetative growth of 21 winged bean cultivars from Indonesia (rating out of 5).***

| Date of Planting | Variety | Rating | Comments |
|---|---|---|---|
| 10.01.77 | Sakonnakhon 0101 | 1 | Seed did not germinate until March 3, 1977 |
| 10.01.77 | Chiang Mai 0101 | 1 | High seed yield |
| 10.01.77 | Chiang Mai 0102 | 1 | |
| 10.01.77 | Chiang Mai 0103 | 1 | |
| 10.01.77 | Chiang Mai 0201 | 1 | |
| 10.01.77 | Chiang Mai 0202 | 1 | |
| 10.01.77 | Chiang Mai 0301 | 1 | |
| 10.01.77 | Phrae 0101 | 2 | High seed yield |
| 10.01.77 | Phrae 0201 | 2 | High seed yield |
| 10.01.77 | Phrae 0301 | 2 | High seed yield |
| 10.01.77 | Ratchaburt 0104 | 1 | High seed yield |
| 10.01.77 | Ratchaburt 0105 | 2 | |
| 10.01.77 | Ratchaburt 0106 | 2 | |
| 18.01.77 | *P. palustris* 424 | — | No germination |
| 18.01.77 | *P. tetragonolobus* 519A | 3 | |
| 18.01.77 | *P. tetragonolobus* 77902B | 3 | High seed yield |
| 18.01.77 | *P. tetragonolobus* 867A(2) | 5 | Very low seed yield but good tuber development |
| 18.01.77 | *P. tetragonolobus* 901(1) | 2 | High seed yield |
| 18.01.77 | *P. tetragonolobus* 904 | 4 | |
| 18.01.77 | *P. tetragonolobus* 909 | 5 | |
| 18.01.77 | *P. tetragonolobus* 112b(6) | 2 | |

***Basis of Rating: (for Indonesian lines only)**

| Area of ground covered per plant | Rating |
|---|---|
| 0 — 0.99 $m^2$ | 1 |
| 1.0 — 1.99 $m^2$ | 2 |
| 2.0 — 2.99 $m^2$ | 3 |
| 3.0 — 3.99 $m^2$ | 4 |
| 4.0 — 4.99 $m^2$ | 5 |

Although the Indonesian lines could scarcely be called determinant, they did display a more determined growth habit than the New Guinea lines. Generally, as soon as mature pods are present on a plant, the rate of appearance of new flowers decrease significantly and senescence starts. This was quite different from the performance of most of the New Guinea lines. It is a characteristic that would facilitate mechanical harvesting.

The Indonesian lines were also examined for their degree of pod shattering. Early maturing pods from the 13 lines planted on October 1, 1977 were tagged individually upon maturity and regularly checked. None of the marked pods had shattered until after all pods had matured. There were, however, individual pods in all varieties that had shattered.

Shattering was promoted by extreme changes in environmnent conditions especially when some pods became wet following irrigation. Mostly, pods remained intact until harvest, and split as they were removed from the plant. Table 11 gives an indication of the relative susceptibility of the 20 varieties to shattering.

**Table 11. Ratings of the degree of shattering of seed pod in 20 Indonesian winged bean cultivars.***

| Variety | Shattering after Senescence of Plant. |
|---|---|
| Sakonnakhon 0101 | 3 |
| Chiang Mai 0101 | 2 |
| Chiang Mai 0102 | 2 |
| Chiang Mai 0103 | 2 |
| Chiang Mai 0201 | 2 |
| Chiang Mai 0202 | 2 |
| Chiang Mai 0301 | 2 |
| Phrae 0101 | 2 |
| Phrae 0201 | 2 |
| Phrae 0301 | 2 |
| Ratchaburt 0104 | 3 |
| Ratchaburt 0104 | 2 |
| Ratchaburt 0106 | 3 |
| *P. tetragonolobus 519A* | 2 |
| *P. tetragonolobus 799(2)B* | 4 |
| *P. tetragonolobus 867A(2)* | 2 |
| *P. tetragonolobus 901(1)* | 2 |
| *P. tetragonolobus 904* | 2 |
| *P. tetragonolobus 909* | 2 |
| *P. tetragonolobus 1126(6)* | 3 |

***Basis of Rating:**
**1. No shattering**
**2. 0 — 10%**
**3. 10 — 30%**
**4. 30 — 50%**
**5. 50%**

## DISCUSSION

The aim of these initial observation was to determine if the winged bean could be integrated into the agricultural system of the Ord River region, an intensive mechanical farming system. There are definite requirements in the area for a leguminous cover crop that can compete with weeds and survive on waterlogging soil conditions during the wet season and at the same time provide a substitute for expensive artificial nitrogenous fertilizers. It was thought that the winged bean may be suited to this role.

The winged bean was relatively easy to establish using a combined seeder. There were also several cultivars that showed good early growth and were able to compete with the weeds, despite the presence of the waterlogged conditions during periods of heavy rainfall. The cultivars from Indonesia appeared to be tolerant to waterlogging since there is no mortality in this group.

The winged bean was also very tolerant to insect attack, a very important criterion in the tropics. None of the plantings received insecticide sprays of any type during their life cycle.

In fact, there appears to be cultivars that satisfy all criteria with the exception of their ability to be mechanically harvested to ensure sufficient seed harvests

The winged bean obviously has a potential for high seed yields when grown as a ground cover that is not trellised (Table 6). Most of the Indonesian lines showed a high level of seed set. However, under a mechanized system it appears to be difficult to harvest a reasonable proportion of the seed that is set. The main factors limiting mechanical harvesting are the seed and the indeterminate nature of the plants. The Indonesian cultivars seem to be more accessible to mechanized farming than do the cultivars from New Guinea. It is possible that a system of cultivation could be developed using dessicant herbicides to obtain a harvestable product prior to serious shattering. In some lines however, the solution will require a breeding program similar to that carried out for seed shattering in the narrow leaf lupin, *Lupinus angustifolius* (Gladstones, 1975). If a solution to seed shattering could be found, winged bean would have considerable potential as a protein and cover crop in a mechanical farming system

## ACKNOWLEDGEMENT

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# Support Systems for Climbing Food Crops

*K. O. Rachie* and *R. A. Luse*[1]

## INTRODUCTION

Current efforts to improve food crops have generally ignored the study of support systems for climbing crops. Nevertheless, a high proportion of tropical food crops require some kind of support, either through an associated crop or with constructed support. It is estimated that in tropical Africa over 90 percent of the cowpeas are grown in association with support crops like sorghum, millet or maize (Arnon, 1972). It is further estimated that about 80 percent of the *Phaseolus* bean crop in tropical Latin America is interplanted with maize and that about 40 percent of the planting utilizes the living or dead maize stalks for support (Gutierrez et al., 1975). Several other crops require support for optimal yields:

1) tropical pulses, e.g. lima bean, sword bean, Mucuna bean and winged bean;
2) root and tuber crops, such as (*Dioscorea spp.*), some forms of sweet potato, "jicama" (*Pachyrrhizus erosus*) and African yam bean (*Sphenostylis stenocarpa*);
3) vegetables, including string beans (*Phaseolus vulgaris*), yard long beans (*Vigna sesquipedalis*), tomatoes and some cucurbits;
4) several fruits, as grapes, passion fruit and berries;
5) forage legume, e.g. *Centrosema* and *Glycine* species.

This broad range of crops offers several options for using plant support systems in intensive cropping. Few farming technologies offer more scope for intensifying production on limited areas and in providing opportunities for gainful returns from labor. Plant supports can be constructed from expensive durable materials like galvanized pipe and wire or from low-cost indigenous materials like tree branches, saplings or bamboo. Much of the assembling and shaping of supports can be done in the off-season when labor is plentiful. Since this technology clearly favors smallholder agriculture it can be classified as scale-negative in character.

The objective of this paper is to point out the benefits of effective plant supports as demonstrated in recent years and to describe some of the options available — especially to the small farmer — for such support systems. This technology is particularly appropriate in the tropics where climbing food crops are utilized extensively, often in year-round cropping systems. This paper will emphasize the tropical food legumes, since it is in these crops that application of this technology can make an immediate and dramatic improvement in food production.

## TYPES OF PLANT SUPPORT

### Constructed Supports

The most common constructed plant supports can be grouped under either staking or trellising. Each has advantages for different needs and purposes. However, they should be constructed strongly enough to carry the crop without collapsing and situated at distances and at heights optimum for the crop being supported.

1. **Staking.** Poles or laths of lengths from one to over five meters pushed firmly into the ground beside plant hills of the crop(s) are probably most common for annual herbaceous crops. The stakes can also be used in multiples of two to four or more in triangulation to provide firm support with lighter materials. Stakes can be constructed of any suitable material easily available, including metal rods or pipes, tree branches, saplings or reeds.

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2. **Trellising.** A wide range of materials and design are possible, but there are really only two basic types: horizontal and vertical. Horizontal trellises consist of some type of netting usually wire) supported horizontally on poles and usually from one to about two meters high. Vertical trellises provide support for a horizontal member — usually wires, strings or poles at a height of 1-2 meters. Either one or two rows of plants can be supported on a single horizontal member. Construction materials most often used are wood, bamboo poles, metal pipes or concrete posts for the supports, poles, wire or heavy string for the horizontal members, and light string, reeds or laths as the vertical leaders needed to train the plants to the top horizontal members.

**Associated Plant Supports**

If two crops — one a cereal such as maize, the other a legume — are planted simultaneously, the legume is usually a strong climber. However, if the legume is planted later in the life cycle of the cereal, it can also be a bush, spreader or weak climber. If a climber, the pulse utilizes the dead stalks of the cereal for support. This kind of association can be with both living or dead support plants and involves a very broad range of species. Although cereals are most commonly used, cassava, sunflower, cotton, ramie, vegetables like okra, shrubs, plantation and shade trees make satisfactory supports for climbing plants. Obviously, climbers perform best when competition from the associated plant is reduced, since both must compete for light, nutrients and water.

## INCREASING CROP PRODUCTIVITY WITH SUPPORTS

The effect of constructed plant supports such as trellises or stakes is to increase crop yields, sometimes by several fold. In the case of associations of climber and support crops, the climber may not necessarily produce higher yields, but the combination is expected to reduce risk and produce more per unit area and time than either crop grown alone.

**Increases with Constructed Supports**

The food legumes grown in the tropics are typically characterized by low seed yields and seldom more than 1800 kg/ha in experimental plots, for *Phaseolus vulgaris* (field bean) and *Vigna unguiculata* (cowpea) as examples. Yet these low seed yields can be raised two to three fold by the use of climbing or viny types supported by trellises. In a series of experiments carried out at the International Institute of Tropical Agriculture (IITA), in southern Nigeria, yield increases averaged 2.5 fold for a semi climbing cowpea, yard long bean, and winged bean when trellised (Table 1). It was observed that trellising has a profound effect on the number of pods produced and that the pods matured earlier than in the untrellised plants.

Viny type lima beans grown at IITA in 1973 on trellises 2.2 m high produced dry seed yields as high as 2800 kg/ha (6 m² plots), 2.3 times the average yield of six dwarf bush type limas grown in a parallel experiment (Rachie, 1974). Multiple pickings are required to reach this level of yield, but this is not considered a disadvantage for the small farmer having a supply of family labor without alternate employment opportunities.

**Table 1. Seed yields of climbing food legumes growth with and without trellis support (Rachie, 1972, 1973).**

| LEGUME | Yield of dry seed, kg/ha | | |
|---|---|---|---|
| | Trellised (T)[a] | Untrellised (U) | Yield ratio T/U |
| *Vigna unguiculata* (var. Iran Grey) | 1476[b] | 720 | 2.1 |
| | 2217 | 1183 | 1.9 |
| *V. sesquipedalis* (var. Pole Sitao) | 1715 | 658 | 2.6 |
| | 2182 | 613 | 3.6 |
| *Psophocarpus tetragonolobus* (var. Tpt 1) | 841 | 362 | 2.3 |
| | 692 | 282 | 2.5 |
| *Phaseolus lunatus* (var. Large White) | 614 | 36 | (17.1) |
| | 999 | 43 | (32.2) |

[a]Trellises were 2.0 m high.
[b]Data on first lines are from 1971, those on second lines are from 1972.

**Associations with Support Crops**

Sometimes the support crop and a legume are planted more or less simultaneously, while in other cases the legume is planted later (usually when the associated crop begins fruiting and matures) to take advantage of residual moisture and to utilize the standing mature crop for support. For example, in an experiment carried out at IITA in 1972, it was found that supporting the legumes on okra (*Hibiscus esculentus*) stalks increased the yield of climbing type cowpeas by nearly 50 percent. Supported climbing varieties of *Phaseolus vulgaris* grown at 1500 m in Popayan, Colombia, produced seed yields of up to 4500 kg/ha, with the average yield of the ten best varieties tested equal to 4250 kg/ha (Francis, 1977). These yield levels were attained by supporting the beans on the dried stalks of a previously grown maize crop.

It must be noted that competition from a leafy support crop such as maize can greatly reduce the yield of the climbing crop if respective planting dates are not carefully chosen. At CIAT in 1977 the optimum plant density for climbing beans (variety P589) was 120,000 plants/ha the lowest maize population tested (20,000 plants/ha) produced the highest bean yields (Francis *et al.*, 1976; Francis, 1977). In this environment, planting both crops (best adapted cultivars) produced excellent yields of 5 to 7 t/ha of maize and about 1.3 t/ha of beans (in two instances yields of 2.1 t/ha of beans were obtained, with about 5 t/ha of maize). However, planting beans 5 or 10 days later than the maize reduced bean yields by about 50 to 75 percent. Similarly, planting the beans only 5 or 10 days earlier than the maize reduced yields of maize by 40 to 90 percent of simultaneous planting levels. The likelihood of strong environmental and genotype effects requires that careful study be done before making recommendations for specific crops and situations.

**Productivity and Kind of Support**

There is very little information on yields obtained from different kinds of support, but preliminary experiments were done with the climbing vegetable cowpea (*Vigna sesquipedalis*) where the height of the horizontal support member was varied from 1 to 3 m and yields compared with vertical staking and living (shrub) supports (Nangju, 1976). Raising the horizontal member increased yields of green pods, but 2 m height was probably optimum. The increased trouble and cost of materials would not justify a 3 m trellis (Table 2).

**Table 2. Effect of type and height of plant support on green pod yield of the climbing, vegetable-type cowpea, cv. FARV-13 obtained at Ibadan, Nigeria (Nangju, 1976).**

| Type of Support | Total Green Pod Yield | | | |
|---|---|---|---|---|
| | Center Rows | | Border Rows | |
| | T/ha | Percent* | T/ha | Percent* |
| None | 7.6 | 100 | 8.7 | 114 |
| 1 m horizontal | 14.7 | 192 | 15.1 | 103 |
| 2 m horizontal | 18.9 | 248 | 18. | 98 |
| 3 m horizontal | 19.3 | 253 | 21.0 | 109 |
| 2 m vertical poles | 12.8 | 168 | 14.3 | 112 |
| "Living" support — 2-3 m | 13.3 | 174 | 16.2 | 122 |

*Percent of yield in unsupported plots.
**Percent of yield in equivalent center rows.

Vertical poles or living support (*Gliricidia faculata*), both about 2 m high, were less efficient than the comparable 2 m trellis by 90 to 74 percent, respectively. However, there was very little difference (3%) between the yields from the centers and borders of trellised plots. Maximum yields of green pods of 19.3 t/ha (153 percent above that of the unsupported plots) were obtained from five-pickings.

The experiments reported in this section, while not replicated over a number of seasons and locations, are sufficient to indicate that considerable increases of food legume production can be achieved by the simple expedient of growing climbing types on supports. Such indeterminate types have a higher production potential by virtue of their indefinite growth, extended flowering period, greater "rusticity", and reduced susceptibility to stresses (due to inherently better recovery). If the production level of such crops as beans, cowpeas and winged beans can be demonstrated to be consistently over 2500 kg/ha, these crops will be more widely accepted by farmers as a valuable component in their farming systems.

## Support and Photosynthesis

Underlying the potential for increased productivity in supported crops is the higher photosynthesis that occurs in an elevated plant canopy, where light penetration is better and gas exchange is more rapid. Little quantitative work has been done to document the physiological changes caused by supporting plants, but recent studies in *Phaseolus* beans serve as an example of the work needed. To evaluate the importance of canopy structure on yield, three heights of support were provided (Laing, 1977). While the variety under test was not a true climbing type, it showed a natural tendency to climb on the strings of the 2 m trellis to reach a final canopy height of 130 cm, well above the canopy height at 62 cm reached on the other lower supports. Attributes of photosynthesis — leaf area index (LAI) and total carbohydrate (sugar and starch) content of stems — were markedly higher in the higher canopy, as was number of nodes per unit area (Table 3). Maximum carbohydrate content occured in the stem 10 days after flowering for all treatments, but declined more slowly thereafter in the trellised as compared to the non supported plants. Indeed, this indicated excess photosynthate availability in the supported plants during the period of pod set, which resulted in higher seed yield.

**Table 3. Effect of canopy height on photosynthetic parameters (Laing, 1977).**

| Parameter* | Canopy height* | |
|---|---|---|
| | 40 cm | 130 cm trellised |
| Leaf area index, $m^2/m^2$ | 0.7 | 2.3 |
| Stem carbohydrate, % dry | 5.8 | 10.9 |
| No. of nodes per $m^2$ | 4.1 | 5.2 |

***Measured at 30 days after flowering, a point at three-fourths of the time between flowering and physiological maturity.**

A comparison between a bush-type variety (P566) and a supported climbing variety (P589) of *Phaseolus* bean shows similar results, though the differences in genetic background cannot be ignored. The several attributes listed in Table 4 give general indication of the advantages for yield possessed by climbing varieties. Longer pod filling period, higher bean yield per day of pod filling, and higher harvest index, all of which resulted in more pods per area of land, more beans per pod, and obviously higher bean yields (Laing, 1977).

Experiments of a comparable nature should be done with other climbing food legumes, especially winged beans, to find those varieties that are most efficient photosynthetically. This type of physiological evaluation becomes meaningful when sufficient plant breeding has been done in a species to identify the extent of yield potential and, to some extent, the constraints of that potential.

**Table 4. Comparison of physiological attributes in two types of *Phaseolus vulgaris* (Laing, 1977)**

| Attribute | Growth Habit | | Difference |
|---|---|---|---|
| | Bush | Climbing | Climbing/bush |
| Days to flowering | 39 | 47 | 21% (+8 days) |
| Days to maturity | 82 | 96 | 17% (14 days) |
| Bean yield (B) per day (%) (maturity flowering) | 3.23 | 4.73 | 46% |
| Harvest index (%) | 57.5 | 67.4 | 17% |
| Beans per pod | 2.97 | 6.22 | 109 |
| Pods per $m^2$ | 255 | 315 | 24 |
| Bean yield ($g/m^2$) at 14% moisture | 2.65 | 4.54 | 71 |

## BETTER QUALITY PRODUCT

A feature of supported crops that is rarely documented but frequently recognized by the consumer is the improvement in seed, vegetable or fruit quality as compared to plants close to the ground. Factors of reduced insect and pest damage, lower relative humidity, and moderated temperature may all be important to this improvement in product quality. Since in many tropical food crops little attention has yet been given to product quality (either in terms of viability after storage, or nutritional content, or of consumer acceptance), there is a great deal of work to be done in this area of research.

An aspect of trellised crops that makes this technology of advantage to the small farmer with a supply of family labor is that harvesting is best done by hand. Such hand harvesting helps ensure that better quality is obtained, since poor quality pods are intuitively rejected by the human harvesters.

## REDUCED DISEASE AND INSECT PRESSURE

Supported plants can fruit and ripen well above ground which can reduce pod insects, rotting and other organisms that thrive under the high humidities and protective foliage canopies near the ground. It has been frequently observed, albeit in a qualitative, subjective sense, that food legumes grown on trellises are less subject to attack by pests and diseases than bush types growing close to the ground (or especially, viny types spreading over the ground without support). Trellised cowpea, limas and winged bean under minimum insecticide treatment, appeared less affected by pests at IITA (Rachie, 1972). This may be explained partially by a more efficient application of insecticide to supported plants, but factors in the canopy micro-climate undoubtedly also play a role. What is needed is a careful comparison of pest and disease damage done to trellised and untrellised legumes grown in minimum impact experiment relying on integrated biological control.

## EXTENDED PRODUCTION TIME

Food legumes such as bush beans are quick growing crops able to flower and set seed in the short, often unreliable, rainy seasons found in the tropics. It usually takes a longer time for the climbing viny types even though their vegetative growth rate is similar to that of the bush type. However, once the viny superstructure is established, such legumes may continue to set pods for an extended period of time, thus providing a continuous source of green vegetables rich in protein and vitamins. The period of pod production of winged bean has been observed at CIAT to be three months or longer when conditions are favorable.

## REDUCED REQUIREMENT FOR PLANTING MATERIALS

Since climbing plants have enormous spreading potential, lower seeding/planting rates may be used. This is particularly important to the small farmer with low income, since traditional methods of planting require very heavy seeding rates to ensure a good stand and can seriously reduce the amount of harvested seed available for market sale or home consumption.

## CHOOSING A PLANT SUPPORT SYSTEM

The most important consideration in designing a plant support system is its profitability. Costs of construction can vary enormously depending on the cost and availability of labor and materials. Obviously, there are trade-offs: a trellis made of galvanized wire and steel pipes will cost much more, but last longer, than one made of sticks and string. However, the requirement of low capital input (and reasonable labor input as well) for most agricultural changes in developing countries means that only simple, locally available materials can be considered for trellis systems, even if this implies one to two season durability.

Francis and Sanders (1977) have found that in Colombia minimal trellis support systems could be constructed for beans at a cost of about US $270/ha, half of which was for labor. This figure represented only 30 percent of total production costs (about US $900/ha.) and was equivalent to the market price of 0.64 t of beans. Since the support system should increase bean yields by at least 1 t/ha., its cost/benefit ratio would be approximately 1.6 in this instance. A more elaborate system would be more costly, up to $400/ha or more for

materials, but would be stronger and last longer (more than 3 years). Its cost/benefit ratio (assuming US$200 annual labor cost) would be about 1.3. In view of the cash liquidity situation on most small farms, there would be a substantial advantage in growing the construction materials on the farm and in using off season family labor for construction. By the same reasoning, emphasis should be placed on plant support systems with virtually no materials cost nor labor input. The most common of these is the dried maize stalk left in the field from a previous crop.

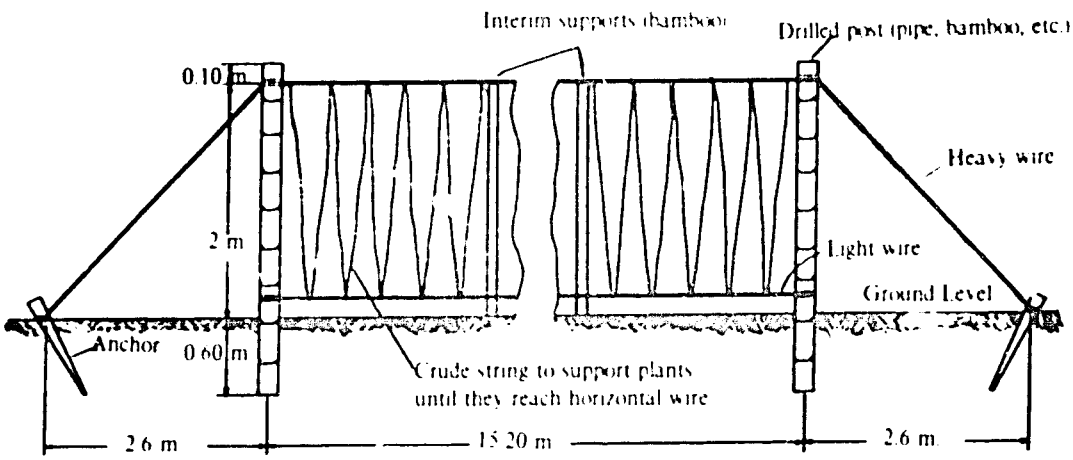
The following are observations that must be considered in the choice of a support system:

1) The already well established climber plus support crop is one of the most economically viable and least risky system available. However, much needs to be learned about genotype x environment x management interactions and about the economic advantage of this system.

2) Simple staking — either singly or triangulated — is a well proven technology but depends on the availability and cost of materials. The possibilities of growing special staking materials like tree sapling or branches, bamboo, wild cane or fibrous species like *Hibiscus* need study from both the agronomic and economic points of view. Sometimes such species can be grown in the off season or waste areas at very low cost. Inexpensive treatment of stakes against insects and rotting organisms should be considered.

3) There are several methods of constructing trellises depending on the needs of the crop and its duration, availability of materials, and construction costs. Some possibilities are:

(a) **Posts and Wire.** This would involve considerable expense for materials (wooden or steel posts, wire and string), but should have a useful life of several years (Figure 1).




**Durable construction**

**Figure 1. Trellis: double wire construction**

(b) **All bamboo.** A trellis constructed entirely of bamboo has been designed at CIAT. It utilizes bamboo poles as the horizontal member and vertical bamboo laths for the growing plants to climb on. Presumably other woods or available construction materials could be used. Costs would be minimal and would depend primarily on labor (see Figure 2).

(c) **Other materials.** Future developments in inexpensive, light insensitive, semi rigid netting made from plastics or metal would allow fabrication of simple horizontal or vertical trellises with low on-site labor inputs.

(d) **In Situ support plants.** Growing plants primarily for support purposes has interesting possibilities. This implies appropriately spacing the support crop and allowing it to mature or be killed before planting the climber, so as to minimize competition. Gaps in the stand of support plants can be linked horizontally at the desired height with heavy string or light wire. At CIAT we are trying *Leucaena leucocephala* plants 2 to 4 meters tall in combination with climbing beans. Before planting

beans, the *Leucaena* is either ring barked or treated with herbicide like 2, 4, 5-T or Picloram. (Concentrated spray applications may leave residues harmful to the climbing bean and application by brush may be safer.) *Leucaena* has the additional advantages that it can also be utilized in a cropping system to provide forage, green manure (coppicing), fire wood and construction materials. Similar multi purpose shrubs or trees can no doubt be found for other locations.

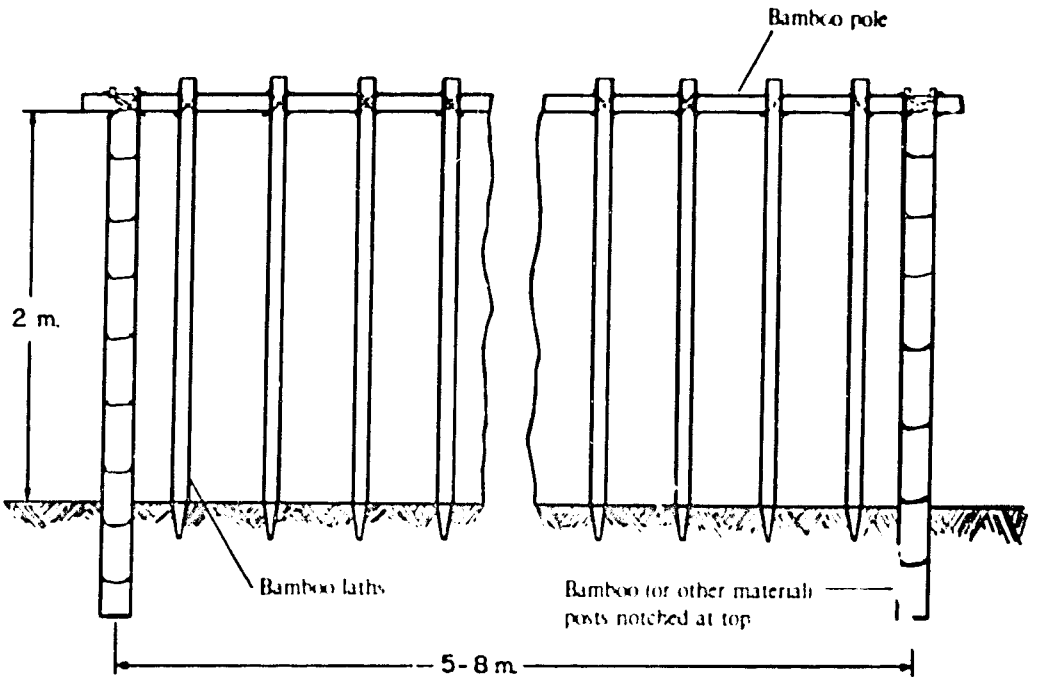



**Figure 2. Trellis: local materials**

## CONCLUSIONS

The basic features of a satisfactory plant support system are that it should make optimum use of the available space, light and moisture and that it is strong enough to support the plant until harvest. Spacing and height are often specific to the crop and genotype as well as the environment.

The use of support systems for climbing food crops is a labor-intensive, scale negative technology that should be evaluated more fully for tropical crops, especially the protein-rich food legumes. While these systems have the potential for intensifying production on limited areas, it is essential to work out the basic agronomy and economics of any system before embarking on large-scale enterprises. The application of plant supports — either constructed or through associated plants — is location specific and highly dependent on economic considerations. Among the several aspects requiring further study are the following agronomic and economic factors:

- cropping association and specific genotype x genotype interactions.
- analysis of the economic benefit obtainable from the available support options for various crops.
- identification or development of durable but inexpensive construction materials, as well as methods of extending their useful lives.
- development at appropriate sequences of climbers and other species.
- improvement of both climbers and support species to raise their individual productivities and also mutual complementaries.

The development of associated cropping and plant support systems has been generally neglected. Few areas of investigation have more potential for intensifying production on small holdings, frequently with minimal externally-purchased inputs. It is therefore suggested that plants support technology is deserving of much more research effort.

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# Field Studies on Winged Bean Growth and Yield

*R. A. Stephenson*[1]

**Initial work involved a comparison, using growth analysis techniques, of two cultivars (UPS31 and UPS122) having different morphology particularly with respect to pod and leaflet size. Both grew vigorously at a similar rate, although the dry matter production of UPS122 was ultimately twice that of UPS31 plants which matured earlier. The mean Relative Growth Rates were 0.13 and 0.14 g day for UPS31 and UPS122 respectively during the period of late vegetative growth while the corresponding mean net assimilation rates were 0.6 and 0.8g dm week respectively. The pattern of partitioning of dry matter during the reproductive phase, however, differed. There were significant differences in the length of the reproductive phase and in the harvest index values for the two cultivars. The harvest index (based on above-ground plant parts only) for UPS31 and UPS122 were 0.25 and 0.12 respectively, indicating that UPS31 is much more efficient in partitioning its dry matter into the economic portion, the pods. The length of the reproductive phase of growth in UPS122 was at least three weeks greater than that for UPS31. The greater growth during this extended pod-filling period was accompanied by increasing accumulation of dry matter in the pods so that, at the final harvest date, there was no significant difference in pod yield between the cultivars. Such differences in growth patterns are expected to influence selection and development of superior commercial genotypes.**

**Plant density experiments have been carried out on UPS122 over two seasons. The optimum spacing was 25cm x 25 cm (ca 150,000 plants/ha). The establishment of optimum spacings should allow more critical assessments of winged bean performance as a field crop.**

## INTRODUCTION

For the potential of the winged bean as a versatile, high protein crop for the tropics to be fully realized, much basic and applied research will have to be undertaken to develop high yielding varieties and to determine optimum growing conditions. Apart from the survey of traditional winged bean cultivation in the highlands of Papua New Guinea (Khan, Bohn and Stephenson; World Crops and Livestock, Sept/Oct:208-214, 1977), there is little documented information on optimum cultural conditions. Moreover, if the crop is to compete with such legumes as soybean and cowpea as a popular food in the tropics, its' potential for growth and yield must be determined and be at least competitive with that of existing food legumes. Field trials at the University of Papua New Guinea provide some preliminary data on the growth of winged bean and on the optimum planting density.

## MATERIALS AND METHODS

### Growth Analysis Experiment

An initial growth analysis experiment, using 2 cultivars, UPS31 and UPS122, was carried out during 1975. UPS31 has small leaflets and produces numerous small pods whereas UPS122 has larger leaflets and produces fewer large pods.

Prior to planting, 50kg/ha each of nitrogen, phosphorus and potassium fertilizer, was applied to the soil along the planting ridges which were 1m apart. The distance between seeds was 1m along the ridge. Trellises, 1.5m high, were provided to support the plants. Irrigation was applied as required and precautions were taken to prevent pest, weed and disease problems from developing.

A completely randomized block design having 6 replicates was used and 5 adjacent plants were harvested from each replicate at each harvest. The first harvest was carried out approximately 3 weeks after

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emergence and subsequent harvests at 1 to 2 week intervals. Individual plants from each plot were carefully separated. Leaflets were removed, total leaf area was calculated and total leaf dry weight was obtained. Pods were removed, counted, dried and weighed. Seeds were removed from the pod walls and the number and dry weight of seeds per plant was recorded. Length of stems was measured and the number of nodes recorded. Stems were then dried and weighed. Derived growth analysis functions such as relative growth rates, net assimilation rates and leaf area ratios were calculated using standard formulas.

**Density Experiment**

Materials and methods were similar to those used in the growth analysis experiment except where otherwise specified. The cultivar, UPS122, was sown on raised 1m × 2m beds on square patterns equivalent to approximately 10,000, 40,000, 100,000, 150,000 and 350,000 plants/ha. A completely randomized block design consisting of 5 densities and 6 replicates was used. Trellises were arranged so that each plant had an individual twine support. Plants were harvested when they reached maturity and were divided into their component parts. Dry weights of leaves, stems, pod walls and seeds were recorded, together with the number of plants, pods and seeds per plot and the 100 seed dry weights.

## RESULTS AND DISCUSSION

**Growth Analysis Experiment**

Considerable differences in patterns of dry matter accumulation are indicated for UPS122 and UPS31 (Fig. 1). Total dry weight of UPS122 continued to increase linearly at a similar rate as that of UPS31. This increase continued until approximately 120 days after emergence when the experiment was concluded whereas that for UPS31 levelled off at approximately 70 days. Consequently, the total dry weight of UPS122 plants, at the final harvest, was nearly twice that of UPS31.

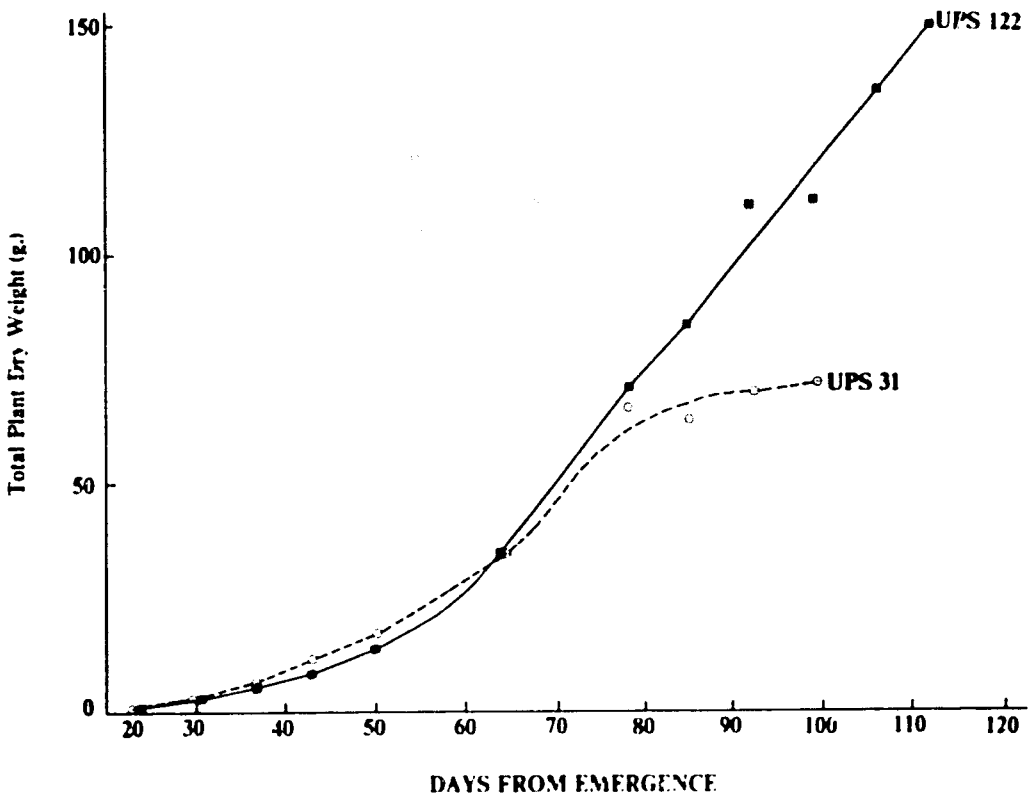


**Fig. 1. Total plant dry weight of UPS31 and UPS122 at various stages after seedling emergence.**

Not surprisingly, the pattern of total dry matter accumulation follows, approximately, that of cumulative leaf area development (Fig. 2). Increase in leaf area occurred at a similar rate for both cultivars. Maximum leaf area of ca 40 $dm^2$ for UPS31 was obtained at 78 days after emergence. The leaf area of UPS122 plants, however, only began to level off at 85 days after emergence and there was no clear indication that the maximum leaf area had been reached.

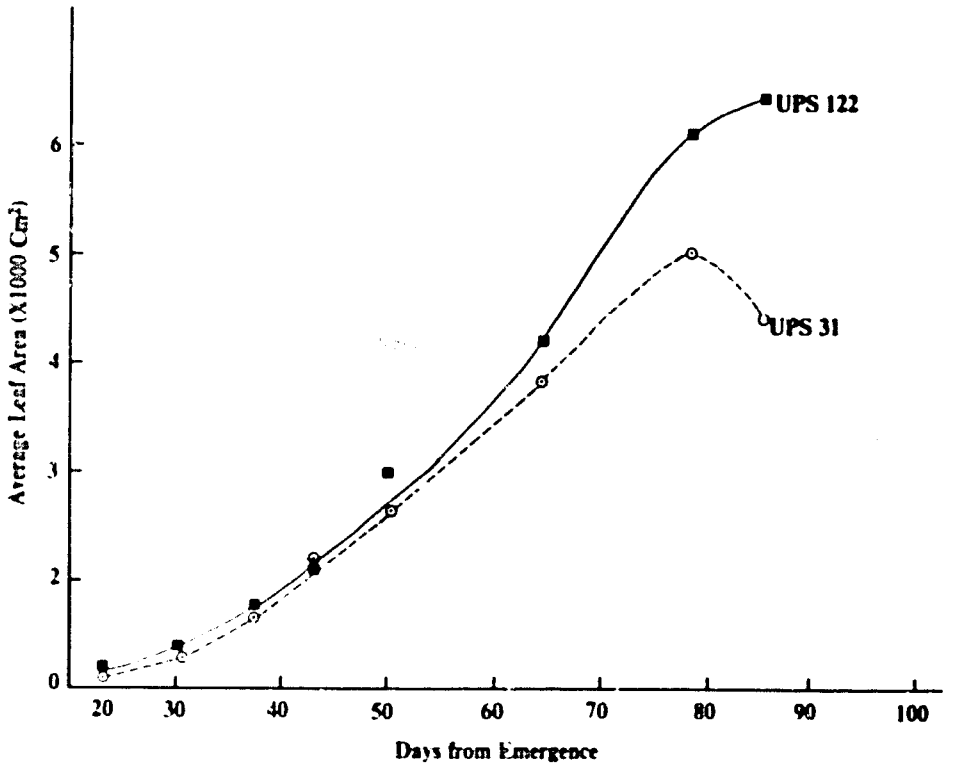


**Fig. 2. Average leaf area per plant of UPS31 and UPS122 at various stages after seedling emergence.**

Both cultivars had similar relative growth rates, although higher levels were maintained over a longer period for UPS31 (Table 1). This can be largely attributed to the higher net assimilation rates of UPS31 plants during the vegetative and early flowering stages. Leaf area ratios of UPS31 were slightly smaller than in UPS122. Thus, there may be scope for selecting plants with high photosynthetic efficiencies.

**Table 1. Growth analysis functions at various stages of growth for the UPS31 and UPS122 cultivars of the winged bean.**

| Days after emergence | Relative growth rate (g/g/day) | | Net assimilation rate ($g/dm^2/wk$) | | Leaf area ratio ($dm^2/g$) | |
|---|---|---|---|---|---|---|
| | UPS31 | UPS122 | UPS31 | UPS122 | UPS31 | UPS122 |
| 23-30 | 0.08 | 0.07 | 0.59 | 0.51 | 2 | 1.5 |
| 30-37 | 0.14 | 0.13 | 0.79 | 0.55 | 1.7 | 1.8 |
| 37-43 | 0.12 | 0.06 | 0.72 | 0.27 | 1.2 | 1.5 |
| 43-50 | 0.06 | 0.09 | 0.38 | 0.40 | 1.1 | 1.6 |
| 50-64 | 0.06 | 0.07 | 0.38 | 0.41 | 0.9 | 1.5 |
| 64-78 | 0.05 | 0.05 | 0.46 | 0.45 | 0.8 | 0.9 |
| 78-85 | — | 0.02 | — | — | | — |
| 85-92 | 0.01 | 0.04 | — | — | — | — |
| 92-99 | 0.004 | 0.03 | — | — | — | — |

Figure 3 shows that total seed dry weight per plant also accumulated differently in the two types, although the expected parabolic pattern was obtained in each case UPS31 accumulated a more consistent and larger amount of material in its seeds. The harvest index values (seed dry weight ÷ total plant dry weight), based on the second last harvest in each case, were 0.25 and 0.12 for UPS31 and UPS122 respectively. Thus, UPS31 was able to partition more efficiently its dry matter into the economic parts, the seeds. Hence, there is considerable scope for increasing harvest index values in winged bean plants. Moreover, the maximum pod yield per plant was obtained at 80 days for UPS31 and at over 100 days after emergence for UPS122. This pattern is similar to that of total plant dry weight.

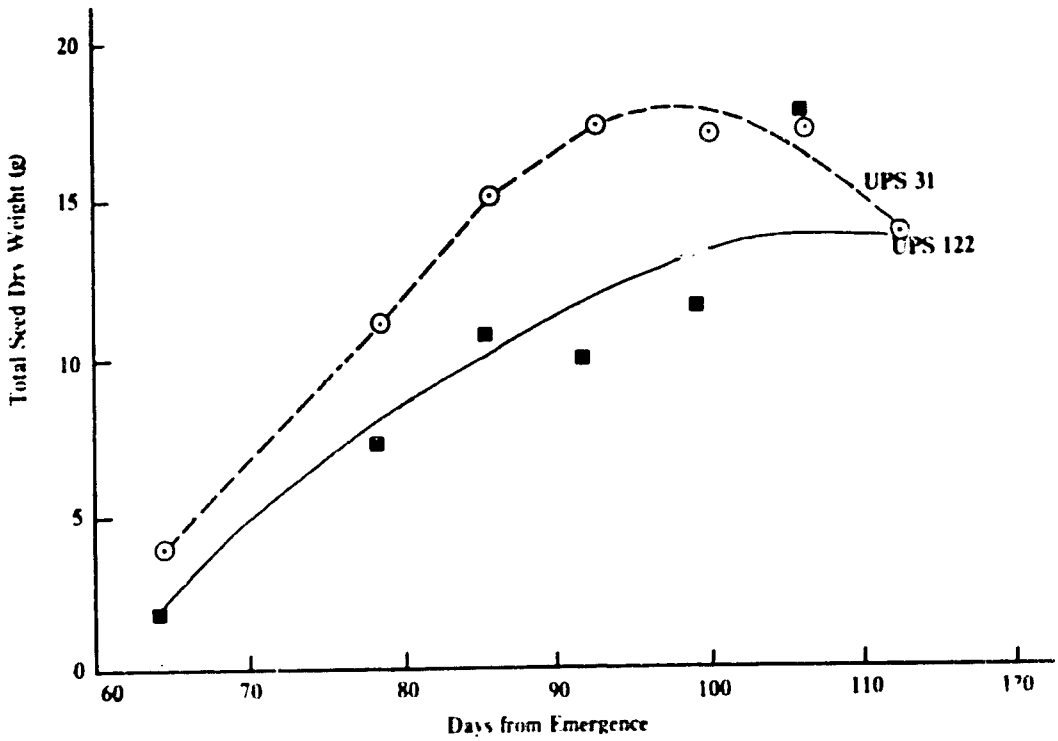


**Fig. 3. Total yield of dry seed per plant of UPS31 and UPS122 at various stages after seed emergence.**

UPS31 had a larger, and more consistent average number of pods and seeds: 13.[illegible] and 77.7 compared with 5.5 and 48.5 for UPS122 respectively. The data suggests that, similar to many other crop plants, the number of seeds is an important characteristic predisposing high yields. Although both had a similar number of potential fruiting sites, UPS31 set more fruits. Presumably, the contribution by adjacent leaves to the accumulation of dry matter in nearby pods was more direct in UPS31 whereas the fewer, larger pods of UPS122 must depend on the photosynthetic activity of a larger number of more remote leaves for pod filling.

The maximum number of seeds was recorded at 80 days for UPS31 and at 90 to 100 days for UPS122. Because UPS122 continued filling its seeds over a longer period, the yield of UPS122 seed tended to approach that of UPS31 at later harvests. The greater tendency for UPS122 pods to shatter at maturity, however, may have contributed to the relatively small seed yield. The pod wall plus seed data (Fig. 4) show that, at later harvests, the yield of both cultivars is similar. UPS31, however, achieves this in a shorter growing period. The larger number of seeds on UPS31 plants more than compensated for their smaller 100 seed weight of 21.1g. The 100 seed weight of UPS122 was 27.9g.

The actual increase in length and dry weight of main stems continued until 80 and 100 days for UPS31 and UPS122 respectively, similar to that in pod dry weight (Fig. 4). Thus, in both cultivars, vegetative growth

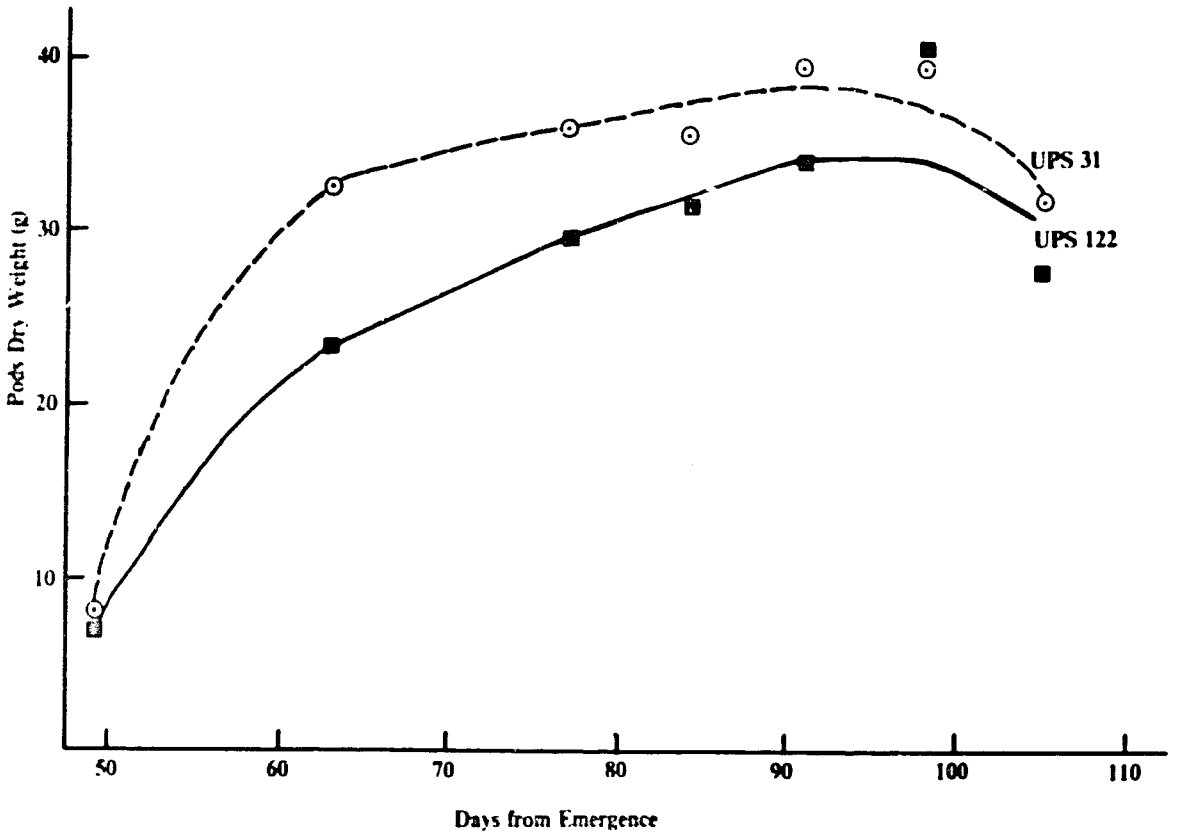


**Fig. 4. Total weight of pods per plant of UPS31 and UPS122 at various stages after seedling emergence.**

competed with that of the economic portion up to the time of pod maturity. There was a difference, however, in the development of side branches between UPS31 and UPS122. The number of side branches in the former levelled off at 4, approximately 50 days after emergence whereas the average number in the latter was 2 side branches until 70 days after which time it increased to about 5 side branches (Fig. 5). This delay in the development of side branches in UPS122 may be important in extending the period of pod development. On the other hand, it may compete with pod filling for available assimilates.

From these preliminary data, it may be suggested that the ideal winged bean plant may have the following characteristics of early maturity with a more compressed flowering period; a large number of relatively small pods; dwarf, bush-type plant with perhaps 4 to 6 side branches, robust stems and high harvest index.

**Density Experiment**

Table 2 shows that density IV (ca 150,000 plants/ha) gave the greatest production of total, above-ground plant dry weight as well as the highest yield of seed. The spacings used for density IV (25cm x 25cm) were similar to those used in traditional cultivation of winged bean in the Papua New Guinea highlands. (Khan, Bohn and Stephenson 1977). Plots at this density produced a dense, closed canopy. The main difficulty in achieving this, howeve was that of providing trellises strong enough to support the mass of plant material.

Although seed pr uced in these plots (density IV) was greater than that at the highest density (ca 360,000 plants/ha), the eight of pod wall material was actually less. Pod number at densities I to V were 44.1, 112.5, 101.0, 157.5 and 178.0 respectively. Thus, competition may have been insufficient to greatly restrict pod set at the highest density but, during seed development, it must have been intense enough to restrict seed filling.

Seed number at densities I to V were 326.8, 766.5, 965.8, 1511.8 and 1381.2 respectively. The corresponding seed sizes (100 seed dry weights) were 25.1 g, 28.1g, 26.6g and 27.5g. Thus the lower seed yields at the highest density were presumably the result of competition which induced seed abortion. Competition dur-

ing seed filling was consequently less at density V than at density IV where the larger number of seed set experienced competition for assimilation during seed filing. Again, the number of seeds rather than the seed size was more important in determining yield.

The optimum planting density using equidistant spacings in approximately 150,000 plants/ha. In practice, however, it is difficult to provide adequate support for plants sown on the square pattern. The optimum density for plants grown on ridges need to be determined. Density experiments with rectangular spacings are now being carried out at the University of Papua New Guinea.

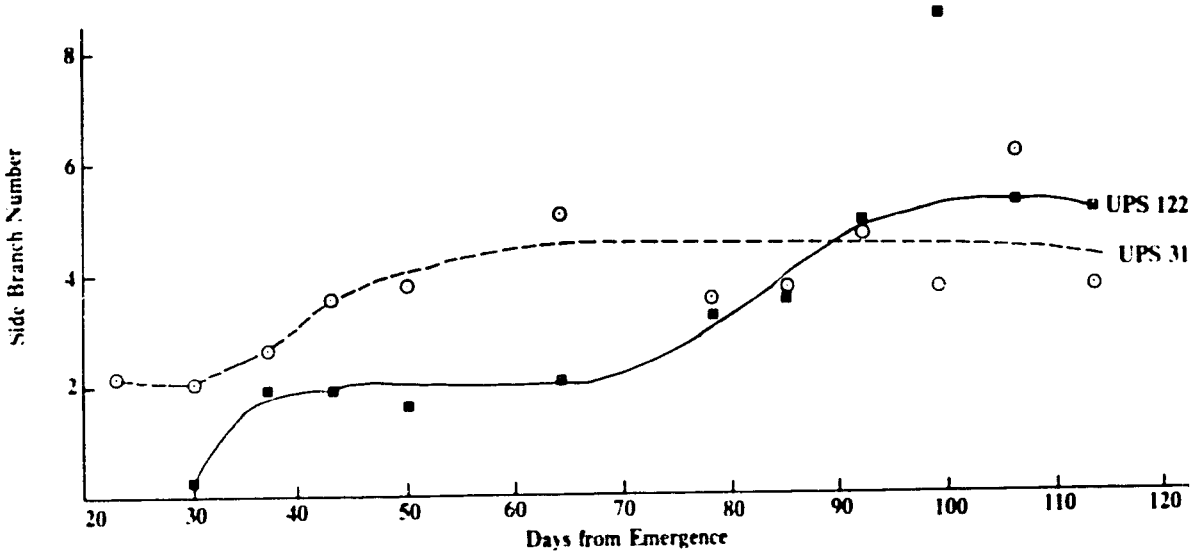


**Figure 5.** Number of side branches per plant of UPS31 and UPS122 at various stages after seedling emergence.

**Table 2.** The dry weights of various plant parts and the total above ground plant dry weight of UPS122 winged bean plants grown at five different densities (I:10,000 plants/ha; II:40,000 plants/ha; III:100,000 plants/ha; IV:150,000 plants/ha and V:360,000 plants/ha) on a square pattern.

| Plant Parts | Dry weights at different densities (mg.) | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | V |
| leaf | 69.7 | 230.3 | 171.1 | 277.3 | 207.3 |
| stem | 93.9 | 294.0 | 237.5 | 435.9 | 416.7 |
| pod wall | 222.1 | 469.5 | 383.1 | 602.2 | 630.8 |
| seed | 93.8 | 215.0 | 265.5 | 400.7 | 372.6 |
| Total Plant | 479.5 | 1,208.8 | 1,057.2 | 1,716.1 | 1,627.4 |

# Winged Bean Investigations at NifTAL: Observational Garden *Rhizobium* Strain Testing and Response Across a Liming Gradient

*Mr. Paul Woomer, Dr. Anacleto Guevarra and Dr. Karl Stockinger*[1]

Three areas of research by the NifTAL Project concerning the winged bean are reported. Two plantings of the winged been were made, first 12 and then 37 additional lines were compared for seed yield, 100 seed weight, pod number, pod length, shelling percentage and percent nitrogen in the green pods. Yields varied from 17 grams to 420 g. of dried seeds per plant. The weight of 100 seeds varied from 21.9 g. to 45.6 g. Pod length varied from 10 cm. to 31 cm. The nitrogen content of green edible pods varied from 3.11% to 5.49%. Pod numbers varied from 6 pods to [illegible] pods per plant. Shelling percentage varied from 42% to 60%. The outstanding varieties under Paia, Hawaii conditions were a long podded selection from the Philippines and MARDI from Malaysia.

Six cowpea-type *Rhizobium* strains were screened for effectiveness on winged bean (Tpt-1 via Fiji). There were no significant differences between the most effective strains. Nodule mass and acetylene reduction were significantly correlated with shoot dry matter production.

Winged bean selection 1014 (Bogor), was grown on a continuous function design lime gradient. The soil pH levels varied from 4.6 to 6.8 across the gradient. Winged bean shoot mass increased twofold between pH 4.7 and 5.5. There were no further increases after pH 5.5. Nitrogen percentage in the tissues showed a similar trend varying from 3.25% at pH 4.7 to 4.03% at pH 6.2.

Nodule mass and acetylene reduction activities were high at low pH levels. Evidence indicates that the winged bean is sensitive $Al^{+++}$ in soil solution, but that it does not have a high calcium requirement.

## INTRODUCTION

Studies of the winged bean (*Psophocarpus tetragonolobus*) at the University of Hawaii NifTAL Project have been pursued from three different aspects in order toevaluate the nitrogen-fixation potential of this legume.

The first approach was to establish an observational garden in order to determine the range in morphology and performance encountered in the species; particularly with respect to pod yield and nitrogen content.

Secondly, a number of *Rhizobium* strains were tested on the winged bean to determine their potential for increasing N fixation through the use of superior *Rhizobium* strains.

Elms (1976) established that the winged bean was nodulated effectively by rhizobia from the host and by CB 756, a *Rhizobium* considered to be a representative of the cowpea miscellany.

Ikram (1977) demonstrated that when the winged bean was innoculated with isolates from other host legumes, there was a wide range in relative symbiotic effectiveness associated with different isolates. Host genera providing isolates which formed the most effective associations included *Psophocarpus*, *Lablab*, *Calopogonium* and *Dolichos* (CB 756). Host legumes associated with the least effective isolates included: *Phaseolus angularis* (adzuki), *Vigna unguiculata* (cowpea), *Arachis hypogaea* (peanut), *Desmodium heterophyllum* and *Samanea saman* (monkeypod).

The objective of this investigation is to establish an effective *Rhizobium* strain to be used in characterizing diurnal changes in nitrogenase activity of the winged bean.

The third aspect studied was the response of winged bean to lime on an acid high aluminum soil, since in many areas of the tropics the soils are highly weathered and are consequently quite acid. These soils are also characterized by deficient levels of bases (especially calcium) and toxic levels of aluminum, manganese or both (Munns, 1976). Aluminum toxicity further affects plant growth by reducing the uptake and translocation

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tion of calcium and phosphorus (Munns, 1977). The availability of molybdenum is depressed in acid soils (Russell, 1973).

There is no one test which accurately measures all of these factors, but soil pH can give a useful index if the soil mineralogy is known.

Fox and Munns (1977) tested a wide range of both temperate and tropical legumes over a pH gradient of 4.75 to 7.1 on a soil high in $Mn^{++}$. They found that both groups showed great diversity in their response to liming. Some of the legumes yielded four or more times as much at pH > 6.2 compared to pH 4.75 (e.g. *Leucaena leucocephala*, *Medicago sativa* and *Phaseolus vulgaris*). Other legumes such as *Stylosanthes gracilis*, *Vigna unguiculata* (cowpea) and *Arachis hypogaea* (peanut) displayed a yield response to lime of less than 100% and attained 90% maximum yield at pH 5.1 to 5.3.

An experiment similar to the one conducted by Fox and Munns was conducted on a high $Al^{+++}$ soil on Maui, to determine the lime responses of several tropical grain legumes on this type of soil. The mineralogy of the soil at the experimental site is dominated by aluminum and iron oxides. It has a pH dependent exchange capacity and differs from the soil employed by Fox and Munns in that the exchange sites of the unamended soil (pH 4.6) are predominantly occupied by $Al^{+++}$. Most of the aluminum is precipitated (as hydroxy aluminum complexes, Tisdale and Nelson, 1966) at about pH 5.2. Thus liming the soil to pH 5.2 should minimize $Al^{+++}$ toxicity effects and further responses to liming would then reflect increased availability of nutrients such as calcium, magnesium or phosphorus.

## MATERIALS AND METHODS

### Observational Garden

Two plantings of winged bean were made on trellises in an experimental garden at Paia, Maui, Hawaii (Typic Haplustoll, 100m. elevation). The first planting (March 14, 1977), consisted of twelve accessions from Mayaguez, Puerto Rico. The second planting (July 15, 1977), consisted of 37 accessions from various sources including some of the same lines from Puerto Rico. Because the seeds were very limited, only two plants per line or variety were grown, using one trellis per pair of plants. The trellises were 4 m. high and were spaced one meter apart. The seeds were scarified with concentrated sulfuric acid prior to planting. Liquid inoculant of *Rhizobium* strain TAL 223 was poured on the seeds at planting. The plants were sprayed with carbaryl insecticide every two weeks to control Noctuid rose beetles. The following data were recorded: (1) seed yield; (2) 100 seed weight; (3) number of pods harvested; (4) pod length; (5) shelling percentage; and (6) the nitrogen content of the green pods. In addition, pod distribution at each meter segment of the trellis was recorded for plants in the first planting. The nitrogen analysis was done by Kjeldahl digestion followed by determination of $NH_4$ by an automatic N analyzer.

### *Rhizobium* Strain Trial

*Psophocarpus tetragonolobus* (Tpt-1, Fiji) seeds were surface sterilized and scarified in concentrated sulfuric acid and then germinated on 10% agar. Three seeds were planted in each vessel and later thinned to two.

Leonard jars with a 750cc volume were prepared using vermiculite as a medium, and a cotton wick (Vincent, 1970). The Broughton and Dilworth (1971) solution used was 0.4 strength adjusted to pH 6.5. Each Leonard jar unit was wrapped in brown paper and autoclaved at 121°C for 1.5 hours. Strains were obtained from the NifTAL culture collection (Table 1) and cultured in yeast extract mannitol mineral broth (YMB) for four days.

**Table 1. Rhizobium strains tested.**

| Strain | Original Host | Area |
|---|---|---|
| TAL 169 | *Vigna unguiculata* | Nigeria |
| TAL 281 | *Desmodium canam* | Hawaii |
| TAL 303 | *Vigna unguiculata* | Philippines |
| TAL 309/CB 756 | *Dolichos africanus* | Australia |
| TAL 420 | *Vigna radiata* | Malaysia |
| UMKL 82 | *Pachyrrhizus tuberosus* | Malaysia |

Host legumes were inoculated after one week using 1.0 ml. of cloudy broth and the growth observed over a 38 day period, refilling the nutrient solution reservoirs as needed.

The winged bean was harvested by cutting at the base of the stem. The shoots were oven dried to constant moisture; and the roots were incubated in 10% acetylene for 0.5 hours after which ethylene production was measured by gas chromatography (Hardy, 1968). Following incubation, the nodules were separated from the roots, counted and oven dried.

### Lime Gradient Trial

A lime gradient was established on a Humoxic Tropohumult (Haiku series), providing a pH continuous function (Bauder, Hanks and James, 1975, Fox, 1973) from pH 4.6 (unamended soil) to 6.8 (17.8 tons lime plus 17.8 tons dolomite ha). Basal fertilizer was applied to eliminate possible deficiencies of P, K, S, Zn, or Mo. Lime gradients were established separately in four blocks, providing four replications, and legumes were grown in rows across the gradients after several months of equilibration and repeated tillage.

Seeds of winged bean selection 1014 (from Dr. Soejani, Bogor) were planted in seedling trays containing vermiculite, inoculated with *Rhizobium* strain TAL 223 (a winged bean isolate), and then transplanted to the field 7 days after emergence on September 11, 1977. One row of plants was established in each block with a plant spacing of 15 cm within the row and 75 cm spacing between the row of winged bean and adjoining rows of other grain legumes.

After ten weeks of growth, the plants in three replications were harvested for dry matter production and nitrogen yield. Acetylene reduction activity and nodule weight were determined at two meter increments (2 plants per sample) along the rows.

Nitrogen in the plant tops and acetylene reduction were determined as described previously except that a lower acetylene concentration (5%) was employed.

Since standard analysis of variance procedures are not appropriate for the continuous function design, the results were averaged and plotted without error estimates.

## RESULTS AND DISCUSSION

### Observational Garden

Yields of dry seed were generally higher (by about 70%) at the first planting compared to the second planting for those varieties common to both plantings (Tables 2 & 3).

The difference in yield was mainly due to the greater numbers of pods at the first planting; 63 pods per plant compared to 30 pods per plant at the second planting.

On the average, the growth period in the first planting was longer (7 months) than the second planting (5 months). This longer growth period permitted more vegetative growth and hence greater reproductive capacities. It is interesting to note that the two high yielding accessions (Table 3) were popular large seeded varieties from Malaysia and the Philippines. The Philippine variety had long pods while the variety from Malaysia had shorter pods but more pods per plant.

The winged bean selections planted at NifTAL showed wide ranges in both productive capacity (35 g. to 838 g. of dry seed per 2 plants) and morphological types, indicating a broad genetic diversity.

**Table 2. Seed yield, green pod nitrogen contents and yield components of the NifTAL winged bean collection.[1]**

| Strain or Cultivar[3] | Seed Yield[2] | 100 Seed Weight | Total Pod Harvested[2] | Pod Length | Shelling Seeds Pod | Green Pod Nitrogen |
|---|---|---|---|---|---|---|
| | g | | No | cm | % | |
| WB6.3 | 838 | 28.5 | 217 | 19.0 | 43.4 | – |
| WB16.11 | 564 | 30.1 | 201 | 17.7 | 49.7 | 4.59 |
| WB15.12 | 555 | 30.7 | 152 | 18.5 | 41.7 | 4.72 |
| WB4.2 | 448 | 31.6 | 83 | 30.0 | 46.7 | 4.34 |
| WB11.2 | 427 | 41.9 | 132 | 17.1 | 41.3 | 3.87 |
| WB12.11 | 385 | 31.6 | 127 | 20.5 | 29.1 | 3.11 |
| WB19.4 | 369 | 27.6 | 120 | 19.7 | 53.3 | — |
| WB19.9 | 318 | 35.3 | 129 | 17.6 | 45.0 | 4.78 |

**Table 2.** *continued*

| Strain Cultivar[3] | Seed Yield[2] | 100 Seed Weight | Total Pod Harvested[2] | Pod length | Shelling Seeds/Pod | Green Pod Nitrogen |
|---|---|---|---|---|---|---|
| | g | | No | cm | % | |
| WB5-1 | 264 | 25.8 | 132 | 11.2 | 44.7 | – |
| WB8-1 | 104 | 26.1 | 62 | 13.3 | 43.1 | – |
| WB10-3 | 63 | 30.4 | 82 | 17.8 | – | 4.16 |
| WB7-2(b) | 40 | 21.9 | 34 | 10.0 | 44.8 | – |

[1]Date planted: March 14, 1977.

[1]Per trellis or two plants.

[3]These strains were obtained from Dr. Franklin W. Martin, Mayaguez Institute of Tropical Agriculture, Mayaguez, Puerto Rico, through Dr. Saleem Ahmed, Resource System Institute — East West Center, Honolulu, Hawaii.

**Table 3.** Seed yield, yield components and green pod nitrogen content of NIFTAL winged bean collection[1].

| Strain or Cultivar | Seed Yield[2] | 100 Seed Weight | Pods[2] | Pod Length | Shelling Percentage | Green Pod N |
|---|---|---|---|---|---|---|
| | g | g | no | cm | % | % |
| MARDI MALAYSIA | 436 | 39.0 | 94 | 20 | 57.9 | 5.49 |
| IRRI PHILIPPINES | 440 | 45.6 | 54 | 31 | 43.5 | 4.56 |
| #5-4 RED RACIPIR | 352 | 38.1 | 96 | 21 | 56.4 | 4.23 |
| WB13-1 | 340 | 35.1 | 74 | 22 | 49.1 | 4.25 |
| WB15-12 | 339 | 39.6 | 90 | 17 | 60.7 | 4.76 |
| WB19-9 | 329 | 36.1 | 76 | 18 | 56.0 | 4.37 |
| HTA (Tpe) | 317 | 34.5 | 66 | 19 | 49.3 | 4.06 |
| WB11-2 | 302 | 42.0 | 55 | 21 | 52.7 | 4.80 |
| WB10-3 | 299 | 36.3 | 58 | 22 | 53.1 | 4.75 |
| U H HORT | 289 | 35.0 | 63 | 19 | 55.5 | 4.14 |
| WB12-1 | 278 | 37.5 | 56 | 20 | 53.2 | 3.74 |
| WB16-11 | 258 | 34.2 | 101 | 18 | 56.1 | 3.91 |
| cv1014 INDONESIA | 247 | 43.9 | 49 | 21 | 55.0 | 4.15 |
| WB19-4 | 235 | 41.0 | 49 | 19 | 57.2 | 4.23 |
| Tpe 1 (FDA 19014) | | | | | | |
| FIJI | 189 | 35.6 | 34 | 30 | 53.3 | 4.34 |
| WB11-4 | 175 | 29.6 | 49 | 20 | 47.7 | 5.15 |
| UPS 71 | 170 | 37.5 | 35 | 19 | 50.4 | – |
| WB12-11 | 157 | 34.2 | 36 | 22 | 50.9 | 3.92 |
| WB4-2 CHIMBU | 152 | 33.4 | 37 | 24 | 50.8 | – |
| WB12-8 | 150 | 45.5 | 26 | 23 | 55.2 | 4.59 |
| WB7-2(a) | 147 | 34.1 | 31 | 16 | 53.3 | 5.01 |
| WB7-3 | 139 | 34.1 | 40 | 18 | 49.2 | 4.09 |
| HTA (Tpe) | 122 | 41.2 | 23 | 26 | 52.3 | 4.41 |
| UPS 31 | 102 | 25.7 | 38 | 10 | 59.4 | – |
| WB8-1 | 99 | 28.9 | 38 | 14 | 51.1 | 4.80 |
| UPS 32 | 97 | 34.7 | 27 | 16 | 52.0 | – |
| WB7-1 | 94 | 25.5 | 36 | 13 | 55.1 | 3.47 |
| WB21-4 | 94 | 37.0 | 42 | 23 | 49.6 | 4.65 |
| UPS 47 | 92 | 27.7 | 30 | 16 | 59.8 | – |
| DOLA | 89 | 35.4 | 23 | 20 | 47.7 | 4.68 |
| UPS 99 | 88 | 31.0 | 27 | 18 | 52.5 | – |
| UPS 45 | 85 | 25.8 | 27 | 15 | 51.0 | – |
| WB6-7 | 72 | 24.4 | 33 | 12 | 53.9 | 4.78 |
| UPS 53 | 71 | 29.6 | 31 | 11 | 52.2 | 4.30 |
| UPS 38 | 63 | 27.3 | 24 | 12 | 55.7 | – |
| WB20-7 | 47 | 37.6 | 12 | 19 | 46.5 | 4.44 |
| WB5-1 | 35 | 22.3 | 16 | 11 | 57.4 | 4.25 |

[1]Planted July 15, 1977.

[2]Per trellis basis (2 plants per trellis)

The weight of 100 seeds varied from 21.9 g. (WB7-2A) to 45.6 g. (Philippines MFS), (Table 3). For the varieties common to both plantings, seed weight was slightly lower at the first planting (32 g/100 seeds) than at the second planting (36 g/100 seeds). Shelling percentage was also higher in the second planting (54%) than the first planting (44%). The length of pods varied from 10.0 cm (UPS 31, WB7-2B) to 31.0 cm (Philippines MFS). Pod length did not appear to be affected by planting date. It seems that more vegetation during the first planting resulted in more pods per plant, but this was compensated by lighter seed weights and lower shelling percentages.

The nitrogen content of the green edible pods varied from 3.11% (WB 12-11) to 5.49% (MARDI-

Malaysia). It seems that the nitrogen content of the green pods was not greatly influenced by the planting date. However, it is interesting to note that the high yielding MARDI-Malaysia variety also contained very high nitrogen in the green pods. More than 70% of the pods of varieties WB16-11, WB11-2, WB10-3 and WB7-2(b) were situated on the lower two meters of the trellis (Table 4). By contrast, varieties WB8-1 and WB19-9 formed the most of the pods at the topmost section of the trellis. It seems desirable to have high yielding varieties with pods distributed at a height from 1 to 2 meters for ease of harvesting.

It was observed that variety Tpt-1 (FDA, 1914) from Fiji was unique in that the reproductive sink is of such strength that the leaves became chlorotic during pod filling, whereas the leaves of all the other varieties remained green during pod filling. Also, WB7-2(B) (UPS 31) produced pods which rapidly photobleached, and (WH7-2(A) had reddish pods. WB12-1 and 12-A (Tpt-3) showed less vegetative vigor than did WB12-11. Of the three selections from the WB-12 series, WB12-1 produced the most seed weight.

Table 4. Percentage distribution of pods along the trellis height.[1]

| Strain or Cultivar | Pod distribution (%) along the trellis (m) | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| WB6-3 | 18 | 21 | 23 | 39 |
| WB16-11 | 42 | 30 | 12 | 16 |
| WB15-12 | 31 | 24 | 19 | 26 |
| WB4-2 | 10 | 46 | 28 | 15 |
| WB11-2 | 55 | 20 | 17 | 8 |
| WB12-11 | 38 | 21 | 22 | 20 |
| WB19-4 | 27 | 19 | 23 | 31 |
| WB19-9 | 24 | 17 | 7 | 52 |
| WB5-1 | 24 | 19 | 33 | 24 |
| WB8-1 | — | 8 | 17 | 75 |
| WB10-3 | 67 | 8 | — | 25 |
| WB7-2(B) | 100 | — | — | — |

[1]Date planted: March 14, 1977.

## *Rhizobium* Strain Trial

No single *Rhizobium* strain proved to be markedly superior for winged bean (Table 5), although most of the strains were significantly better than the uninoculated control. This confirms the usual experience that there is limited strain specificity associated with the promiscuous tropical legumes, and the cowpea miscellany remains miscellaneous.

Certain trends, however, may be detected. Total nodule weight was better correlated with shoot dry matter production (Figure 1) than was the specific activity of root nodules (Table 6). Specific activity was negatively correlated with total nodule weight per plant.

Also there is some indication that average nodule size was correlated with shoot dry matter production. Large spherical nodules would be expected to have a proportionately greater bacteriodal zone than smaller nodules.

Table 5. Performance of six *Rhizobium* strains on winged bean in sterile culture.[1]

| Rhizobium Strain | Shoot Dry Weight (g. per jar) | Nodule Dry Weight (mg. per jar) | Nodule No. (per jar) | Average Dry Weight per Nodule (mg.) | Acetylene Reduction (uM per Hour) Per Plant | Per mg. Nodule |
|---|---|---|---|---|---|---|
| Uninoculated | 1.48 | 12 | 7 | 1.7 | 1.1 | 0.09 |
| TAL 303 | 2.14 | 110 | 29 | 3.8 | 14.7 | 0.13 |
| TAL 420 | 2.15 | 188 | 40 | 4.7 | 20.4 | 0.11 |
| TAL 281 | 2.35 | 160 | 35 | 4.5 | 13.9 | 0.09 |
| USMKL 82 | 2.54 | 215 | 43 | 2.5 | 20.2 | 0.09 |
| TAL 169 | 3.02 | 196 | 22 | 8.8 | 20.8 | 0.11 |
| TAL 309/CB 756 | 3.12 | 245 | 42 | 5.8 | 21.2 | 0.09 |

[1]Average of three replicate Leonard jars, two plants per jar.

Nodule mass was more significantly correlated to shoot weight than was acetylene reduction. Nodule number (as a measure of strain infectivity) was not well correlated with shoot weight production. Acetylene reduction values were rather low. This may be inherent in short term experiments of this kind since the nitrogen content of winged bean seeds is high and the initial seedlings growth is relatively slow.

**Table 6. Correlation of symbiotic parameters with shoot weight of winged bean.**

| | r value |
|---|---|
| Nodule weight per plant | 0.88** |
| Acetylene reduction per plant | 0.82* |
| Average nodule weight | 0.76 |
| Nodule number | 0.62 |
| Average nodule weight | 0.61 |

***Significant at 95%.**
****Significant at 99%.**

Ikram (1977), when working with many cowpea type isolates found no response to inoculation in the field even though he had documented that certain strains were both highly effective on the host and highly competitive against other rhizobia. This does not mean that growth responses to rhizobia inoculation of the winged bean are not possible. However, it does indicate that significant responses to inoculation could be expected only where a) most of the native rhizobia population in the soil are relatively ineffective and b) a very large inocalum of highly effective and highly competitive *Rhizobium* is applied. Such responses are likely to be quite site specific, and consequently it is not possible to make a general statement concerning the need for inoculation of winged bean. We know of no "super effective" *Rhizobium* strain for winged bean, but NifTAL presently recommends use of the Australian strain CB 756. This strain has been proven to be persistent, infective, and effective over a broad range of conditions.

It must be emphasized that a significant response to inoculation would be unlikely in most tropical soils. NifTAL will continue to serve as a repository and distribution agent for *Rhizobium* strains found to be effective on winged bean (and other tropical legumes) and will welcome submissions of strains to the NifTAL collection.

**Lime Gradient Trial**

The dry matter yield of winged bean top growth increased as pH increased from 4.7 to 5.5 (Fig. 2a). This increase was positively correlated with the increase in pH (r = 0.97). This response may have been due in part to higher levels of soil nitrogen (Fig. 2c). However, the increase was out of proportion to that increase in mineral nitrogen, and it is most likely that the increased yield was due primarily to the direct effects of liming on plant growth and symbiosis.

There was no yield response of winged bean to liming above pH 5.5 (Note: shoot yields at pH 5.87 were abnormal and ignored in plotting the data).

Nitrogen percentage in the shoots varied from 3.25% at pH 4.7 to 4.03% at pH 6.2 (again ignoring the pH 5.87 data) and generally followed the same trend as the yield response (Fig. 2b).

Although our results were confounded by a lime effect on the levels of mineral nitrogen in the soil, it seems clear that the winged bean is intermediate in its response to lime. There was an approximate doubling of yield between pH 4.7 and 5.5, with near optimum yields in the pH range 5.2 to 5.5. Apparently winged bean responded to reduced levels of active $Al^{+++}$ but did not require high levels of $Ca^{++}$ in the soil solution for vigorous growth. There was probably a response to the release of mineral nitrogen from the organic matter – especially in the seedling stage before symbiosis was fully effective.

Winged bean proved capable of effective symbiosis at low pH levels. Nodule weight was near maximum at pH 4.8 and decreased markedly over the pH range 4.9 to 6.6 (Fig. 3a) with a negative linear regression coefficient of -0.98. This undoubtedly reflected the increasing supply of nitrogen from mineralization of organic matter as pH increased (Fig. 3c).

Acetylene reduction per plant also was very high at the lowest pH (4.8) and peaked at about pH 5.0 (in contrast to shoot yields which peaked at pH 5.5).

Specific acetylene reduction activity increased with increases of soil pH up to about pH 6.1, thereby compensating somewhat for lower nodule weights. This increase in nodule efficiency may be due to reducted

$Al^{+++}$ toxicity and/or increased $Ca^{++}$ availability, or nearly inhibition of nodulation by high soil nitrogen levels followed by nitrogen stress after the plants became larger, or a combination of these factors.

The high levels of symbiotic performance at low pH indicates that both *Rhizobium* strain and winged bean variety are well adapted to these soils. However there is an indication that mineral nitrogen in the seedling stage can improve yields without seriously reducing nitrogen fixation at later stages of growth.

The site specific nature of these results must be emphasized. Tolerance to one soil acidity factor does not guarantee tolerance to another (Munns 1977). This one experiment cannot provide an overall measure of the tolerance of winged bean to soil acidity in general, and more detailed work will be required to adequately define the potential of the winged bean on highly weathered soils.

**Table 7. Performance of winged bean (cv 1014) at different pH levels, harvested 10 weeks after transplanting, average of three replications.**

| Distance Along Row | Soil pH | Shoot Dry Weight per Meter | N in Shoots | Nodule Dry Weight per Plant | Acetylene Reduction (uM hr) Per Plant | Per g Nodule |
|---|---|---|---|---|---|---|
| m | | g | % | mg | | |
| 0-2 (2) | 4.71 | 65 | 3.25 | | | |
| | | | | 768 | 19.8 | 26.0 |
| 2-4 (4) | 4.87 | 73 | 3.14 | | | |
| | | | | 821 | 21.5 | 26.1 |
| 4-6 (6) | 4.99 | 91 | 3.25 | | | |
| | | | | 801 | 24.7 | 30.9 |
| 6-8 (8) | 5.19 | 121 | 3.67 | | | |
| | | | | 640 | 20.8 | 32.6 |
| 8-10 (10) | 5.50 | 133 | 4.01 | | | |
| | | | | 594 | 25.0 | 41.1 |
| 10-12 (12) | 5.87 | 101 | 4.26 | | | |
| | | | | 494 | 22.8 | 44.3 |
| 12-14 (14) | 6.20 | 135 | 4.03 | | | |
| | | | | 317 | 10.5 | 33.3 |
| 14-16 (16) | 6.43 | 137 | 3.97 | | | |
| | | | | 259 | 8.9 | 36.4 |
| 16-18 (18) | 6.80 | 128 | 3.85 | | | |
| | | | | — | — | — |

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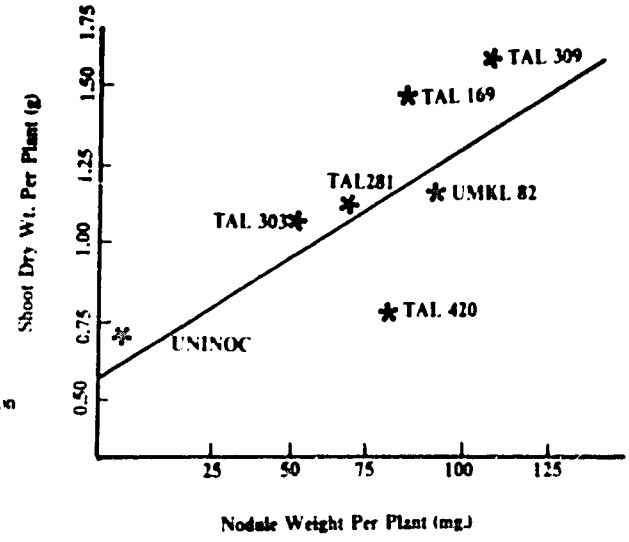


Fig. 1. Nodule dry weight vs. shoot dry matter production on a per plant basis for 38 day old winged beam (Tpt-1) using 6 Rhizobium strains (r = 0.83)

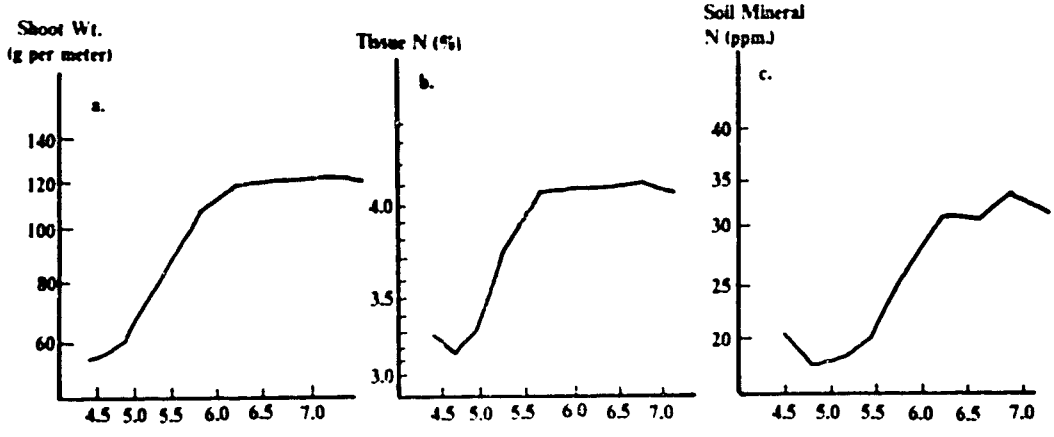


Fig. 2 Response to liming *kuiha* soil: Changes in winged bean shoot weight, percent nitrogen in tissue and ppm extractable soil nitrogen vs. resultant soil pH.

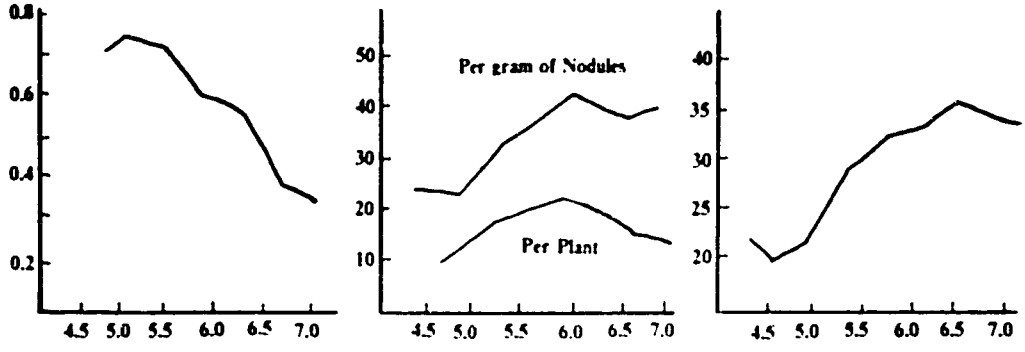


Fig. 3. Winged bean nodule weight and acetylene reduction across the Kuiaha lime gradient.

# Rhizobia in Tropical Legumes: Inoculation of *Psophocarpus tetragonolobus* (L.) D.C.

*Ahmad Ikram*[1] and *W. J. Broughton*[2]

***P. tetragonolobus*** **is an extremely promiscuous legume capable of forming effective symbiotic associations with rhizobia from a wide range of tropical legumes. Because, rhizobia are widely distributed, successful introduction of rhizobia for these plants under field conditions is difficult. As an example, it was found out that a rhizobial isolate which was moderately effective on *P. tetragonolobus* under sterile conditions performed much better in non-sterile soil. The opposite case was also observed wherein an "elite" strain under sterile conditions performed poorly in pots. Obviously, the different responses of inoculant *Rhizobium* to competition from indigenous soil micro-organisms will profoundly affect the performance of this plant under field conditions. In a field trial performed on a soil containing 690 indigenous rhizobia per gram capable of nodulating *P. tetragonolobus*, none of the various inoculants used was responsible for the formation of more than eighteen percent of the nodules. Of the other inoculants tested, two were incapable of producing even a single nodule under these conditions. RRIM 56, the "most promising" isolate in earlier tests, formed 90% of the nodules when the indigenous soil rhizobial population was 5 per gram, and 14% when it was 690 per gram. There were however, some evidence of increasing inoculant representation in the nodules with time.**

## INTRODUCTION

Many tropical legumes, like *Macroptilium atropurpureum*, *Phaseolus lathyroides*, and *Vigna unguiculata* are extremely non-selective in their rhizobial requirements (Norris, 1967). Other legumes like *Leucaena leucocephala* (Trinick, 1968), *Lotononis bainesii* (Norris, 1968), and *Glycine max* (Norris, 1967) have highly specific requirements. Between these two extremes are such legumes as *Centrosema pubescens* (Broughton, Ikram, and Padmanabhan, 1975), *Desmodium* spp, *Dolichos lablab*, and *G. javanica* which possess strain specifically of an intermediate type (Norris, 1967). Furthermore, variation in nodulating ability among host lines and cultivars of *Medicago sativa* (Erdman and Means, 1953), *C. pubescens* (Bowen and Kennedy, 1961), *G. max* (Vest, Weber, and Sloger, 1973), and *Cajanus cajan* (Ramaswami and Nair, 1965) is known. All of these means that introduction of a legume into a new environment is greatly complicated by a variety of unpredictable plant-and soil-related factors.

There is only one solution to this problem — to ensure that due attention is paid to the root-nodule bacteria associated with the legume as well as to normal agronomic criteria. Broughton and John (1978) detailed the normal experimentation of this type, and due to the prominence recently given to *P. tetragonolobus* by the National Academy of Sciences, Washington (1975) we decided to thoroughly investigate the inoculation requirements of this plant. The following summarizes the results of two years investigation into the nature of the *P. tetragonolobus* — *Rhizobium* symbiosis, as revealed in Leonard jar, pot and field trials.

## MATERIALS AND METHODS

Twenty one isolates from *P. tetragonolobus*, and fourteen isolates from twelve other plant genera were isolated, purified, and verified, as rhizobia by standard bacteriological techniques (Broughton and John, 1978; Ikram and Broughton, 1978a). These isolates were used in a preliminary screening trial on *P. tetragonolobus* plants raised in Leonard jars as described elsewhere (Broughton and John, 1978; Ikram and Broughton, 1978a). Based on the results of this trial, selected isolates were chosen for further investigation. The first of the more extensive trials was conducted in a non-sterile virgin soil held in pots as described by Ikram and Broughton (1978a). From these data five isolates were selected for field testing. In order to ascertain the degree of success of the applied inoculants in the complex millieu of the field environment, anti-sera to the

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selected rhizobia were developed in rabbits. When these were used in immunodiffusion arrays, it enabled rapid serotyping of all nodules harvested from the field-grown plants. These techniques are described in detail elsewhere (Ikram and Broughton 1978b). The field experiments were laid down on a free draining Sungei Buloh series soil (loamy sand, pH 5.8, high in organic matter), that had been under weeds, being cropped to maize. Six treatments were used (five rhizobia plus an uninoculated control); the plot size was 3.66 × 3.05 m² with 1.52 m buffer rows between the plots. Each treatment was replicated four times, and the experiment arranged in a randomized block design (see Ikram and Broughton, 1968c).

## RESULTS

*P. tetragonolobus* displayed a wide range of symbiotic effectiveness with different tropical rhizobia (Fig. 1). Of all the isolates tested, only UMKL 67 (isolated from *Pithecellobium jiringia*) failed to nodulate *P. tetragonolobus*. Twenty three of the isolates significantly increased yields of nitrogen over that in uninoculated plants. Of these, five isolates from hosts other than *P. tetragonolobus* were equally as efficacious as the homologous strains (UMKL 36 from *Dolichos lablab*, UMKL 44 from *Calopogonium muconoides*, UMKL 25 from *Canavalia gladiata* and UMKL 56 from *Pueraria phaseoloides*). UMKL 36, RRIM 41 and RRIM 56 produced nitrogen content that were significantly greater than the mean nitrogen content of all inoculated plans ($p$ 0.05). Plant top dry weight was highly correlated with total nitrogen content, although other correlations, as for example between nodule number and plant dry weight, or nodule mass and plant nitrogen content were not significant. Indeed RRIM 56, the top ranked isolate, produced twenty eight nodules weighing 0.11 g while NGR 258 which was ranked twenty fourth in terms of nitrogen accumulation produced forty-five nodules weighing 0.17 g (See Table 1).

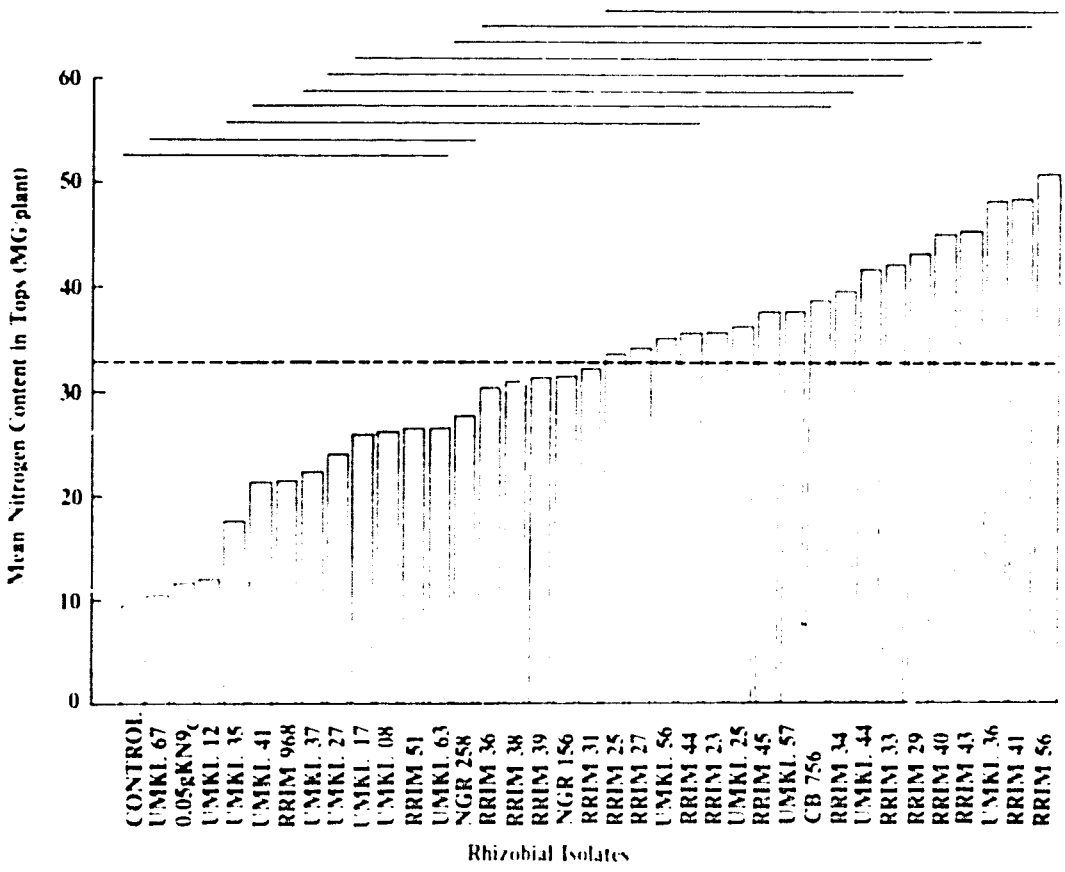


**Figure 1.** Effect of various isolates on the total nitrogen content on the tops of *P. tetragonolobus*. The broken lines represent the means of all inoculated plants. The Range Test Diagram indicated values under a common line are not significantly different from one another at the 5% level.

**Table 1. Nodulation responses of *P. tetragonolobus* to inoculation with different rhizobia (Ikram and Broughton, 1978a).**

| Rhizobial isolate[a] | Host of Isolation | Nodule Number[b] | Nodule Dry weight[b] (g) |
|---|---|---|---|
| RRIM 56 | *P. tetragonolobus* | 28 | 0.11 |
| RRIM 41 | *P. tetragonolobus* | 19 | 0.09 |
| UMKL 36 | *Dolichos lablab* | 21 | 0.10 |
| RRIM 43 | *P. tetragonolobus* | 24 | 0.09 |
| RRIM 40 | *P. tetragonolobus* | 35 | 0.10 |
| RRIM 29 | *P. tetragonolobus* | 21 | 0.08 |
| RRIM 33 | *P. tetragonolobus* | 22 | 0.09 |
| UMKL 44 | *Calopogonium muconoides* | 26 | 0.12 |
| RRIM 34 | *P. tetragonolobus* | 17 | 0.08 |
| CB 756 | *Dolichos africanus* | 21 | 0.07 |
| UMKL 57 | *P. tetragonolobus* | 20 | 0.07 |
| RRIM 45 | *P. tetragonolobus* | 28 | 0.09 |
| UMKL 25 | *Canavalia gladiata* | 23 | 0.09 |
| RRIM 23 | *P. tetragonolobus* | 28 | 0.09 |
| RRIM 44 | *P. tetragonolobus* | 23 | 0.10 |
| UMKL 56 | *Pueraria phaseoloides* | 18 | 0.08 |
| RRIM 27 | *P. tetragonolobus* | 25 | 0.08 |
| RRIM 25 | *P. tetragonolobus* | 21 | 0.09 |
| RRIM 31 | *P. tetragonolobus* | 17 | 0.07 |
| NGR 156 | *P. tetragonolobus* | 45 | 0.21 |
| RRIM 39 | *P. tetragonolobus* | 18 | 0.05 |
| RRIM 38 | *P. tetragonolobus* | 11 | 0.49 |
| RRIM 36 | *P. tetragonolobus* | 23 | 0.06 |
| NGR 258 | *P. tetragonolobus* | 45 | 0.17 |
| UMKL 63 | *Alysicarpus vaginalis* | 19 | 0.07 |
| RRIM 51 | *P. tetragonolobus* | 26 | 0.07 |
| UMKL 08 | *Centrosema pubescens* | 20 | 0.08 |
| UMKL 17 | *P. tetragonolobus* | 21 | 0.10 |
| UMKL 27 | *Samanea saman* | 16 | 0.06 |
| UMKL 37 | *Desmodium heterophyllum* | 18 | 0.06 |
| RRIM 968 | *C. pubescens* | 20 | 0.05 |
| UMKL 41 | *Arachis hypogea* | 28 | 0.10 |
| UMKL 35 | *Vigna unguiculata* | 10 | 0.04 |
| UMKL 12 | *Phaseolus angularis* | 9 | 0.03 |
| 0.05 g $KNO_3$ | | 0 | 0 |
| UMKL 67 | *Pithecellobium jiringia* | 0 | 0 |
| Uninoculated control | | 0 | 0 |

[a]Ranked in order of decreasing nitrogen content of the plant tops. See Fig. 1.

[b]Number per plant. Means of three replicate jars.

From these studies, isolates RRIM 56, UMKL 36, CB 756, NGR 258, RRIM 968, and UMKL 12 were selected for further investigation. Of these, RRIM 56, UMKL 36, and CB 756 can be considered as 'elite' strains, NGR 258 as a strain of intermediate effectiveness, while RRIM 968 and UMKL 12, which were only poorly effective, were included in future experiments for comparison purposes.

The next series of experiments were designed to test the performance of these selected strains in non-sterile soils containing low-levels of indigenous rhizobia. Under these conditions, significant responses to inoculation with some isolates were observed. RRIM 56 and NGR 258 performed well, but surprisingly the relative performance of CB 756 and NGR 258 was almost exactly reversed from that found under optimal conditions in the Leonard Jar trials (see Table 2). Inoculation with CB 756 or RRIM 968 did not significantly increase dry matter production. This was not due to the lack of nodules (see Table 2), but apparently to different efficiencies of the nodular tissue. Although UMKL 12, and UMKL 36 produced increases in plant top yield, the foliage however, was of pale green colour indicative of nitrogen deficiency.

**Table 2. Symbiotic performance of eight rhizobial isolates when used to inoculate *P. tetragonolobus* in a non-cultivated soil[a] (Ikram and Broughton, 1978a).**

| Rhizobial isolates | Dry weight of tops[b] (g/plant) | Fresh weight of nodules (g/plant) | Nodule[c] number |
|---|---|---|---|
| UMKL 36 | 10.25 | 3.8 | 64 |
| RRIM 56 | 8.76 | 3.4 | 59 |
| NGR 258 | 8.34 | 4.6 | 84 |
| UMKL 12 | 7.87 | 4.6 | 87 |
| RRIM 43 | 7.71 | 2.8 | 41 |
| UMKL 36 | 7.64 | 4.2 | 41 |
| CB 756 | 5.93 | 3.4 | 66 |
| RRIM 968 | 5.05 | 6.6 | 55 |
| Uninoculated control | 4.15 | 1.5 | 7 |
| Significance | ** | ** | *** |

[a]Level of indigenous rhizobia — 1.54/g soil as determined by plant-dilution counts (Date and Vincent, 1962).
[b]Means of five replicate pots.
**$p < 0.01$
L.S.D.... P = 0.05 (2.89) P = 0.01 (3.83)

[c]Means of five replicate pots.
**$P < 0.01$, ***$P < 0.001$

| L.S.D. | P. = 0.05 | P = 0.01 |
|---|---|---|
| Nodule weight | 2.3 | 3.1 |
| Nodule number | 24 | 32 |

In the field experiment, responses to inoculation attributable to the introduced strains were not obvious at harvest (Table 3). In other words, the dry matter yield, and nitrogen contents of the plant tops as well as pod and seed yields were unaffected by inoculation with various rhizobia. Irrespective of treatment, all plants were well nodulated (Table 4). In this particular experimental site, low percentage recoveries of all inoculum strains were achieved. None of the serologically distinct inoculants was recovered in more than eighteen percent of the nodules. Strains UMKL 36 and CB 756 failed to produce any nodule, while strains NGR 258 and RRIM 968 formed very few nodules. Only RRIM 56 showed promise as an inoculant which may be used under field conditions. Even then, its performance was far from satisfactory. However, when some plants were harvested 39 days after planting, RRIM 56 was responsible for ten percent of the nodules formed, which slowly increased to eighteen percent over the next hundred days or so. At the first sampling none of the other inoculants had produced any nodules at all, so we interpret the slow increase in inoculant success to a gradual re-adaptation of the introduced strains to the soil.

In view of the above, the lack of response to inoculation is readily understandable — a soil containing 690 rhizobia per gram capable of nodulating *P. tetragonolobus* possesses sufficient bacteria to occupy the majority of infection sites on the root surface, and the introduced organisms cannot successfully compete with their more numerous soil relatives.

**Table 3. Effect of inoculation on nitrogen contents, foliage, pod and seed yields of field grown *P. tetragonolobus* plants.**

| Treatment | Mean Foliage Weight (g plant$^{-1}$) | N% | Pod Number (per plant) | Pod Weight (g plant$^{-1}$) | Cumulative Seed Yield (g plant$^{-1}$) |
|---|---|---|---|---|---|
| RRIM 56 | 40.4 | 2.62 | 6.8 | 57.5 | 27.6 |
| UMKL 36 | 43.3 | 2.28 | 7.0 | 59.2 | 26.7 |
| CB 756 | 31.4 | 2.46 | 6.4 | 54.5 | 22.6 |
| NGR 258 | 42.9 | 2.28 | 6.5 | 52.2 | 23.9 |
| RRIM 968 | 31.5 | 2.39 | 7.2 | 63.8 | 32.3 |
| Uninoculated control | 45.2 | 2.61 | 7.2 | 62.9 | 28.4 |
| Significance | n.s | n.s. | n.s. | n.s. | n.s. |

Values are means of all plants harvested 142 days after sowing.
Level of indigenous *P. tetragonolobus* nodulating rhizobia — 690 g soil.
Data from Ikram and Broughton (1978c).

**Table 4. Effect of inoculation on nodulation of field grown *P. tetragonolobus* plants.**

| Treatment | Number of Nodules per Root System | Fresh Weight of Nodules per Root System (g) | Percentage Nodules Due to Inoculum (%) |
|---|---|---|---|
| RRIM 56 | 14.4 | 0.47 | 18 |
| UMKL 36 | 15.4 | 0.40 | 0 |
| CB 756 | 13.3 | 0.29 | 0 |
| NGR 258 | 14.5 | 0.41 | 3 |
| RRIM 968 | 15.8 | 0.41 | 3 |
| Uninoculated control | 9.9 | 0.31 | 0 |

Values are means of all plants harvested 142 d after sowing.
Level of indigenous *P. tetragonolobus* nodulating rhizobia — 690 g soil.
Data from Ikram and Broughton (1978c).

## DISCUSSION

The final approach to evaluation of potential inoculant strains, is to test their performance in the complex environment of the field (Vincent, 1970; Date, 1976; Broughton and John, 1978). In this environment, both biological and non biological factors operate in affecting the several levels of symbiosis between a *Rhizobium* and its host (Vincent, 1965; Lie, 1974; Dart, 1974). RRIM 56 performed exceptionally well under sterile conditions, or in other trials where the number of indigenous *P. tetragonolobus* nodulating rhizobia was few (e.g. in pot trials containing 5 rhizobia per gram, 90% of the nodules were formed by RRIM 56), but its response was greatly modified in the presence of competing indigenous soil rhizobia. The promiscuity of the host itself encouraged this effect. As it could be effectively nodulated with organisms from a wide variety of plants, even soils that had not previously been cropped to *P. tetragonolobus* contained large numbers of organisms capable of nodulating the test plant. This in turn made attempts of inoculation in such soils difficult. Whether or not the native soil rhizobia were as effective as the introduced strains cannot be stated from the present data, as the inoculum success was so low, and there is no data based on a completely controlled inoculation of plants raised under identical conditions.

Such results were not unexpected. With *C. pubescens* we could not demonstrate a significant response to inoculation in soils that had previously supported legumes (Ikram, Padmanabhan, John, and Broughton, 1978). Subba Rao (1976) even obtained decreased yields with simple *Rhizobium* inoculations on *Arachis hypogaea* which was explained in terms of competition between introduced strains and native strains resulting from the promiscuity of the genus, and the prevalence of *A. hypogaea* nodulating rhizobia in Indian soils.

These competitive effects were partly, but not wholly, explained in terms of the numbers of competing organisms. Obviously, the numerical advantage enjoyed by the native soil organisms is important. Weaver and Frederick (1974) found that the proportion of nodules formed on *G. max* by the inoculant strain was greater with higher inoculum dosages, when studying competition in twenty two soils containing populations of *R. japonicum*. The effect of different rates of inoculum varies with strain and locality as has been shown with *G. max* (Johnson, Means and Weber, 1965) and with *Trifolium* species (Jenkins, Vincent, and Waters, 1954; Holland, 1970). It seems therefore that the interaction between the native and introduced organisms is complex and worthy of further investigation.

Finally, we must address ourselves to the question of whether inoculation of *P. tetragonolobus* is necessary or even desirable in tropical soils. Obviously, if there has been a history of legume growth on the particular soil, inoculation may be only partially successful. Without determining the most probable numbers of rhizobia present in the particular soil however, it will not be possible to accurately predict the effect of inoculation. Due to this uncertainty therefore, inoculation is recommended. Furthermore, it is suggested that an increasing percentage of nodules due to the inoculant occurs with time, and this could be an important consideration in repeatedly planting *P. tetragonolobus* on the same soil. As suggested above, it may also be possible to increase the chances of inoculum success by experimenting with large numbers of seed borne rhizobia, and/or by changing the methods of inoculation with rhizobia.

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# The Potential for Green Pod Production in Winged Bean

V. Kesavan and W. Erskine[1]

**Ten varieties and an $F_2$ population from a diallele cross of eight selected genotypes of winged bean were assessed for green pod production at the Waigani farm, University of Papua New Guinea during 1976 and 1977. Green pod yield components such as length, width, size and number of pods and time to flower were studied in relation to earliness, combining ability and the spread of harvest.**

Significant differences between genotypes and populations were observed for yield, flowering and yield components except for pod number per plant. The average potential yield varied from 11 to 15 ton/ha. General combining ability for yield, yield-related characters and flowering was two to ten times higher than the specific combining ability, indicating additive genetic control of these characters. Early yield, harvested within 100 days from sowing, accounted for 49% of the total yield. Genotypes and populations were variable in their spread of harvest.

The yield potential of winged bean is compared to the yields of the winged bean in Malaysia and the snake bean in the tropics. Two possible approaches to selection for commercial and subsistence agriculture are also discussed.

## INTRODUCTION

The winged bean (*Psophocarpus tetragonolobus*) (L.) DC.), has received considerable attention in the recent past. Its value as a 'multi-purpose' crop and a source of protein has been recognized (Masefield, 1973; Anonymous, 1975; Claydon, 1975 and Khan *et al.* 1977).

Though the winged bean is grown in the highlands of Papua New Guinea (PNG) for its protein-rich seeds and tubers, young pods are also used as vegetable (Powell, 1976; Khan *et al.* 1977). In West Africa, India and throughout South-East Asia, the winged bean is grown as a minor vegetable crop for its tender, green pods (Pospisil *et al.* 1971, Masefield, 1973; Wong Kai Choo, 1976).

As part of a comprehensive programme on winged bean improvement, work was initiated in 1976 at the University of Papua New Guinea to assess its potential for green pod production. From the wealth of genetic material available in PNG (Khan, 1976), ten accessions were selected for a preliminary yield trial. Eight promising genotypes were utilized in a non-reciprocal diallele cross to understand the inheritance of green pod yield and related characters. The results of two experiments conducted during 1976 to 1977 at the Waigani farm, University of Papua New Guinea are discussed in relation to the potential for green pod production, combining ability of the selected genotypes, earliness, heterosis and harvesting patterns in winged bean.

## MATERIALS AND METHODS

The yield trial consisted of ten selected lines of Papua New Guinean origin (Table 1) planted on August 20, 1976 in a randomized block design with three replications. Individual plot size was 1.5 $m^2$ with parallel ridges 1.5 m long and 1 m apart. Within each row, seeds were dibbled at 30 cm spacing. Harvesting of young pods was started 76 days after sowing and continued over the next two and a half months at 4 to 5 day intervals.

For the diallele cross experiment, eight promising genotypes of winged bean were cross in a non-reciprocal diallele during 1976. Of the eight genotypes, six lines originated from PNG, one from Indonesia (UPS 133), and one from Nigeria (UPS 132). The $F_2$ generation and parental lines comprising 36 populations were planted on May 30, 1977 in a randomized block experiment with three replications. Individual plot size was 2.1 $m^2$ with plots 3 m long and 70 cm apart. Within rows, plants were sown 48 cm. apart.

Both experiments received fertilizer at the time of planting. The rate of application per hectare was 60

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**Table 1. Green pod yield and yield components in winged bean.**

| Accession | Yield per 1.5 sq. m plot (kg) | Mean: Yield plant (gm) | Mean: No. of pods plant | Mean: Pod Size (gm) | Mean: Pod length (cm) |
|---|---|---|---|---|---|
| UPS 2 | 2.7 | 287.2 | 22.9 | 12.6 | 18.6 |
| UPS 31 | 1.5 | 166.2 | 37.2 | 6.6 | 10.5 |
| UPS 34 | 1.9 | 209.7 | 31.1 | 6.7 | 11.5 |
| UPS 45 | 1.7 | 253.8 | 33.2 | 7.6 | 12.8 |
| UPS 47 | 2.4 | 289.2 | 33.5 | 8.7 | 14.9 |
| UPS 67 | 2.7 | 337.7 | 29.7 | 11.2 | 17.3 |
| UPS 81 | 2.6 | 282.0 | 29.7 | 9.4 | 14.6 |
| UPS 100 | 2.4 | 279.0 | 24.4 | 11.5 | 16.7 |
| UPS 115 | 1.3 | 162.3 | 17.2 | 9.5 | 13.5 |
| UPS 122 | 3.9 | 466.9 | 25.9 | 16.8 | 22.3 |
| Grand $\bar{x}$ | 2.3 | 273.4 | 27.3 | 10.1 | 15.3 |
| S.E. ± | 0.48 | 57.28 | N.S | 0.68 | 0.98 |
| L.S.D. at 5% level | 1.08 | 120.34 | — | 1.44 | 2.05 |

kg N, 55 kg P and 86 kg K. After emergence, plants were trained up on wood and string trellises, 2m above ground. Weeding, irrigation and prophylactic spraying were undertaken as and when necessary.

The number of plants per plot and pod length of 10 to 15 random pods were recorded. At each harvest, pod number and weight were also measured. In addition, the number of days to first bloom and pod width was recorded in the diallele experiment. From these observations, green pod yield per plot and per plant, average pod size and number per plant, average pod length and width and finally the time from sowing to bloom were calculated and used for statistical analysis.

Two of the $F_2$ families (UPS 31 x 99 and UPS 89 x 99) showed no segregation of marker genes and were presumed to be self-pollinated. For these two families substituted values were obtained by averaging the figures for the families in the arrays. Following a preliminary analysis of variance, the diallele results were analyzed for combining abilities as in Method 2 Model 1 of Griffing (1956). Heterosis from either the mid parent (P) or better parent (B.P.) was calculated as

$$\frac{\bar{F}_2 - \bar{P}}{\bar{B.P.}} \times 100 \text{ and } \frac{\bar{F}_2 - \bar{B.P.}}{\bar{P}} \times 100$$

## RESULTS

Significant differences between genotypes were observed for green pod yield, pod size and pod length in the yield trial. The character pod number per plant however, was not significant. The results are presented in Table 1.

Yield per 1.5 $m^2$ varied from 1.3 to 3.9 kg with an average of 2.3 kg. This would give an average yield of 15 ton/ha and a range of 8 to 26 ton/ha. UPS 122 which recorded the highest yield per plot (3.9 kg) and per plant (467 g) also had the highest pod size (16.8 g) and pod length (22.3 cm.)

The early yield, calculated by pooling the pod yields of the first five harvests, accounted for 49% of the total yield over 15 harvests. This early yield was harvested within 99 days from sowing. It varied from 0.6 to 1.7 kg/1.5 $m^2$ with an average of 1.1 kg/plot or 7.6 ton/ha. The highest early yield was given by UPS 99. The pattern of harvest over the 2.5 month period showed two peaks; a first peak on the 76th day and a second one in the tenth harvest taken on the 132nd day from sowing.

Significant differences between populations were also observed in the diallele experiment for all the characters except the pod number per plant. Parental means and analysis of variance of combining abilities for the characters with significant differences between populations are shown in Tables 2 and 3.

Green pod yield varied from 0.9 to 3.7 kg/plot or 4.7 to 17.8 ton/ha with a mean yield of 10.9 ton/ha. The $F_2$ populations showed positive heterosis ** in both the mid parent mean (34.1 ± 7.0%, P < 0.001) and the better parent 12.3 ± 6.4%, P < 0.05 > 0.1) for green pod yield per plot. Since there was no significant

**Table 2. Mean squares for combining abilities for characters with significant genotypic effects.**

| Source | d.f | Yield/plot | Yield plant | Pod size | Pod length | Pod width | Flowering |
|---|---|---|---|---|---|---|---|
| Replications | 2 | 11.65** | 59.758* | 3.44 | 2.65 | 0.171 | 2.79 |
| Populations | 35 | 1.26** | 4.725* | 8.49** | 16.47** | 0.143** | 15.25** |
| G.C.A | 7 | 2.64** | 8.970* | 34.01** | 68.61** | 0.550** | 28.86** |
| S.C.A | 28 | 0.91* | 3.663 | 2.10** | 3.43** | 0.041* | 11.84* |
| Error | 70 | 0.44 | 2.465 | 0.58 | 0.92 | 0.021 | 6.30 |

**Table 3. Parental means with standard errors, $F_1$ range and mid-parent heterosis (%) for characters with significant genotypic effects.**

| Parents | Yield kg 2.1 m² plot | Yield g plant | Individual pod size | Pod length cm | Pod width cm | Days to flowering |
|---|---|---|---|---|---|---|
| UPS 31 | 1.40 | 93.5 | 5.9 | 11.0 | 1.9 | 46 |
| 66 | 0.99 | 74.1 | 6.2 | 10.8 | 1.5 | 44 |
| 89 | 1.47 | 98.3 | 5.9 | 9.6 | 1.8 | 48 |
| 99 | 1.75 | 122.8 | 8.9 | 11.5 | 1.9 | 43 |
| 121 | 2.74 | 193.7 | 8.8 | 13.0 | 2.2 | 45 |
| 122 | 2.43 | 161.5 | 11.1 | 17.4 | 2.2 | 47 |
| 132 | 1.35 | 109.8 | 11.9 | 18.6 | 2.5 | 54 |
| 133 | 2.50 | 160.7 | 10.1 | 16.6 | 1.6 | 50 |
| S.E. ± | 0.38 | 28.7 | 0.4 | 0.6 | 0.1 | 1.0 |
| $F_2$ Range | 1.05-3.74 | 89.0-243.0 | 6.0-11.7 | 10.3 – 19.2 | 1.7-2.3 | 43-50 |
| Heterosis (%) | 34.1 ± 7.0*** | 32.8 ± 6.1*** | −2.0 ± 2.0 | − 1.5 ± 1.7 | 1.5 ± 1.4 | |

heterosis for average pod size, heterosis in green pod yield was due to the variable character pod number per plant. Both green pod yield per plot and per plant had significant general combining ability effects. However, yield per plot also had significant specific combining ability. Despite the lack of heterosis for the characters associated with pod shape (pod size, length and width), all the three characters showed highly significant general combining ability variances that were at least ten times larger than their respective specific combining ability variances. This indicates that additive genetic effects are important in the control of these characters and selection between families for a particular pod size or shape would be fruitful.

The earliest mean time to flower from sowing was 43 days with the latest 54 days. Flowering continued far in excess of nine weeks until harvesting was discontinued. Both general and specific combining ability effects were significant for flowering. General combining ability for flowering accounted for 44.4% of the total variation.

## DISCUSSION

The present results on green pod production in the winged bean clearly demonstrate the horticultural potential of this crop. The average yields of 11 and 15 ton/ha obtained in the two experiments compares favourably with the yields of snake beans (*Vigna sinensis*) in lowland Papua New Guinea (Khan et. al. 1976) and other countries (Pospisil *et al.* 1974, and Wong Kai Choo, 1976). The winged bean outyields French bean (Knott and Deanon, 1967), another popular vegetable.

However, Wong Kai Choo (1976) recorded green pod yields of 35.5 ton/ha in winged bean under Malaysian conditions, more than twice the yield obtained in the present studies. The use of adapted varieties, suitable cultural and environmental factors may account for this difference. Two selected lines, UPS-121 and 122, showed a greater potential of 17 and 26 ton/ha of pod yield, respectively. The yield trials with selected genotypes and $F_3$ families are being extended to other sides in Papua New Guinea to assess the stability of performance across differing environments.

The greater general combining ability of the genotypes for green pod yield, yield related characters and flowering indicates that these characters are under additive genetic control. Selection for earliness and high yield could prove successful.

Two approaches to selection are possible. In market gardening, where there is a premium on early yield, genotypes could be selected for earliness. Our results on early yield (49% within 100 days from sowing) agreed closely with those of Pospisil *et al.* (1971). Genotypes such as UPS 99, 121 and 122 will be useful for this type of commercial agriculture. Alternatively, selection could be pursued for extended periods of harvest to suit subsistence agriculture and home gardening. Here again, a plant breeder can operate successfully, using the genetic diversity that exists in this crop. The differing pattern of harvest is not understood clearly at present and seems to be associated with the various character pod number per plant.

Another future possibility for maximizing green pod yield would be through the use of heterosis that is expressed in winged bean. Commercial exploitation of hybrid vigor may depend on quicker and efficient techniques such as male sterility.

Reports on the nutritive value (Platt, 1962; Pospisil, 1971; Claydon, 1975) indicate that the winged bean pod is a good source of calcium, iron and vitamin A as compared to other vegetable legumes. To avoid stringiness and to maintain good cooking quality, frequent harvests at 3 to 5 day intervals are necessary.

## ACKNOWLEDGEMENT

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# Effect of Lime and Inoculum on Nodulation and Growth of *Psophocarpus tetragonolobus* and *Arachis hypogaea*

*Zulkifli Shamsuddin* and *Aini Zakaria*[1]

**The effects of lime and inoculum on nodulation and growth of winged bean (*Psophocarpus tetragonolobus* (L.) DC) and groundnut (*Arachis hypogaea* L.) were studied in pots over a 112-day period using an uncultivated Serdang sandy loam soil of pH 3.6 (1:2.5 suspension of soil in 0.1N KCl).**

**In both the winged bean and groundnut, liming to pH 4.3 increased nodule dry weights and leaf N. The perennial winged bean showed increased effective nodulation throughout the experiment. The annual groundnut showed no significant increase in nodulation after reaching a maximum at 56 days. The initial growth period for effective nodulation for both crops was between 28 and 56 days.**

**Liming significantly increased dry matter production of both crops and raised the groundnut yield by 66%.**

**Liming improved the effective nodulation and growth of both winged bean and groundnut. Seed inoculation with NGR156 and CB756 had no effect on nodulation or growth of either crop, indicating the competitive ability and effectiveness of the indigenous rhizobia.**

## INTRODUCTION

Tropical legumes are generally considered to be more tolerant to acid conditions than most temperate legumes (Norris, 1958). These crops seem to nodulate well under natural conditions without any soil amendments or rhizobial inoculation. Winged bean (*Psophocarpus tetragonolobus* (L.) DC), a tropical facultative perennial, has been found to nodulate heavily and effectively under Malaysian conditions (Masefield, 1961, 1973).

Recent studies have shown that tropical legumes are also responsive to liming and introduced strains of rhizobia. An increased in yield of groundnut (*Arachis hypogaea* L.) has been reported to be due to liming (Adams and Pearson, 1970) and seed inoculation (Hickey *et. al.*, 1974). The beneficial effect of lime could be due to the supply of calcium and other plant nutrients or a reduction in soil acidity, which effects the survival and multiplication of rhizobia, nodulation or symbiotic nitrogen fixation. Little, however, is known of the effects of liming and inoculation on winged bean.

The experiment presented in this paper was undertaken to confirm a preliminary observation by Zulkifli Shamsuddin and Othman Yaacob (1977) by examining the effect of lime and inoculum on nodulation and growth of winged bean. Groundnut, an established annual crop, was included for comparison.

## MATERIALS AND METHODS

Winged bean and groundnut were grown in unglazed clay pots which measured 30 cm in diameter and 20 cm in depth, filled with 5.6 kg (oven dry equivalent) of a nitrogen-deficient, Serdang sandy loam soil (<2 mm size) from an uncultivated plot carrying natural grasses.

A total of 128 pots were used: half was limed at a rate equivalent to 2.5 tons/ha by using ground magnesium limestone, to raise the soil pH from 3.6 to 4.3 (1:2.5 suspension of soil in 0.1N KCl). Nitro 26, Double Superphosphate and Muriate of Potash were applied to supply N:P:K at the rate of 9.5 : 15.9 : 28.3 and 38.2 : 24.3 : 52.9 kg/ha for the winged bean and groundnut, respectively. Nitrogen was used only in the basal application but phosphorus and potassium were applied twice, the second as a top dressing, a month later.

The seeds were inoculated and planted a week after liming. Winged bean was inoculated with NGR 156 (an isolate from winged bean) and groundnut with CB756. To ensure sufficient numbers of viable cells pre-

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sent, the coir dust inoculum compost was moistened with water and applied at the recommended rate of 10g/20 lb seeds (John, 1966). The experiment was arranged in a randomized complete block design.

Two plants per pot were maintained throughout the 112-day experiment for the perennial winged bean, which required staking, while the smaller, annual groundnut had three plants per pot. Watering was done once daily except on hotter days when midday temperature reached between 32° and 39°C.

Four harvests were made at 28-day intervals. Nodules were carefully removed, oven-dried at 75°C for 2 hours and weighed. Leaf, stem and root weights were taken after drying at 60°C for four days. At the second and subsequent harvests, weights of groundnut pods and nuts were also recorded.

The dried leaves were digested using concentrated sulphuric acid and hydrogen peroxide and their nitrogen contents were determined on an autoanalyzer (Thomas *et. al* 1967). Soil pH was determine in a 1:2.5 ratio with water and 0.1N KCl

## RESULTS

### Effective Nodulation

Liming produced a significant increase in the nodule dry weights and leaf nitrogen of both winged bean and groundnut. In winged bean, these increases correspond directly with age of the plant; the maximum values for plants with unlimed and limed treatments, after 112 days, were 91 and 301 mg/plant for nodule dry weight and 33 and 107 mg/plant for leaf N content (Figure 1). Plants with unlimed treatment took twice as long to reach these maximum levels as compared to those with limed treatment. The respective maximum values in plants with unlimed and limed treatments, after 56 days, were 20 and 42 mg/plant for nodule dry weight and 30 and 52 mg/plant for leaf N content (Figure 1). The leaf N concentrations in both crops, under all treatments, showed a decline after reaching their peaks at 56 days.

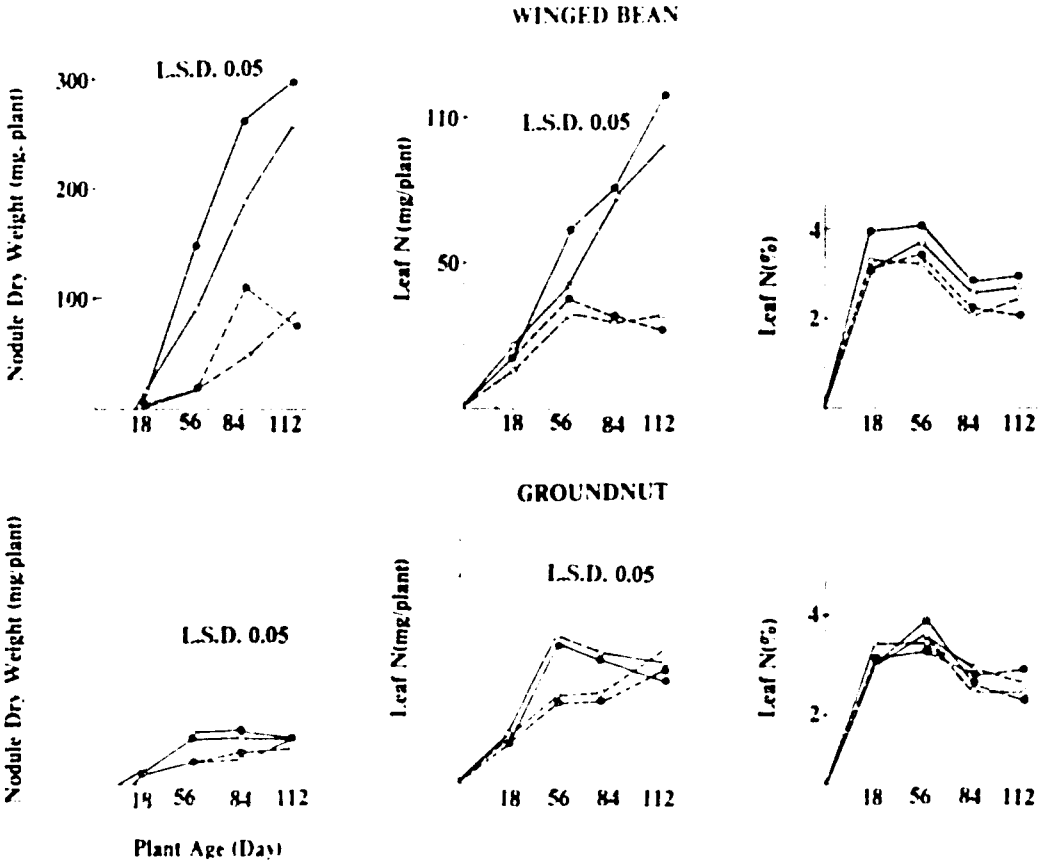


Fig. 1. Nodule dry weight and leaf N of winged bean and groundnut (—•—•—Limed, Inoculated; —•—•— Limed, Non-inoculated; ··•·•·· Unlimed, Inoculated ··o·o·· Unlimed, Non-inoculated).

Inoculation with NGR156 or CB756 did not affect the nodule dry weight and leaf N content of either crop.

## Growth

1. **Root and dry matter production (tops).** In the perennial winged bean, both unlimed and limed treatments showed a marked increase in root and dry matter (DM) production with time; the lime treated plants gave distinctly higher values than those unlimed (Table 1). The root ratio is higher in plants with unlimed treatment compared to those limed. Root weight of the annual groundnut showed an increase until the 56th day. No observable growth could be detected during the subsequent four weeks, which corresponded to the flowering stage and the initiation of podding, but was later followed by a marked increase due to full podding stage (Table 2). Greater root growth was recorded a slower increase in DM. The delayed maximum DM value, 3.17 g/plant, was lower than that from limed treatment 3.53 g/plant, which was obtained from 84-day plants. The latter value subsequently dropped, due to plant senescence. Pod formation also caused a doubling in the root ratio of limed plants to a maximum of 0.43, after 112 days of growth. The root ratio for groundnut, like the winged bean, were higher in unlimed plants. No response to inoculation was observed for either crop.
2. **Groundnut yield.** An increase in pod size was observed throughout the experiment, after 56 days of growth. Liming resulted in a 50% increase in the weight of pods, to a maximum weight of 4.34 g/plant, and raised the percentage of filled nuts to 70% (Table 3). Liming also increased the yield of total nuts by 66%. Seed inoculation did not produce any effect on yield of groundnut.

**Table 1.** Root growth and dry matter (DM) production of winged bean.

| | Sampling Period (Days) | Soil pH | | Uninoculated | | | Inoculated | | |
|---|---|---|---|---|---|---|---|---|---|
| | | KCl+ | $H_2O$ | Root (g/plt) | DM (g/plt) | Root Ratio | Root (g/plt) | DM (g/plt) | Root Ratio |
| UNLIMED | 28 | 3.7 | 4.5 | 0.51 | 0.51 | 0.99 | 0.51 | 0.71 | 0.73 |
| | 56 | 3.7 | 4.6 | 1.03 | 1.60 | 0.65 | 1.14 | 1.74 | 0.66 |
| | 84 | 3.6 | 4.4 | 1.38 | 2.06 | 0.67 | 1.60 | 2.19 | 0.74 |
| | 112 | 3.6 | 4.4 | 1.63 | 2.27 | 0.72 | 1.89 | 2.31 | 0.82 |
| LIMED | 28 | 4.4 | 5.5 | 0.54 | 0.86 | 0.63 | 0.48 | 0.56 | 0.85 |
| | 56 | 4.2 | 5.3 | 0.77 | 1.87 | 0.41 | 1.05 | 2.54 | 0.41 |
| | 84 | 4.2 | 5.3 | 1.96 | 4.70 | 0.42 | 1.74 | 4.25 | 0.41 |
| | 112 | 4.1 | 5.2 | 2.67 | 5.87 | 0.46 | 3.39 | 6.52 | 0.52 |
| | L.S.D. 0.05 | | | 0.19 | 0.57 | | 0.19 | 0.57 | |

+ pH in a 1:2.5 suspension of 0.1 N KCl.

**Table 2.** Root growth and dry matter (DM) production of groundnut.

| | Sampling Period (Days) | Soil pH | | Uninoculated | | | Inoculated | | |
|---|---|---|---|---|---|---|---|---|---|
| | | KCl+ | $H_2O$ | Root (g/plt) | DM (g/plt) | Root Ratio | Root (g/plt) | DM (g/plt) | Root Ratio |
| UNLIMED | 28 | 3.6 | 4.4 | 0.37 | 0.93 | 0.40 | 0.42 | 0.74 | 0.56 |
| | 56 | 3.7 | 4.5 | 0.78 | 1.69 | 0.46 | 0.85 | 1.68 | 0.51 |
| | 84 | 3.6 | 4.3 | 0.88 | 2.24 | 0.39 | 0.88 | 2.01 | 0.44 |
| | 112 | 3.6 | 4.2 | 1.52 | 3.17 | 0.48 | 1.16 | 2.30 | 0.50 |
| LIMED | 28 | 4.2 | 5.1 | 0.31 | 0.90 | 0.35 | 0.25 | 0.85 | 0.29 |
| | 56 | 4.2 | 5.1 | 0.62 | 2.71 | 0.23 | 0.62 | 2.45 | 0.25 |
| | 84 | 4.3 | 5.2 | 0.70 | 3.53 | 0.20 | 0.67 | 3.33 | 0.20 |
| | 112 | 4.2 | 5.2 | 1.18 | 2.94 | 0.40 | 1.11 | 2.59 | 0.43 |
| | L.S.D. 0.05 | | | 0.16 | 0.40 | | 0.16 | 0.40 | |

+pH in a 1:2.5 suspension of 0.1N KCl.

**Table 3. Yield of groundnut.**

| | Sampling Period (Days) | Uninoculated Unshelled Pods | | Inoculated Unshelled Pods | |
|---|---|---|---|---|---|
| | | Weight (g/plt) | Nuts (%) | Weight (g/plt) | Nuts (%) |
| UNLIMED | 56 | 0.14 | 7 | 0.19 | 11 |
| | 84 | 1.23 | 29 | 1.38 | 40 |
| | 112 | 2.90 | 52 | 2.73 | 64 |
| LIMED | 56 | 0.45 | 15 | 0.47 | 14 |
| | 84 | 2.51 | 60 | 2.24 | 57 |
| | 112 | 4.34 | 68 | 3.52 | 70 |
| | L.S.D. 0.05 | 0.44 | | 0.44 | |

## DISCUSSION

### Effects of Lime and Inoculum on Nodulation

The influence of lime on nodulation can be due to the direct effect of reducing soil acidity, the greater availability of molybdenum and reductions in concentrations of aluminum and manganese (Dobereiner, 1966), the increased supply of calcium and higher incidence of rhizobial infections and nodule initiation (Lowther and Loneragan, 1968; Small, 1968), and a higher rate of survival and multiplication of the rhizobia (Anderson, 1956; Munns, 1968). A larger quantity of inoculum could help ensure a greater survival of introduced rhizobial strains in a new soil environment and in their competition with local rhizobia.

In the present study, liming produced a positive effect on nodulation of winged bean and groundnut; no effect due to seed inoculation was observed. According to Ayanaba and Nangju (1974), inoculation without the application of nitrogen, which would provide the necessary root growth in a nitrogen-deficient tropical soil, would not produce any significant effect on nodulation and $N_2$ fixation.

In both winged bean and groundnut, the nodule weight compared favourably with the data by Masefield (1957, 1961). Liming increased nodule weight and leaf N content of both crops. In the perennial winged bean, these plants showed an increasing trend in nodule weight and leaf N content throughout the experiment, although the concentration of nitrogen in the leaves showed a decline after 56 days. Those unlimed showed a marked decrease in nodulation after 56 days of growth, corresponding to the decrease in leaf N concentration. This could be due to the translocation of nutrients during blossoming (Henderson and Kamprath, 1970; Hanway and Weber, 1971) which normally occurs 10 to 11 weeks after planting (Wong, 1975). In annual groundnut, a marked effect was observed due to flowering and podding. The nodule weight and leaf N content declined after reaching a maximum at the 56th day. The data suggest, more evidently in the annual groundnut than the perennial winged bean, that the initial effect of nodulation is between 28 and 56 days of growth. This confirmed an earlier observation by Zulkifli Shamsuddin and Othman Yaacob (1977).

Inoculation did not produce any significant effect of nodulation of both crops. The result indicates the presence of competitive and effective indigenous strains in the soil, supporting the observation by Masefield (1961). Elmes (1976) noted that winged bean nodules formed by strain NGR156 were no more effective than those infected by CB756; the plant has been observed to nodulate well, even without inoculation, in Papua New Guinea. The possibility of a positive effect on nodulation by a more adaptable strain (Vincent, 1976) is, however, not discounted.

### Effects of Lime and Inoculation on Growth

In both winged bean and groundnut, liming produced a significant increase in root growth and DM and gave lower root ratios than non-limed plants. Similar results were obtained by Andrew (1976) in other tropical and temperate legumes. Liming increased pod formation in groundnut and raised the percentage of total nuts formed by 66%. A marked increase in root growth from the 56th day was observed to correspond to the initiation of podding and the decline in DM, after 84 days, to plant senescence.

The nitrogen content in both crops showed higher levels in plant tops from limed treatments. Andrew and Johnson (1976) observed a similar response in plant N due to lime with other nodulated tropical legumes.

The maximum nitrogen content was noted to coincide with the maximum DM, which is in agreement with the finding of Jensen (1944).

Inoculation did not produce any significant effect on growth of both winged bean and groundnut.

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# Agronomy of the Winged Bean in Malaysia

*Wong Kai Choo*[1]

**In a preliminary observation at the University of Agriculture Malaysia (3°N latitude) involving varieties from Papua New Guinea, Nigeria and Malaysia, the period from sowing to flowering was found to range from 57 to 105 days. UPS 122 and UPS 31 were the earlier flowering varieties while Tpt 11 and Tpt 1 were late flowering. Local varieties (ML1 and M 14.4) were intermediate in flowering. Varieties which showed vigorous growth were ML1, M 14.4, UPS 122, Tpt 3, Tpt 11 and Tpt 14.**

**Using local variety (M 14.4), the performance of winged bean plants supported on trellises was compared with unsupported plants. Supported plants flowered earlier, thus giving rise to earlier commencement of ripe pod harvest. Dry seed as well as fresh tuber yields of supported plants were significantly higher than yields of unsupported ones. Comparison among the supported plants showed that those on taller trellis (180 cm) outyielded those on shorter trellis (120 cm) in dry seed yield. Tuber yield was, however, not affected by differences in trellis height. Using different types of trellises (wire-raffia vs. conventional trellises) had no significant effect on both seed and tuber yields.**

**Local variety of winged bean could yield about 35.5 tons/ha. of green pods and 2.0 to 4.5 tons/ha of dry seeds. Tuber yield of 2 to 3 tons/ha could be obtained from plots for dry seed production while higher tuber yield could be expected from plots for green pod production.**

**Frequently encountered pests and diseases on winged bean in Malaysia were aphids, false rust and virus.**

## INTRODUCTION

The Malaysian economy depends considerably on agriculture, based mainly on export-oriented permanent crops. Export of products from rubber, oil palm, coconut and pineapple accounts for about 50% of the total foreign exchange earnings. While Malaysia has progressed well in the production of the major export crops, the production of food crops in general has lagged behind. Thus substantial quantities of food and feedstuffs are imported annually to meet domestic demand.

The major source of plant protein in Malaysia at present comes from soyabean, which is extensively used for human consumption and animal feed. The value of total imports of soyabean and its derivatives amounted to M$29.3 million in 1974 (Table 1). The import trend over 1970 to 1974 indicates that local demand for soyabean has increased substantially.

**Table 1.** Net import of soyabean products in Peninsular Malaysia, 1970-1974[a].

| Product | 1970 | | 1974 | |
|---|---|---|---|---|
| | Quantity | Value (Million M$) | Quantity | Value (Million M$) |
| Bean, Cake, Flour and Oil | 39.900 tonnes | 13.7 | 45.500 tonnes | 28.9 |
| Sauce | 376.00 tonnes | 0.6 | 147.800 tonnes | 0.4 |
| Total | - | 14.3 | — | 29.3 |

[a]Source: Statistical Digest, Peninsular Malaysia Ministry of Agriculture, Kuala Lumpur, Malaysia, 1976.

There is an urgent need to look for a suitable supplementary, if not alternative, source of plant protein. Winged bean, being indigenous in this country, would be the most suitable choice. Moreover, the nutritive value and the composition of the winged bean seeds compared favourably to those of soyabean (National Academy of Sciences, 1975; K. C. Wong, 1976).

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Winged bean, locally called "Kacang botor," has been a long standing crop in this country. The pods are commonly cooked with chillies; sometimes they are eaten raw as salad. Its potential as a heavy nodulating crop was first realized by Masefield (1957) when he carried out a field reconnaisance in Malaysia on the nodulation of leguminous crops.

**Climate**

Malaysia comprises of Peninsular Malaysia (with eleven states) and the States of Sabah and Sarawak. Since winged bean work was initiated in Peninsular Malaysia, this paper will specifically refer to this part of Malaysia. Peninsular Malaysia extends from 1° 15'N to 6° 45'N latitudes and 99° 40'E to 104° 35'E longitudes. It is placed in the zone usually referred to as the humid tropics — the region where winged bean is commonly grown. Winged bean in Peninsular Malaysia is confined mainly to the lowlands of the country, where the average minimum temperature is about 22°C and the average maximum temperature is about 32°C. Relative humidity varies from 85% to 95%. Total annual rainfall ranges from 165 cm to 400 cm, depending on the location within the country.

**Varieties**

Local varieties of winged bean consist of two distinct types. The apparent variation between these two types in their leaflet form. The more commonly grown type (M 14 lines) has broad, ovate leaflets while the other type (e.g. $ML_1$) has lanceolate leaflets. The latter type is mainly confined to the northern parts of the country. This less commonly grown type may have been introduced from Thailand.

The common winged bean type possesses light brown to dark brown seeds. The variation in the seed color was found to be due to the length of storage. Freshly harvested seeds will be light brown in color but through prolonged storage, especially when exposed to air-conditioned environment, the color intensity will increase. The plants produce foliage profusely with mid-leaflet length ranging from 6.5 to 11.2 cm and mid-leaflet width ranging from 5.6 to 11.8 cm. The vines are consistently green in color and the opened flowers are blue, with green calyx. Young pods are all green, including the wings, with rectangular cross-section. Pod length ranges from 14.3 to 24.3 cm with 8 to 15 seeds per pod and mean seed weight of 0.34 to 0.40 g. The plants produce both pods and tubers. Analyses of the dry seeds and tubers are presented in Table 2.

Winged bean varieties have also been introduced from Papua New Guinea and Nigeria. A preliminary observational planting at the University of Agriculture Malaysia (3°N latitude) revealed great diversity in flowering dates among the varieties. The number of days from sowing to first flowering ranged from 57 to 105 days (Table 3). UPS 122 and UPS 31 (from Papua New Guinea) were the early flowering varieties while Tpt 11 and Tpt 1 (from Nigeria) were the late flowering ones. Local varieties ($ML_1$ and M 14/4) were intermediate in flowering.

The varieties also exhibited differences in growth vigour. Varieties $ML_1$, M 14/4, UPS 122, Tpt 3, Tpt 11 and Tpt 14 were very vigorous in growth while UPS 47, Tpt 1 and Tpt 10-1 showed extremely poor growth. In between these two groups, Tpt 2 and Tpt 8 performed better than UPS 71 and Tpt 6, while UPS 31 and UPS 53 showed little vegetative growth.

**Table 2. Composition of seed and tuber of common local variety of winged bean.**

| Items | Seed (full-fat raw) (% of air-dry sample) | Tuber (% of air-dry sample) |
|---|---|---|
| **Proximate analysis** | | |
| Dry matter | 89.06 | 83.87 |
| Ash | 3.73 | 3.09 |
| Ether extract | 15.14 | 0.49 |
| Crude fibre | 0.05 | 8.13 |
| Protein (N × 6.25) | 35.53 | 18.31 |
| N free extract | 26.61 | 53.85 |
| Gross energy (kcal/kg) | 4860 | 4059 |

**Table 2.** *continued*

| Item | Seed (Full-fat raw) (% of air dry sample) | Tuber (% of air-dry sample) |
|---|---|---|
| **Amino acids** | | |
| Aspartic acid | 3.75 | 1.74 |
| Threonine | 1.41 | 0.57 |
| Serine | 1.61 | 0.50 |
| Glutamic acid | 5.67 | 1.19 |
| Proline | 2.10 | 0.31 |
| Glycine | 1.27 | 0.40 |
| Alanine | 1.13 | 0.33 |
| Cystine | 0.53 | 0.04 |
| Valine | 1.19 | 0.44 |
| Methionine | 0.42 | 0.14 |
| Isoleucine | 1.72 | 0.50 |
| Leucine | 2.77 | 0.67 |
| Tyrosine | 0.96 | 0.21 |
| Phenylalanine | 1.05 | 0.31 |
| Lysine | 2.03 | ND |
| Histidine | 0.90 | ND |
| Arginine | 2.16 | ND |
| Tryptophan | ND | ND |

ND — Not determined

**Table 3. Performance of winged bean varieties grown at University of Agriculture Malaysia.**

| Variety | Days to first flowering | Mean pod length (cm) | Growth vigour |
|---|---|---|---|
| UPS 122 | 57 | 24.8 | 5 |
| UPS 31 | 58 | 11.2 | 2 |
| UPS 53 | 61 | 11.1 | 2 |
| UPS 71 | 61 | 15.0 | 3 |
| Tpt 14 | 61 | 18.7 | 5 |
| Tpt 8 | 63 | 11.0 | 4 |
| UPS 47 | 66 | 13.6 | 1 |
| Tpt 6 | 67 | 19.0 | 3 |
| ML 1 | 68 | 24.3 | 5 |
| M 14/4 | 69 | 22.0 | 5 |
| Tpt 10-1 | 69 | 21.4 | 1 |
| Tpt 3 | 74 | 17.7 | 5 |
| Tpt 2 | 79 | 19.8 | 4 |
| Tpt 11 | 90 | 21.7 | 5 |
| Tpt 1 | 105 | 23.0 | 1 |

**Growth vigour rating: 1 = very poor; 2 = poor; 3 = medium; 4 = good; 5 = very good.**

## Staking

It is customary in winged bean growing to support the plants on stake or trellis. Pospisil et. al (1971) have recommended hedge staking of 122 cm instead of pole staking of higher heights. They reported that hedge staking allowed easy harvesting of pods. In Burma, crops grown for tuber production were allowed to trail on the ground (Purseglove, 1968; National Academy of Sciences, 1975). In experiments carried out at the International Institute of Tropical Agriculture in Nigeria, seed and pod yields of plants supported on trellises or poles were more than double the yield of unsupported plants (National Academy of Sciences, 1975). There is no published report on how staking would affect both the seed and tuber yields. A trial was thus set up in 1975/76 to answer the following questions:

1. Is staking the plants essential for high seed and/or tuber yields?
2. If staking is essential, will different height of trellises affect the production of seeds and tubers?
3. Will different types of trellises used affect the seed and tuber yields?

## MATERIALS AND METHODS

The experiment was conducted on the farm area at the University of Malaya from June, 1975 to January 1976. A randomized complete block design with four replications was employed in this study. Plot size was 6.0 × 3.6 m with 90 cm between plots. The experimental area was rotovated twice and during the second rotovation 560 kg/ha magnesium limestone was incorporated into the soil. Seeds of a local variety (M 14/4) were sown on 26th June, 1975 in rows 60 cm apart with 60 cm between plants in a row. Initially three seeds were planted per hole and 2 to 3 weeks later the seedlings were thinned down to 1 plant per planting point. The seeds were not treated with any inoculum.

Fertilizers were applied at the rates of 40 kg/ha N, 80 kg/ha $P_2O_5$ and 50 kg/ha $K_2O$ in the form of ammonium sulphate, double superphosphate and muriate of potash, respectively. All the phosphorous dosages were applied at planting; half the dosages of nitrogen and potassium were applied at planting while the other half at 5 weeks after planting. The fertilizers were applied in between planting rows.

The treatments investigated were:

$T_1$: Control — the plants were not given any support.
$T_2$: Wire raffia trellis of 120 cm high.
$T_3$: Wire-raffia trellis of 180 cm high
$T_4$: Conventional trellis of 180 cm high

### The Wire Raffia Trellis

The wire raffia trellis was made up of two heavy posts set at the ends of each plant row and with two strands of No. 10 wire fastened to the posts, one at the top and the other near the base. The bottom wire was maintained at 30 cm from the soil surface while differences in trellis height was achieved by altering the height of the top wire. Raffia was strung between the two wires in a zigzag manner, with the point of each "V" accommodating one plant. The plane of the trellis for each plant row was vertical. Such a trellis is easy and fast to construct and the heavy posts and wires can be used again for many plantings.

### The Conventional Trellis

This type of trellis is commonly used by local farmers to grow trailing plants, including winged bean. It was made up of long sticks driven into the ground near the bases of the plants. The upper ends of the sticks in one plant row were tied to the corresponding sticks in the adjoining row to increase the stability of the trellis. This was further aided by passing a common wire through the tied ends of the two rows of sticks; the wire being fastened to two heavy posts set at the ends of the plant row. The height of the trellis was taken as the height of the common wire from the soil surface. The plane of the trellis for each plant row was about 25° to 30° from the vertical. This type of trellis is tedious to construct and a great amount of long sticks are needed.

## RESULTS

### Vegetative Growth

Sampling of plants was carried out at 9 weeks after sowing. Four plants were randomly sampled from each plot. Leaf area, dry matter weights of leaves, vines and roots, nodule number and nodule dry weight were determined from the sampled plants. The results are presented in Table 4.

Though not statistically significant, the unsupported plants ($T_1$) had lower leaf area and dry matter production than all the supported plants ($T_2$, $T_3$ and $T_4$). Nodulation was also poorer in the unsupported plants when compared to the supported plants.

Among the supported plants, those on higher trellis height ($T_3$ and $T_4$) tend to have larger leaf area than those on lower trellis ($T_2$). Nodulation was better on wire raffia trellises than on the conventional trellis.

**Table 4. Effects of staking on vegetative characters at 9 weeks after sowing (on mean per plant basis).**

| Treatment | Leaf Area ($cm^2$) | Dry matter (g) | | | | Nodule No. | Nodule Dry Weight (g) |
|---|---|---|---|---|---|---|---|
| | | Leaves | Vines | Roots | Total | | |
| $T_1$ | 5053 | 14.7 | 10.3 | 1.81 | 26.8 | 29.1 | 0.23 |
| $T_2$ | 5798 | 16.9 | 11.0 | 2.46 | 30.4 | 72.3 | 0.50 |
| $T_3$ | 6490 | 18.9 | 12.7 | 2.55 | 34.1 | 73.9 | 0.55 |
| $T_4$ | 6214 | 18.1 | 11.7 | 1.98 | 31.8 | 35.4 | 0.31 |
| $S.E._{\bar{x}}$ | 1249 | 3.69 | 2.44 | 0.35 | 6.35 | 14.0 | 0.09 |

**Earliness of Flowering and Pod Harvest**

Unsupported plants took longer time to flower hence, later harvesting of pods than supported plants (Table 5). No significant differences were found among the different trellises in their time to flower. The conventional trellis, however, gave earlier pod harvest when compared to the wire-raffia trellis of 120 cm.

**Table 5. Effects of staking on flowering, pod harvest, dry seed yield and tuber yield.**

| Treatment | Days to 50% flowering | Days to first dry pod harvest | Dry seed yield (kg/ha) | Fresh tuber yield (kg/ha) |
|---|---|---|---|---|
| $T_1$ | 96.7 a | 148 a | 203 c | 764 b |
| $T_2$ | 81.0 b | 136 b | 884 b | 2268 a |
| $T_3$ | 80.0 b | 132 bc | 2016 a | 2234 a |
| $T_4$ | 82.2 b | 128 c | 1531 a | 2708 a |
| C.V. | 1.3% | 1.5% | 16.9% | 7.8% |

**N.B. Values in the same column having the same letter are not significantly different at the 5% level of probability based on New Duncan's Multiple Range Test.**

**Dry Seed Yield**

Dry pods and seeds were harvested commencing from 18 weeks to 26 weeks after sowing. Unsupported plants produced significantly less seed yield than supported plants (Table 5). Those supported on 180 cm wire-raffia trellis produced almost 10 times more seeds than the unsupported plants.

Comparison among the supported plants showed that seed yield was affected by trellis height. Plants supported on the 120 cm wire-raffia trellis produced significantly lower seed yield than either the 180 cm wire-raffia trellis or the 180 cm conventional trellis. No differences in seed yield were obtained between the latter two types of trellises.

**Tuber Yield**

Tubers were harvested twenty four weeks from sowing. The fresh weights were determined after washing off all the soil. The results are presented in Table 5.

Unsupported plants produced significantly less tubers than the supported plants. Tuber yields was not affected by either the height of trellis or the types of trellis.

## DISCUSSION

It should be pointed out here that harvesting of pods coincided with the rainy season and the attack by false rust (*Synchytrium psophocarpii*) was quite intense. Rotting of some ripe pods were also encountered. Thus, the yield figures, particularly those for seed yields, were on the low side.

From the results of this trial, it could be concluded that staking is essential for high yield of both seeds and tubers in winged bean. A probable explanation for the increase in yields due to staking would be the encouragement of vine growth and hence leaf area together with better leaf distribution and display. This would allow greater amount of photosynthate formed, thus there would be more translocation of photosynthate for pod and tuber formation. Although the measurements of vegetative characters made at 9 weeks after sowing

did not show significant results, there was an indication of lower leaf area and dry matter productivity of unsupported plants when compared to supported plants. Perhaps, measurements made later than 9 weeks after sowing might show significant results as more vegetative growth would be expected on supported plants than the unsupported ones. Further explanation for the increase in yields, particularly that of seed, on supported plants was the earlier harvesting of pods. This allowed a longer harvesting period of pods on the supported plants. The significant effect of staking on tuber yield has brought to light the question of validity of the practice in Burma where winged bean crops grown for tubers were not provided with supports (Purseglove, 1968; National Academy of Sciences, 1975).

Height of trellis has a significant effect on seed yield but not the tuber yield. Plants on higher trellis (180 cm) produced about twice as much seeds than those on shorter trellis (120 cm). The higher seed yield on higher trellis could again be due to better foliage display of the extra leaf area developed. There is little doubt that had the trellis further than 180 cm been used, the vines would have ever'ned further the higher trellis, it is quite possible that this would have been reflected in extra seed yield. However, too high a trellis would cause difficulty in harvesting the pods formed at the top. This has been noted and reported by Pospisil *et al* (1971).

Although seed yield was increased by higher trellis, no increase in tuber yield was obtained. If the foregoing explanations that higher trellis led to better foliage display and thus more formation of photosynthate were to be maintained, then the failure of increase in tuber yield due to higher trellis could probably be due to limitation of sink capacity of the tubers. This aspect warrants further investigation.

No significant differences in seed and tuber yields were obtained when the wire raffia trellis and the conventional trellis, both of 180 cm high, were used. However, with the conventional trellis, harvesting of pods was found to be more difficult especially those on the undersides of the inverted "V". It was also noted that due to the more "open" nature of the conventional trellis, particularly at position of every two plant rows, more weeds were encountered with this type of trellis even at maturity stage. The construction of the conventional trellis was tedious and the amount of sticks required was difficult to obtain. Driving the stick down near the base of the plant. This was indicated by the result of vegetative measurements in Table 4. Thus between the wire raffia trellis and the conventional trellis, the former is preferred to the latter.

## PESTS AND DISEASES

The most frequently encountered insect pest on winged bean in Malaysia was the aphid.

The common disease on winged bean in Malaysia was the false rust (*Synchytrium psophocarpii*). It was noted that the most severe attack by false rust was at the time of flowering and pod formation stage. When the harvesting period of pods coincided with the rainy season, especially between November to early January, heavy infection by false rust was observed.

In plots where there was heavy attack by aphids, it was noted that curled-leaf virus occurred.

## CONCLUSIONS

It is essential to support winged bean plants to obtain good yield of seeds and tubers. The height of trellis should not be too low as to cause reduced seed yield or too high as to cause difficulty in pod harvesting. A trellis height of 180 cm is recommended. The wire raffia trellis of 180 cm is considered to be an ideal type of trellis as it is easy and fast to construct and more effective in controlling weed growth.

### Harvesting and Productivity

The harvesting pattern of local variety of winged bean depend on the products harvested. For green pods, harvesting commenced at about 13 to 14 weeks after sowing and continued for about 12 weeks. Peak harvests occurred at 3 to 8 weeks after commencement of harvest (Fig. 1). The total yield from the first 10 weeks of harvest accounted for about 98% of the total yield. Green pod yield of 35.5 tons/ha had been recorded from the local variety.

For dry seeds, harvesting of ripe pods commenced at about 18 to 19 weeks after sowing and continued for about 8 weeks. Peak harvest occurred at 3 to 4 weeks after commencement of harvest (Fig. 2). The

harvest from the first 5 weeks accounted for about 98% of the total yield. Dry seed yield of 2.0 to 4.5 tones/ha had been obtained from local variety.

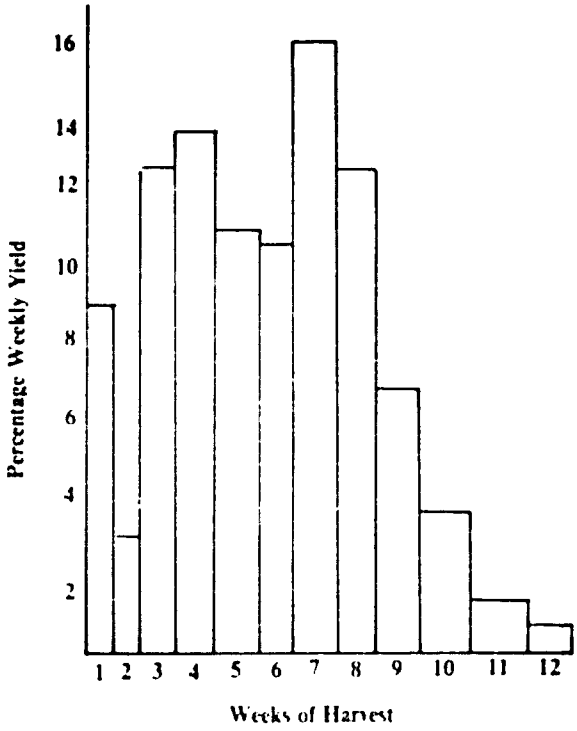


**Figure 1.** Green pod production pattern of local winged bean variety.

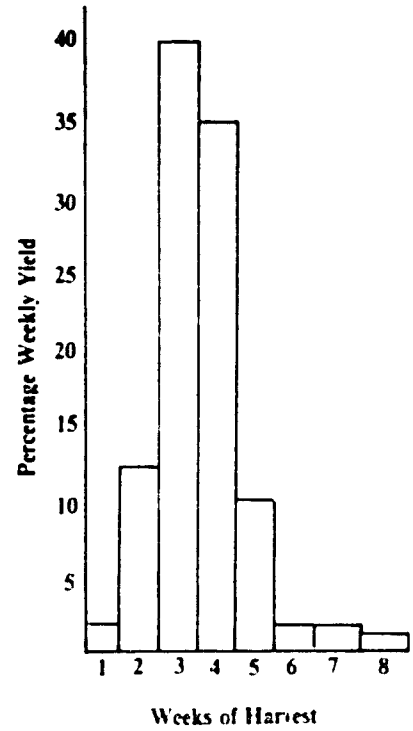


**Figure 2.** Dry seed production pattern of local winged bean variety.

Tubers could be harvested 24 weeks after sowing. There would be an increase in tuber yield if the plants were left in the ground for a longer period. Fresh tuber yield of 2 to 3 tones/ha had been obtained from plots for dry seed production. Tuber yield was found to be double in plots where the pods were harvested as green succulent pods for vegetable than those harvested for dry seed.

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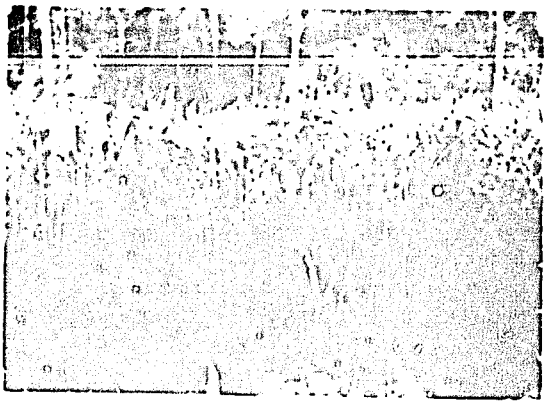

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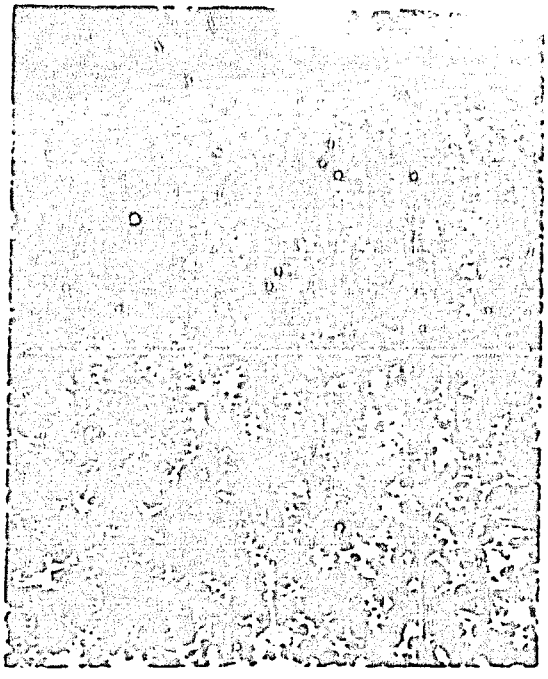

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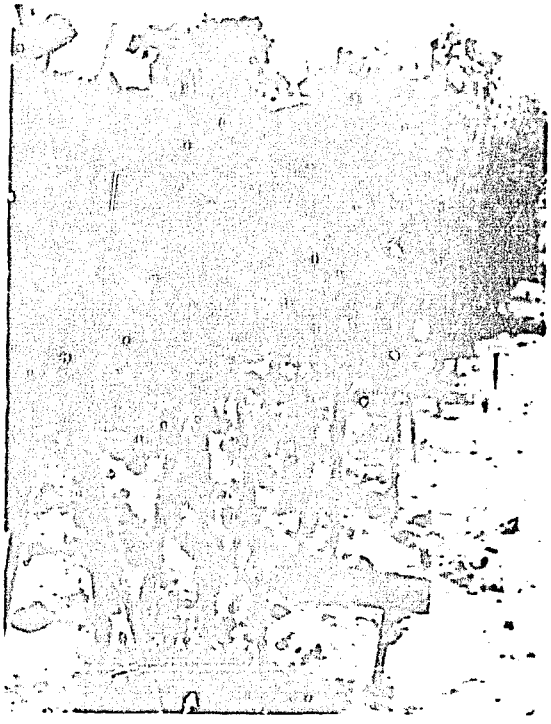

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*1 and 2. Winged bean intercropped with corn in Papua New Guinea. 3. One acre of winged bean field grown for tubers in Papua New Guinea. 4. Tripod forms native plant support in the Philippines. 5. Digging for tubers in Papua New Guinea.*

1

*1 Staking in the Ivory Coast 2 Harvesting for tubers in Papua New Guinea 3 Trellising in the Philippines*

2

3

# Entomology and Pathology

- *Insect and Mite Pests of Winged Bean and their Control*
- *Diseases of the Winged Bean*
- *Investigations of the Biology of Synchytrium psophocarpi (RACI) The Cause of False Rust Disease in the Winged Bean*
- *Some Insect Pests Associated with the Winged Bean*
- *Preliminary Observations on the Arthropod Fauna of Winged Bean at Kade, Ghana*

# Insect and Mite Pests of Winged Bean and Their Control

*K. P. Lamb and Dr. J. V. Price*[2]

**Although the winged bean is an ancient traditional crop in Melanesia there has been little effort to study their diseases and pests until very recently. The crop is generally free of insect pests — especially in the New Guinea Highlands up to 2200 m where it is grown extensively in subsistence gardens. At lower altitudes and especially in drier areas, insect pests can be of importance.**

**Major seedling pests are *Ophiomyia phaseoli* (Tryon) and Epilachnids which sometimes sever the stem. In Guam, *Aphis craccivora* Koch and *Polyphagotarsonemus latus* (Banks) are major pests. Mature flowering plants are sometimes attacked by *Maruca testulalis* (Geyer) and less often by *Lampides boeticus* (L.) or other Lepidoptera. A blotch leaf miner *Leucoptera* sp. (Lyonetiidae) may cause extensive leaf damage in drier areas. The root gall nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood is potentially a serious pest in Papua New Guinea. Minor pests include thrips, red spider mites, pentatomid bugs and leaf-feeding lepidoptera.**

**Insecticides should be avoided where possible. The considerable genetic diversity of the crop should be exploited for insect resistance. Research should be intensified on winged bean pests, their ecology, economic significance and management.**

## INTRODUCTION

Although winged beans have been grown in South East Asia for centuries, they have been grown almost entirely as a vegetable subsistence crop on a small scale. Recently, there has been an upsurge of interest in this crop (Khan et al., 1974; Anon 1975a) since its agronomic and nutritional potential has been recognized (Cerny et al., 1974; Pospisil et al., 1971; Masefield, 1973). The seeds are unusually high in protein (37%) and contain oil (18%) with desirable properties. Nutritionally they resemble soya beans and are better than ground nuts. All parts of the plant can be eaten (shoots, leaves, flowers, tubers, young pods and ripe seeds), while the seed cake and plant residues are acceptable stock food. The richly nodulated roots improve soil fertility.

Several authors agree that this crop is relatively free of diseases and insect pests (Pospisil et al., 1971; Rache, 1973; Anon. 1975a) but there have been no systematic studies made of its insect and mite pests. This paper summarizes the little information available (mostly unpublished) in the hope that this will stimulate more intensive and extensive investigation. If there is a move from subsistence garden cultivation to more intensive cropping we may expect pests and diseases to assume more importance in the future (Lamb, 1974).

## PESTS OF FLOWERS

The most widespread flower pest of winged bean in Papua New Guinea is the bean pod borer *Maruca testulalis* (Geyer) (Table 1). This species attacks a wide range of legumes from the Pacific through eastern Australia, Papua New Guinea and Asia to Japan in the east and India in the west. It also occurs in Madagascar and the southern part of Africa and in South and Central America (Anon. 1975b). In a recent field trial in Port Moresby, 49/158 5 or 31% of the flowers examined were found to be infested at harvest time. Nevertheless there was little pod damage and no effect on yield was observed from this late infestation. Further studies of the effects of this species on winged beans would be desirable.

The other species recorded appear to be of minor significance though *Lampides boeticus* (L.) has been reported attacking the pods and flowers of other legumes in Senegal (Appert, 1964) and East Africa (Le Pelley, 1959).

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**Table 1. Pests of flowers of winged bean.**

| | Taxon | | Country Reference |
|---|---|---|---|
| Lepidoptera: | Pyralidae | *Maruca testulalis* (Geyer) | Papua New Guinea (Lamb, 1976, Fenner, 1976) |
| | Lycaenidae | *Lampides boeticus* (L.) | Whagi P.N.G. (Fenner) Java (Kalsovan, 1958) |
| | Lymantriidae | *Porthesia scintillans similis* Moore | Malaysia (Ooi, 1976) |
| | Yponomeutidae | *Hyenia similis* Moore | (Ooi, 1976) |
| Coleoptera: | Rhizophagidae | *Mimemodes* sp. nr. *maculicapitatus* Champ | Malaysia (Ooi, 1976) |

## PESTS OF PODS

*Maruca testulalis* damage, though not uncommon in Papua New Guinea, tends to be slight and is often restricted to the stem end of the developing pod. No significant damage has been observed from light *Nezara viridula* L. infestation but this cosmopolitan species must be regarded with suspicion as it is a major pest of other legumes (especially of shoots and developing seeds). The other species are of minor importance (Table 2).

**Table 2. Pests of pods of winged bean.**

| | Taxon | | Country Reference |
|---|---|---|---|
| Lepidoptera | Pyralidae | *Maruca testulalis* (Geyer) | Papua New Guinea (Lamb, Young, 1976) |
| | Lycaenidae | *Euchrysops cnejus* (F.) | Malaysia (Ooi, 1976) |
| Hemiptera: | Pentatomidae | *Nezara viridula* L. | Papua New Guinea (Lamb, 1976) |

## PESTS OF BUDS, STEMS AND YOUNG WINGED BEAN PLANTS

The pests of buds, stems and seedlings are shown in Table 3. The bean fly, *Ophiomyia phaseoli* (Tryon), is sometimes a serious pest of seedlings. Larvae bore through the stems and mine the leaves and may kill young plants that are not growing vigorously – particularly in drier conditions in Papua New Guinea. This major pest of grain legumes is distributed from the Pacific through Australia, Papua New Guinea and S.E. Asia to India and Pakistan and also occurs in the Middle East and Africa (Anon, 1974).

**Table 3. Pests of buds, stems and young winged bean plants.**

| | Taxon | | Country Reference |
|---|---|---|---|
| Hemiptera | Aphididae | *Aphis craccivora* Koch | Papua New Guinea (Lamb, 1976) Guam (Muniappan, 1976) |
| | Alydidae | *Riptortus annulicornis* | Papua New Guinea (Young, 1976) |
| | Pentatomidae | *Nezara viridula* L. | Papua New Guinea (Khan et al., 1974) |
| Diptera: | Agromyzidae | *Ophiomyia phaseoli* (Tryon) | Papua New Guinea (Khan et al., 1974) |
| Acarina | Tarsonemidae | *Polyphagotarsonemus latus* (Banks) | Guam (Muniappan, 1976) |

The black bean aphid, *Aphis craccivora* Koch, is commonly found on the shoots of young winged beans in Papua New Guinea but seldom does any harm. On the other hand this species may damage up to 20–30% of the crop in Guam unless it is controlled (Muniappan, 1976). Another major pest in Guam is the cosmopolitan bread mite, *Polyphagotarsonemus latus* (Banks) which may destroy 50 to 60% of the crop (Muniappan, 1976).

The plant suckers *Riptortus* [illegible] and *Nezara viridula* L. may seriously damage or kill small plants through the injection of toxic saliva but so far only small populations have been reported on winged beans in Papua New Guinea.

## PESTS OF LEAVES OF WINGED BEAN

As in other grain legumes a wide range of insects feed on the leaves from time to time (Table 4). Their pest status depends upon climate, natural enemies, age and growth condition of the host and probably varietal susceptibility, which in turn may be influenced by agronomic practices. *Ophiomyia phaseoli*, *Aphis craccivora* and *Planococcus citri* are more damaging to young plants. Dry conditions accentuate the damage caused by these and by *Tetranychus* spp. and *Polyphagotarsonemus latus*. We do not know that environmental conditions favour infestation by the leaf blotch miner, *Leucoptera* sp. This caused serious damage at one stage in Port Moresby field trials in early 1976 but most plants had recovered later in the season. This species should be studied further.

The ladybird, *Henosepilachna signatipennis* Boisd. (and probably other Epilachnids) cause quite extensive leaf damage through the feeding activities of both adults and larvae. Epilachnids are quite important vegetable pests in Papua New Guinea but their significance as winged bean pests has not yet been assessed.

Apart from the leaf miners, the Lepidoptera listed appear to be of minor importance. It is likely that other polyphagous species will also feed on winged beans occasionally but they do not seem to be favoured hosts for the common polyphagous species in the Port Moresby area.

**Table 4. Pests of leaves of winged bean.**

| | Taxon | | Country Reference |
|---|---|---|---|
| Hemiptera | Aphididae | *Aphis craccivora* Koch | Papua New Guinea (Khan et al., 1974) |
| | Pseudococcidae | *Planococcus citri* (Risso) | Malaysia (Ooi, 1976) |
| Thysanoptera | Undetermined | | Papua New Guinea (Lamb, 1976) |
| Diptera | Agromyzidae | *Ophiomyia phaseoli* (Tryon) | Papua New Guinea (Khan et al., 1974, Fenner, 1976) |
| Coleoptera | Coccinellidae | *Henosepilachna signatipennis* Boisd | Papua New Guinea (Young, 1976, Lamb, 1976) |
| Lepidoptera | Lyonetiidae | *Leucoptera* sp | Papua New Guinea (Lamb, 1976) |
| | Phyllocnistidae | *Phyllocnistis* sp | Papua New Guinea (Young, 1976) |
| | Pyralidae | *Lamprosema diemenalis* Guen | Malaysia (Ooi, 1976) |
| | | *L. indicata* F | Malaysia (Ooi, 1976) |
| | Nymphalidae | *Neptis hylas* (*L. mamata*) | Malaysia (Ooi, 1976) |
| | Sphingidae | *Acherontia lachesis* F | Malaysia (Ooi, 1976) |
| | Limacodidae | *Setora nitens* Walk | Malaysia (Ooi, 1976) |
| Acarina | Tarsonemidae | *Polyphagotarsonemus latus* (Banks) | Guam (Muniappan, 1976) |
| | Tetranychidae | *Tetranychus* sp | Malaysia (Ooi, 1976) |
| | | (*telarius* group) | Papua New Guinea (Lamb, 1976) |

## PESTS OF SEEDS AND ROOTS

No pests of stored seed have yet been recorded. It has not been village practice to store seeds in Papua New Guinea, indeed seed is rather scarce. No doubt as this crop becomes more popular and seed stocks accumulate some stored products pests will be found. No tuber pests have been recorded.

A potential major root pest is the eelworm *Meloidogyne incognita* (Kofoid and White) Chitwood which causes the formation of rough-surfaced root galls (Lange, 1976). These should not be confused with the smooth surfaced nitrogen fixing root nodules. This nematode has become a problem in areas where the same host has been grown several seasons. It also has a wide host range.

## CONTROL OF PESTS

In subsistence agriculture no chemical control measures are taken against insect pests. Where possible, insecticides should be avoided as most of the minor pests are normally dealt with by biological or natural control methods. If the cultivation of winged beans is to be intensified into cash cropping or monoculture this may prove to be inadequate. There is, however, a great reservoir of genetic diversity within the species (even within Papua New Guinea) and it is to be hoped that this will be fully exploited for resistance to the major pests.

Some limited experiments have been carried out with chemical sprays. *Ophiomyia* on seedlings was controlled with 0.02% diazinon sprays while mealybugs were controlled with 0.02% propoxur. Perry, (1976) obtained control of unidentified lepidopterous larvae feeding on leaves and pods with carbaryl at 0.18% a.i. It must be stressed, however, that chemical control should not be resorted to lightly.

## DISCUSSION AND CONCLUSION

It is important to take into account growth conditions when considering pest status. Thus, in Papua New Guinea, pests seem to be least troublesome in the highlands up to 2000 meters where rainfall is high and uniform. They are worse on the seasonally wet north coast at sea level and are most severe in the drier, low rainfall area around Port Moresby.

This review is incomplete as little information is available from some countries, e.g. Burma, where cultivation of winged beans has been extensive in the past. It has, however, revealed some important gaps in our knowledge which should be remedied. These are as follows:

(1) An international survey of insects associated with winged bean with special reference to pests and their relative importance, to insect parasites and predators, and to pollinating insects.
(2) Identification and ecological study of the major pests including quantitative assessment of crop losses and the establishment of economic thresholds where appropriate.
(3) A study of virus and other insect borne diseases and their vectors. In this connection the observation of Burkill (1906), that crops grown from local seed in the lowlands of Burma tend to decline each year unless fresh seed is obtained from the Shan Hills, may be significant.
(4) There should be close co-operation between entomologists and plant breeders to ensure that maximum advantage is taken of genetic resistance towards insect pests and nematodes.
(5) If a need is demonstrated by (1) and (2), studies should be made to develop pest management programs which will minimize the use of pesticides. This will require the close co-operation of agronomists to ensure appropriate cultural methods and the best utilization of the desirable agronomic properties of winged beans, e.g. in crop rotation and mixed cropping.

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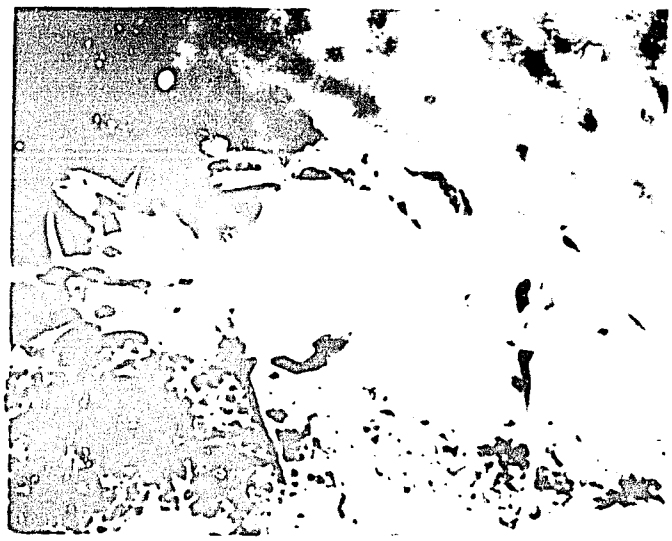

*1. Dried winged bean seedling as a result of bean fly (**Ophiomyia phaseoli**) damage. 2. Black bean aphid (**Aphis craccivora**) infestation on the growing point of the plant.*

# Diseases of the Winged Bean

*Dr. T. V. Price*[1]

**The winged bean (*Psophocarpus tetragonolobus* (L.) D.C.) can be attacked by viruses, fungi and nematodes. Viral diseases (Yellow mosaic) have been noted but not identified properly. Major fungal diseases are caused by *Synchytrium psophocarpi* (Rac.) Gaumann (False rust), *Pseudocercospora psophocarpi* (Yen) Deighton (leaf spot) and *Oidium* (*Erysiphe cichoracearum*, powdery midlew). *Macrophomina phaseolina* (Tassi) Gold, *Fusarium semitectum* Berk. and Rav., *F. equiseti* Corda, *F. moniliforme* Sheld. and *Rhizoctonia solani* Kuhn have been associated with collar rot. Less is known of the role of *Cercospora psophocarpicola* Yen (leaf spot), *Mycosphaerella* sp. (Concentric leaf spot), *Thanatephorus cucumeris* Donk (leaf blight), *Choanephora cucurbitarum* (Beck and Rac) Thaxt. (flower blight). Nematode disease of major importance are caused by *Meloidogyne incognita* (Kofoid and White) Chitwood and *M. javanica* (Treub) Chitwood.**

**Major research in Papua New Guinea has aimed at identifying the diseases, causal organisms, and studying their biology, epidemiology, host range and control. All the pure lines are susceptible to both major fungal diseases but *Psophocarpus scandens* is immune. Different cultivars exhibit different degrees of susceptibility and disease keys have been produced to assess both disease intensity and incidence in survey work.**

**The use of horizontal resistance as practised by Papua New Guineans appears a necessary requirement until further work on genetical resistance is initiated. Selection programs should take into account the susceptibility of winged bean to the main diseases. Fungicides that offer short term control are available to countries that possess adequate technology but this is inappropriate to developing countries.**

## INTRODUCTION

The booklet produced in 1975 (Anon, 1975) briefly mentioned that the winged bean was unusually free of serious pests and diseases but warned that this situation could change once a system of monoculture was introduced. Since that time serious disease problems have arisen in Papua New Guinea which have led to initiation of further researches on diseases. This paper describes the various diseases that have been recorded on the winged bean, the causal organisms and their possible control.

## VIRUS DISEASES

Dale (1949) reported that a cowpea mosaic virus also infected winged bean in Trinidad. Newton and Pieris (1953) reported that a yellow mosaic virus of pigeon pea from Sri Lanka (Ceylon) produced conspicuous vein-banding on new foliage 10 to 15 days after inoculation followed by a pale yellowish mottle whereas a pale mosaic virus had no effect in 20 days. They also showed that a sap-transmissible mosaic could be transmitted from *Crotolaria striata* to *Psophocarpus tetragonolobus*, the symptons on the latter resembling pigeon pea mosaic virus.

There has been little work on viruses since that time. More recently a severe virus attacked the winged bean crop at the University of Ghana (Sinnadurai, 1977) and there have also been some studies made at the International Institute of Tropical Agriculture (IITA) in Nigeria. Symptoms of yellow mosaic have been observed at Lae and in the Highlands of Papua New Guinea but it has not been confirmed as being a virus. There is certainly a need to elucidate which viruses can infect the winged bean by applying modern techniques. There are numerous pests which are present on the crop and their role in transmission also needs evaluating. A joint programme on viruses that can attack winged beans is now being undertaken.

## BACTERIAL DISEASES

There are no bacterial diseases recorded attacking the winged bean.

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## FUNGAL DISEASES

There are a number of fungal diseases that have been recorded.

### "False Rust"

"False Rust" or orange gall was first recorded in Java by Raciborski in 1898 (Fitzpatrick, 1930) and later in the Philippines (Reinking 1918, 1919), Malaya (Thompson and Johnson, 1953) and Papua New Guinea (Shaw, 1963). Fospisil *et al* (1971) recorded a disease in West Africa which they assumed to be "false rust" although this has never been confirmed. This disease is of economic importance in the Philippines (Reinking, 1918, 1919, De Vera, 1973) and Papua New Guinea (Price, 1976).

More recent research on this disease and the causal organism has been carried out in the Philippines (Alicbusan, 1965, De Vera, 1973) and in Papua New Guinea (Price, 1976, Drinkall & Price, unpublished results).

1. **Symptoms.** The disease is termed "false rust" because of the bright orange pustules that arise and burst on infected tissues. All above ground parts are attacked (leaves, stems, flowers, pods) and infection leads to hypertrophy, hyperplasia and galling of the host. The symptoms were first described by Raciborski (Fitzpatrick, 1930) and later by Reinking (1918, 1919), Gaumann (1927), Alicbusan (1965) and De Vera (1973).
2. **Leaf Symptoms.** Alicbusan (1965) observed that infection could occur anywhere on the upper or lower leaf epidermis and on the petiole. Infection occurs primarily along the primary and secondary veins and young leaves are most susceptible to infection. This has been confirmed in Papua New Guinea (Drinkall, pers. comm.). In severe cases cupping and curling occurs.
3. **Stem Symptoms.** The entire stem may be covered with galls and growth of apical buds is often arrested leading to formation of side shoots at the nodes.
4. **Flower Symptoms.** The sepals are the only parts of the flower to be attacked. This is probably due to the absence of photosynthetic tissue in the petals.
5. **Pod Symptoms.** Young pods are readily infected (Alicbusan, 1965) and the entire pod may be distorted and covered with pustules.
6. **The Causal Organism.** The disease is caused by a chytrid fungus *Synchytrium psophocarpi* (Rac.) Gaumann. Details on the biology of this organism are described by Drinkall (1978).
7. **Host range.** Gaumann (1927) failed to infect *Vigna sinensis* L. and *Phaseolus lunatus* L. with sporangia of *S. psophocarpi* and came to the conclusion that the parasite is host specific. This was supported by Alicbusan (1965) who failed to achieve infection of *Phaseolus limensis* Macf. var. *limenanus* Bailey, *P. vulgaris* L., *Vigna sinensis* Savi, *V. sesquipedalis* var Singapore, *V. mungo* Wil. and Hep., *V. sinensis* (L.) Hask. subsp. *sesquipedalis* (L.) Fsett., *Calopogonium mucunoides* Desv., Cyperus rotundus L., *Paspalum conjugatum* Berg, *Amaranthus spinosus* L., *Capsicum frutescens* L. var. *Convides*, *Cajanus cajan* (L.) Milsp., *Dolichos lablab* L., and *Lycopersicon esculentum* Mill. using zoospore suspensions.

   In Papua New Guinea *Psophocarpus scandens* has been found to be immune from natural infection.
8. **Susceptibility of cultivars.** Price and Murro (unpublished results, Table 1) scored all 120 winged bean lines growing at the University of Papua New Guinea in May 1976 when "false rust" first appeared in the experimental plots. All except UPS 53, 55 and 82 were susceptible (Price, 1976). The ten lines grown for seed were also assessed twice in 1977 at Kuk and Port Moresby and these were all susceptible (Table 2), confirming the earlier results. A disease key has been drawn up for assessing disease in the field and this has proved useful in evaluating qualitatively the amount of disease present in subsistence plantings. The effect of "false rust" on yield has yet to be determined.
9. **Control.** There has been little work on control of the disease. The only work was done by Alicbusan (1965) who reported that diseases may be reduced by removal of affected parts at an early stage. Ten fungicides (the concentration of which are unknown) were also found to prevent sporangial germination. These were Orthocop 53, Tersan 75, Ferbam, Duphar Zineb, Dithane Z 78, Zerlate, Manzate, Orthocide 50 and Shell Bordeaux. Drinkall (unpublished results) has tested twenty fungicides including systematic fungicides. The results (Table 3) show that tridemorph, triforine and captan were highly effective followed by mancozeb, mancozeb plus Zinc ion, EL 222 and Pyrazaphos. These are being evaluated further in the field.

Table 1. Susceptibility of winged bean to *Pseudocercospora psophocarpi* and *Synchytrium psophocarpi* at University of Papua New Guinea, 1 June 1976.

| Variety | No. of rows assessed | Presence or absence[1] of *Pseudocercospora* | Severity | Presence or absence[1] of *Synchytrium* | Parts attacked | Severity |
|---|---|---|---|---|---|---|
| UPS 1 | 2 | + | 2 | + | L.S.P. | 2 |
| 2 | 1 | + | 2 | + | L.S. | 2 |
| 4 | 1 | + | 2 | + | L.S. | 2 |
| 5 | 1 | + | 2 | + | L.S. | 2 |
| 6 | 1 | + | 2 | + | L.S. | 2 |
| 7 | 1 | + | 2 | + | L.S. | 2 |
| 8 | 1 | + | 2 | + | L.S. | 2 |
| 9 | 1 | + | 2 | + | L.S. | 2 |
| 10 | 1 | + | 2 | + | L.S. | 2 |
| 11 | 1 | + | 2 | + | L.S. | 2 |
| 12 | 1 | + | 2 | + | L.S. | 2 |
| 13 | 1 | + | 2 | + | L.S. | 2 |
| 14 | 1 | + | 2 | + | L.S. | 3 |
| 15 | 1 | + | 2 | + | L.S. | 2 |
| 16 | 1 | + | 2 | + | L.S. | 2 |
| 17 | 1 | + | 2 | + | L.S. | 2 |
| 18 | 1 | + | 2 | + | L.S. | 2 |
| 19 | 1 | + | 2 | + | L.S. | 2 |
| 20 | 1 | + | 2 | + | L.S. | 2 |
| 21 | 1 | + | 2 | + | L.S. | 2 |
| 22 | 1 | + | 2 | + | L.S. | 2 |
| 23 | 1 | + | 2 | + | L.S. | 2 |
| 24 | 1 | + | 2 | + | L.S. | 2 |
| 25 | 1 | + | 2 | + | L.S. | 2 |
| 26 | 1 | + | 2 | + | L.S. | 3 |
| 27 | 1 | + | 2 | + | L.S. | 2 |
| 28 | 1 | + | 2 | + | L.S. | 2 |
| 29 | 1 | + | 2 | + | L.S. | 2 |
| 30 | 1 | + | 2 | + | L.S. | 2 |
| 31 | 8 | + | 2 | + | L.S. | 2 |
| 32 | 1 | + | 2 | + | L.S. | 2 |
| 33 | 1 | + | 3 | + | L.S. | 2 |
| 34 | 1 | + | 2 | + | L.S. | 2 |
| 35 | 1 | + | 2 | + | L.S. | 2 |
| 36 | 1 | + | 2 | + | L.S. | 2 |
| 37 | 1 | + | 2 | + | L.S. | 3 |
| 38 | 1 | + | 2 | + | L.S. | 2 |
| 39 | 1 | + | 2 | + | L.S. | 2 |
| 40 | 1 | + | 3 | + | L.S. | 3 |
| 41 | 1 | + | 2 | + | L.S. | 2 |
| 42 | 1 | + | 3 | + | L.S. | 3 |
| 43 | 1 | + | 2 | + | L.S. | 2 |
| 44 | 1 | + | 2 | + | L.S. | 2 |
| 45 | 1 | + | 2 | + | L.S. | 2 |
| 46 | 1 | + | 2 | + | L.S. | 2 |
| 47 | 1 | + | 3 | + | L.S. | 2 |
| 48 | 1 | + | 2 | + | L.S. | 2 |
| 49 | 1 | + | 2 | + | L.S. | 3 |
| 50 | 1 | + | 2 | + | L.S. | 2 |
| 51 | 1 | + | 2 | + | L.S.P. | 3 |

Table 1. *continued*

| Variety | No. of rows assessed | Presence or absence[1] of *Pseudocercospora* | Severity | Presence or absence[1] of *Synchytrium* | Parts attacked | Severity |
|---|---|---|---|---|---|---|
| UPS 52 | 1 | + | 2 | + | L.S. | 2 |
| 53 | 1 | + | 2 | — | | |
| 54 | 1 | + | 2 | + | L.S. | 2 |
| 55 | 1 | + | 2 | — | | |
| 56 | 1 | + | 2 | + | L.S. | 2 |
| 57 | 1 | + | 2 | + | L.S. | 2 |
| 58 | 1 | + | 2 | + | L.S.P. | 3 |
| 59 | 1 | + | 2 | + | L.S. | 2 |
| 60 | 1 | + | 2 | + | L.S. | 2 |
| 61 | 1 | + | 2 | + | L.S. | 2 |
| 62 | 1 | + | 2 | + | L.S. | 2 |
| 63 | 1 | + | 2 | + | L.S. | 2 |
| 64 | 1 | + | 2 | + | L.S. | 2 |
| 65 | 1 | + | 3 | + | L.S. | 2 |
| 66 | 7 | + | 2 | + | L.S. | 2 |
| 67 | 1 | + | 2 | + | L.S. | 2 |
| 68 | 2 | + | 2 | + | L.S. | 2 |
| 70 | 1 | + | 2 | + | L.S. | 2 |
| 71 | 1 | + | 2 | + | L.S. | 2 |
| 72 | 1 | + | 2 | + | L.S. | 2 |
| 73 | 1 | + | 2 | + | L.S. | 2 |
| 74 | 1 | + | 2 | + | L.S. | 2 |
| 76 | 1 | + | 2 | + | L.S. | 2 |
| 77 | 1 | + | 2 | + | L.S. | 2 |
| 78 | 1 | + | 2 | + | L.S. | 3 |
| 79 | 1 | + | 2 | + | L.S. | 2 |
| 80 | 1 | + | 2 | + | L.S. | 2 |
| 81 | 21 | + | 2 | + | L.S. | 2 |
| 82 | 1 | — | | — | | |
| 83 | 1 | + | 2 | + | L.S. | 2 |
| 84 | 2 | + | 2 | + | L.S. | 2 |
| 85 | 1 | + | 2 | + | L.S. | 2 |
| 86 | 1 | + | 2 | + | L. | 2 |
| 87 | 1 | + | 2 | + | L.S. | 2 |
| 88 | 1 | + | 2 | + | L.S | 2 |
| 90 | 1 | + | 2 | + | L.S. | 3 |
| 91 | 1 | + | 2 | + | L.S | 2 |
| 92 | 1 | + | 2 | + | L.S. | 3 |
| 93 | 1 | + | 2 | + | L.S.P. | 3 |
| 94 | 1 | + | 2 | + | L.S. | 2 |
| 95 | 1 | + | 2 | + | L.S. | 2 |
| 96 | 1 | + | 2 | + | L.S. | 2 |
| 97 | 1 | + | 2 | + | L.S. | 2 |
| 98 | 1 | + | 2 | + | L.S. | 2 |
| 99 | 1 | + | 2 | + | L.S. | 2 |
| 100 | 1 | + | 2 | + | L.S. | 2 |
| 101 | 1 | + | 2 | + | L.S. | 2 |
| 102 | 1 | + | 2 | + | L.S.P. | 2 |
| 103 | 1 | + | 2 | + | L.S. | 2 |
| 104 | 1 | + | 2 | + | L.S. | 2 |
| 105 | 1 | + | 2 | + | L.S. | 2 |
| 106 | 1 | + | 2 | + | L.S. | 2 |
| 107 | 1 | + | 2 | + | L.S. | 2 |

Table 1. *continued*

| Variety | No. of rows assessed | Presence or absence[1] of *Pseudocercospora* | Severity | Presence or absence[1] of *Synchytrium* | Parts attacked | Severity |
|---|---|---|---|---|---|---|
| UPS 108 | 1 | + | 2 | + | L.S | 2 |
| 109 | 1 | + | 2 | + | L.S. | 2 |
| 110 | 1 | + | 2 | + | L.S. | 2 |
| 111 | 1 | + | 2 | + | L.S. | 2 |
| 112 | 1 | + | 2 | + | L.S. | 3 |
| 113 | 1 | + | 2 | + | L.S. | 2 |
| 114 | 1 | + | 2 | + | L.S. | 2 |
| 115 | 1 | + | 2 | + | L.S. | 2 |
| 116 | 1 | + | 2 | + | L.S. | 2 |
| 117 | 1 | + | 2 | + | L.S. | 2 |
| 118 | 1 | + | 2 | + | L.S. | 3 |
| 119 | 1 | + | 2 | + | L.S. | 3 |
| 120 | 1 | + | 2 | + | L.S. | 2 |
| 121 | 1 | + | 2 | + | L.S. | 2 |
| 122 | 7 | + | 1 | + | L.S. | 2 |
| 123 | 1 | + | 1 | + | L.S. | 2 |
| 124 | 1 | + | 1 | + | L.S. | 2 |
| 125 | 1 | + | 1 | + | L.S. | 2 |

L = Leaf S = Stem P = Pod

[1]Presence (+), absence (—)

Table 2. Susceptibility of ten winged bean lines to diseases in Papua New Guinea, 1977.

| Disease | Locality | Date assessed | Variety (U.P.S.) 31 | 32 | 45 | 47 | 53 | 62 | 99 | 102 | 121 | 122 | P. scandens |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| False rust | Kuk | 26/4/77 | — | — | + | — | + | + | — | — | — | + | |
| | | [illegible] | + | + | + | + | + | + | + | + | + | + | |
| *S. psophocarpi* | Pt. Moresby (U.P.N.G.) | 27/5/77 | + | + | + | + | + | + | + | + | + | + | — |
| *Pseudocercospora psophocarpi* | Kuk, Mt. Hagen | 26/4/77 | — | — | — | — | — | — | — | — | — | — | |
| | | 27/[illegible] | + | + | + | + | + | + | + | + | + | + | |
| | Pt. Moresby (U.P.N.G.) | 26/[illegible] | + | + | + | + | + | + | + | + | + | + | — |
| Powdery mildew | Kuk | 26/4/77 | — | — | — | + | — | — | — | — | — | — | |
| | | 7/7/77 | + | + | + | — | — | + | + | — | — | + | |
| | Pt. Moresby | 27/5/77 | — | — | — | — | — | — | — | — | — | — | — |

Presence (+) or absence (—) of diseases.

Table 3. Effect of fungicides on germination of sporangia of *Synchytrium psophocarpi*.

| Fungicide | Control means (transformed percentages) | Germination means (expressed as angular transformed percentages of control) Dose of fungicide (ppm) 10 | 50 | 100 | 250 | 500 | 1000 |
|---|---|---|---|---|---|---|---|
| Fentinacetate + Maneb | 73.89 | 86.24 | 78.17 | 30.80 | 0 | 0 | 0 |
| Mancozeb | 78.91 | 87.92 | 67.17 | 0 | 0 | 0 | 0 |
| Mancozeb + Zinc ion | 68.87 | 77.57 | 67.30 | 48.64 | 0 | 0 | 0 |
| Maneb | 77.89 | 81.01 | 80.30 | 87.54 | 86.52 | 76.31 | 57.93 |
| Zineb | 77.48 | 82.12 | 75.79 | 66.46 | 50.77 | 33.44 | 0 |
| Bordeaux | 77.08 | 82.72 | 76.94 | 70.73 | 46.0 | 29.26 | 23.33 |
| Copper hydroxide | 80.90 | 55.21 | 42.05 | 42.30 | 38.22 | 33.04 | 19.46 |
| Copper oxychloride | 75.82 | 81.57 | 72.34 | 60.25 | 53.75 | 16.50 | 0 |

*Table 3. continued...*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Captan | 73.15 | 54.67 | 25.79 | 11.23 | 0 | 0 | 0 |
| Panoctine | 78.46 | 91.59 | 74.49 | 65.11 | 23.57 | 0 | 0 |
| Bavistin | 79.70 | 85.38 | 92.13 | 79.73 | 82.38 | 71.12 | 70.96 |
| Benomyl | 80.90 | 82.56 | 83.54 | 84.25 | 80.45 | 70.97 | 59.80 |
| E.L. — 222 | 82.51 | 87.0 | 45.38 | 22.62 | 18.60 | 0 | 0 |
| Oxycarboxin | 76.19 | 91.89 | 87.72 | 95.77 | 79.95 | 84.40 | 81.67 |
| Pyrazaphos | 81.47 | 65.41 | 59.28 | 33.74 | 24.89 | 0 | 0 |
| Thiabendazole | 76.82 | 93.11 | 91.61 | 88.21 | 62.89 | 51.11 | 29.74 |
| Thiophanate methyl | 79.70 | 84.74 | 83.85 | 92.54 | 90.93 | 90.26 | 89.11 |
| Thiophanate methyl + oxycarboxin | 80.54 | 78.16 | 85.67 | 83.75 | 83.9 | 84.38 | 83.11 |
| Tridemorph | 80.90 | 56.34 | 0 | 0 | 0 | 0 | 0 |
| Triforine | 81.47 | 72.15 | 0 | 0 | 0 | 0 | 0 |

Standard error of concentration fungicide interaction mean ± 2.51
Standard error of fungicide mean + 1.02
Standard error of concentration mean + 0.56
Least significant difference (P = 0.01) = 9.16

10. **Conclusions.** *S. psophocarpi* does not form any resting spores and its means of survival is unknown. Our studies have indicated that sporangia are short-lived under natural conditions and dispersal is mainly by wind. Alicbusan (1965) did not find any seed transmission. The susceptibility of most known lines, some of which are more susceptible than others, does make sele on for resistance difficult although a closely related species (*P. scandens*) was found to be immune, and such resistance could be incorporated into a breeding programme. Control through fungicide usage is unsuitable for peasant subsistence growers who lack finance and technology although there are fungicides that show promise. These are being evaluated in the field. Systematic fungicides will be ideal for controlling this disease especially since young tissue is most susceptible to infection.

In Papua New Guinea the dispersal of sporangia occur at a time when optimum conditions for germination are present (e.g., leaf wetness) and thus conditions are suitable for infection daily; during the wet season there are longer periods suitable for infection and the disease possibly reaches the epidemic proportions during this time.

**Leaf Spot**

Welles (1924) investigated the taxonomy of *Cercospora* on various hosts in the Philippines and observed that a *Cercospora* sp. occurred on *P. tetragonolobus*. He also successfully inoculated this host with *C. lussoniensis* Sacc. (syn. *C. cruenta* Sacc.) and later reported that a *Cercospora* caused serious damage to *P. tetragonolobus* (Welles, 1925). Borlaza and Roldan (1964) described symptoms of the *Cercospora* disease on this host and established a new species, *C. aranetae*. Yen (1967) found three species of *Cercospora* on leaves of winged bean in Singapore — *C. aranetae* and two new species which were named *C. psophocarpi* and *C. psophocarpicola*. Deighton (1976) regarded *C. aranatae* as invalid and did not think it was different from *C. psophocarpi* which he renamed *Pseudocercospora psophocarpi* (Yen) Deighton.

*P. psophocarpi* was first recorded on *P. tetragonolobus* in Papua New Guinea in 1973 by Khan (Price and Munro, 1978). The leaves are only plant parts attacked. The first symptoms are small yellow spots on infected leaves. The under surface of these spots have a whitish bloom which becomes grey as the spots become older and finally black. These are the sporulating structures of the fungus. The entire leaves may become infected leading to severe necrosis of the lamina. Price (1976) reported that *P. psophocarpi* caused severe damage on winged beans growing at the University of Papua New Guinea during the rainy season (December-March) and initiated studies on the biology and control of the disease.

1. **The Causal Organism.** The causal organism is a deuteromycete fungus, recently transferred to the genus *Pseudocercospora*. The perfect stage of this fungus is still unknown. This fungus produces characteristic conidia on conidiophores which emerge in fascicles through the stomata of infected leaves. The conidia range in size from 12.5 — 47.5 (27.7) *um* × 2.5—8.8 (5.6) *um* with 0-4 septa. Ma-

jority have three septa. Conidia germinate at temperatures of 10°C with an optimum at 30°C; maximum germination occurred at 100% r.h. but this decreased rapidly, with more germinating at 84% r.h. (Price and Munro, 1978). Conidia from infected leaves germinate equally well after 14 days storage at room temperature but declined to 4% after 38 days. A single germ tube appeared after 4 hours, this increased in length and a second germ tube appeared after 9 hours; branching began at 26 hours.

2. **Infection.** The germ tubes of conidia inoculated onto winged bean leaves appear to enter via stomata as well as by direct penetration although this is still unclear. Leaves 1 to 5 days old are all susceptible and sporulation occurred 14 days after inoculation (Price and Munro, 1978).
3. **Host range.** There are no data on the host range of *P. psophocarpi*. *P. scandens* was immune under natural inoculum and conidia germinated following artificial inoculation but failed to infect. Inoculation of *V. unguiculata*, *Cajanus cajan* and *P. vulgaris* have not been successful, but this needs to be repeated.
4. **Susceptibility of winged bean lines.** Price and Munro (Price, 1976, unpublished results, Tables 1, 2) found all the lines were susceptible to leaf spot. A disease key has been drawn up and has been used to assess severity of disease in various locations in Papua New Guinea.
5. **Control.** Germination of conidia *in vitro* was inhibited by 0.1 ppm benomyl and total inhibition occurred at 0.5 ppm benomyl. Fortnightly sprays of 3.5 g benomyl in 14 l $H_2O$ gave good control although the minimum dose and frequency of application have yet to be determined (Price and Munro, 1978). Twelve fungicides have since been assessed for activity *in vitro*, the most effective fungicides were the benzimidazoles — Bavistin, Benlate, Topsin, TBZ (Tables 4, 5).

**Table 4. Germination of *Pseudocercospora psophocarpi* conidia on tap water agar containing benomyl.**

| Concentration of Benomyl (ppm) | Mean % germination after 24 h at 30° | Average germ-tube length (um) | Further growth, 48 h (±) |
|---|---|---|---|
| 0 | 92 | 180 | + |
| 0.1 | 70 | 30 | — |
| 0.2 | 25 | 20 | — |
| 0.3 | 0* | 10* | — |
| 0.5 | 0* | | — |
| 1.0 | 0* | | — |
| 10 | 0 | | — |

*Germ-tubes present but less than half the length of the spore and very distorted.

**Table 5. Effect of fungicides on germination of *Pseudocercospora psophocarpi*.**

| Fungicide Concentration (ppm) | % germination (24 h) | | | | | | | | Germ tube length (um) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 0.1 | 0.2 | 0.5 | 1.0 | 2.0 | 10 | 20 | 0 | 0.1 | 0.2 | 0.5 | 1.0 | 2.0 | 10 | 20 |
| Control | 100 | — | — | — | — | — | — | — | 300 | — | — | — | — | — | — | — |
| Bavistin | | 0* | 0* | 0* | 0* | 0* | 0* | — | | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Benlate | | 100 | 0* | 0* | 0* | 0* | 0* | — | | 100 | 0 | 0 | 0 | 0 | 0 | 0 |
| Topsin M | | — | 100 | 100 | 0* | 0* | 0* | — | | — | 110 | 40 | 0 | 0 | 0 | — |
| Brestan | | — | 78 | 0* | 0 | — | 0 | — | | — | 50 | | 10 | | 0 | — |
| Tecto (TBZ) | | — | 100 | 100 | 0* | 0* | 0* | — | | | 110 | 40 | 0 | 0 | 0 | — |
| Manzate 200 | | | | | 52 | 0 | 0 | 0 | | | | | 30 | 0 | 0 | 0 |
| Calixin M | | | 100 | 95 | 60 | — | 0 | — | | | 90 | 60 | 30 | — | 0 | — |
| Kocide 101 | | — | — | — | 100 | | 100 | 0 | | — | — | — | 200 | — | 40 | 0 |
| Rimidin | | | 100 | 100 | 100 | 100 | 100 | 100 | | | 100 | 100 | 100 | 50 | | |

*Distorted germ tubes not long enough to be counted as germinated.

6. **Conclusions.** *P. psophocarpi* causes a destructive leaf spot with subsequent loss of photosynthetic tissue. The spores are fairly long-lived and can survive on dead leaves. The conidia may be dispersed by wind, rain splash, and also insects although there is no quantitative data on this. The use of a disease key will assist in identifying differences in degree of susceptibility although all lines are susceptible; the closely related species *P. scandens*, however, appears to be immune. The benzimidazole fungicides gave good control under field conditions. More information is required on *Cercospora psophocarpicola* which has not been recorded in Papua New Guinea.

**Powdery Mildew**

This disease was first recorded in Papua New Guinea in 1975 (Price, 1977). The perfect stage of the fungus has not been found but the conidia of the *Oidium* stage resemble that of *E. chichoracearum*. Powdery mildew is fairly prevalent in the Highlands of Papua New Guinea. Hirata, (personal communication), informed me that this disease has also been recorded on winged beans in North Borneo (Johnstone, 1960). The fungus can attack other hosts and although there are no data available it appears that control can be achieved by the newer systemic fungicides effective against powdery mildews.

**Collar Rot**

This is one of the diseases that were reported to have been observed (Anon., 1975). Price and Munro (1978) found that 40% of seedlings growing at Port Moresby and at Kompiri in the Eastern Highlands of Papua New Guinea died of collar rot in 1976.

The symptoms are wilting of the leaves followed by death of the plants which are usually seedlings three to four weeks old. The hypocotyl region of affected plants is usually constricted with black necrotic lesions at soil level.

1. **Organisms associated with the disease.** *Macrophomina phaseolina* (Tassi) Gold was isolated from plants growing in the field at the University of Papua New Guinea. *Fusarium semitectum* Berk. and Rav., *F. equiseti* (Corda) Sacc. and *F. moniliforme* Sheld. from plants in the greenhouse, and *Rhizoctonia solani* Kuhn and *F. semitectum* from plants from Kompiri (Table 6).

**Table 6. Organisms isolated from winged bean plants showing collar rot.**

| Date | Locality | Organisms isolated | Proportion of isolates |
|---|---|---|---|
| 9th March, 1976 | U.P.N.G. Wargani | *Macrophomina phaseolina* (Tassi) Gold (IMI 203040, U.P.N.G. 5570) | 13/15 |
| 15th August, 1976 | Greenhouse | *Fusarium semitectum* Berk. & Rav. (IMI 209434, U.P.N.G. 6016, IMI 209435, U.P.N.G. 6017, IMI 209437, U.P.N.G. 6019, IMI 209440, U.P.N.G. 6022, IMI 209441, U.P.N.G. 6023, IMI 209444, U.P.N.G. 6026) | 6/10 |
| | | *Fusarium equiseti* (Corda) Sacc. (IMI 209436, U.P.N.G. 6018, IMI 209439, U.P.N.G. 6021) | 2/10 |
| | | *Fusarium moniliforme* Sheld. (IMI 209442, U.P.N.G. 6024, IMI 209444, U.P.N.G. 6025) | |
| 3rd November, 1976 | Kompiri, Eastern Highlands | *Rhizoctonia solani* Kuhnn (IMI 209445, U.P.N.G. 6027, IMI 209446, U.P.N.G. 6028) | 2/9 |
| | | *Fusarium semitectum* Berk. & Rav. (IMI 209447, U.P.N.G. 6029) | 2/9 |

The pathogenicity of these organisms were shown to be dependent on soil type, depth of sowing and inoculum density (Price and Munro, 1978). The best control recommended for subsistence growers is shallow planting in well drained soils.

**Leaf Blight**

*Thanatephorus cucumeris* (Frank) Donk (*R. solani*) has been recorded on leaves of plants growing at Lae and Keravat in Papua New Guinea (IMI 199337a) but there have been no studies of its importance.

**Leaf Spot**

*Mycosphaerella* sp. (IMI 199337b) has also been associated with a concentric leaf spot which has only seen on plants growing at Lae in 1975.

**Other Fungi**

Keane (1974) has also stated that *Colletotrichum lindemuthianum* and *Sclerotium* sp. occur on winged bean in Papua New Guinea.

**Flower Blight**

Many flowers were found to be blighted especially following rain at the University of Papua New Guinea in 1977 and were colonized by *Choanephora cucurbitarum* (Beck and Rae) Thaxt. It is not known whether this organism is a primary or secondary parasite and studies on this are needed.

## NEMATODE DISEASES

The only records of nematode diseases of winged bean are those due to root knot nematodes. This was first reported in Mauritius (Sornay, 1913) and then in the Philippines (Fajardo and Palo, 1933). Winged bean from Papua New Guinea was attacked by *Meloidogyne javanica* (Treub) Chitwood in the Netherlands (Oostenbrink, 1961). *M. incognita* was first recorded on winged bean at Aiyura (P.N.G.) in 1959 (Shaw, 1963; pers. comm.). Khan (1976) reported that several lines were lost in a field trial at Waigani in 1974 due to an unidentified root disease and Price (1976) stated that root knot was one of the three major diseases of the winged bean in Papua New Guinea. This was supported by Khan, Bohn and Stephenson (1977) who stated that root knot nematode appeared to be the most widely distributed pest and may cause considerable damage in some areas.

**Symptoms**

The main symptoms are below ground. Infected roots show abnormal galling. Both tuberous and non tuberous roots are attacked. Above ground the plants may show stunting and some yellowing of the foliage but this is not always evident.

The importance of root knot nematode to the winged bean research programme in Papua New Guinea led to basic studies on the biology of the pest(s) by Linge (1976). He examined the roots of 192 lines from Khan's trial in 1974 and found 160 were affected with root-knot nematode. This was identified as *Meloidogyne incognita* (Kofoid and White) Chitwood.

**Infection Studies**

In the field, it was recorded that invasion occurred one week after planting, and the first adult female was observed 4 weeks after seedling germination. The increase in the mean fresh weight of root led to an increase in the mean number of nematodes per root system. Samples of infected roots from other areas of Papua New Guinea revealed that winged beans were attacked by *M. incognita* and *M. javanica* (Table 7).

**The Effect of Temperature on Hatch**

1. *M. incognita*. Greatest occurred at 25°C and 30°C.
2. *M. javanica*. After 3 days incubation more eggs hatched at 20°C but after 7 days the order was 25° 20° > 30° > 15° > 37° > 5°C.

**Table 7. Distribution and identity of root-knot nematodes on winged bean in Papua New Guinea.**

| Date Collected | Locality | Species | Identified by |
|---|---|---|---|
| Feb. 1975 | U.P.N.G. Waigani | *M. incognita* (Kofoid & White) Chitwood | D. Linge<br>Dr. Fisher<br>Dr. Colbran |
| 4/11/76 | Kuk, Mt. Hagen | *M. javanica* (Treub) Chitwood | Commonwealth Institute of Helminthol |
| 4/11/76 | Avi, Mt. Hagen | *M. javanica*<br>*M. incognita* | Commonwealth Institute of Helminthol.<br>Commonwealth Institute of Helminthol |
| 4/11/76 | Aiyura, Eastern Highlands | *M. incognita* | Commonwealth Institute of Helminthol. |
| 9/10/75 | Keravat, New Britain | *M. incognita* | Commonwealth Institute of Helminthol. |

### The Effect of Population Density on Root Invasion and Gall Development

In a pot experiment, 18 g of sterile soil were inoculated with 100 or 500 hatched larvae of *M. incognita* and planted with winged bean seed. Four weeks later the seedlings were removed and assessed. Root knots were present on all plants; there were fourteen larvae per root in pots inoculated with 500 larvae and nine larvae per root in pots inoculated with 100 larvae. These differences were significant ($P = 1\%$).

### Conclusions

The few studies carried out so far indicate that root knot nematodes can cause considerable damage to tuber production although the effect on yield and tuber production have not been quantitatively assessed. A programme on this is envisaged at Hawkesbury Agricultural College in 1978. The two species of nematode that attack winged bean are cosmopolitan with wide host ranges although it did appear that in Papua New Guinea, *M. incognita* was predominant in the coastal areas whereas *M. arenaria* was only found in samples from the highlands. The field trial in 1975 during the wet season led to sparse infection and it is possible that the population density of the nematodes can be reduced by flooding. Lajardo and Palo (1933) showed that the majority of nematodes in badly infested soil could be killed by flooding for 35 to 40 days. There is certainly circumstantial evidence that in Papua New Guinea nematode attack is more prevalent in the dry season (Khan 1976).

The rate of development of adult females, means that at least four nematode generations are produced during the growing of the winged bean, and thus such infested soil should not be used for susceptible hosts. There is no information on which lines are susceptible but techniques for evaluating this are now available and this work can be carried out in Australia.

Use of nematicides is both costly and out of place and development of resistance lines should take top priority.

## DISTRIBUTION OF DISEASES OF WINGED BEAN IN PAPUA NEW GUINEA

Table 8 summarizes the results of field surveys carried out in Papua New Guinea between 1975 and 1977.

**Table 8. Incidence and distribution of diseases recorded on winged bean in field surveys in Papua New Guinea (Price and Drinkall, unpublished results).**

| Locality | Site | Year assessed | Disease (Presence (+) or absence (—)) | | | |
|---|---|---|---|---|---|---|
| | | | False Rust | Leaf Spot | Powdery Mildew | Collar Rot |
| Goroka | Ketarabo | April, 1977 | + | + | — | — |
| | Kapogomdrib | April, 1977 | + | + | + | — |
| | Onanika | April, 1977 | + | — | — | — |
| | Kamarliki | April, 1977 | + | + | + | — |
| | Notopono | April, 1977 | + | + | — | — |
| Mt. Hagen | Kuk | November, 1976 | + | — | + | — |
| | | July, 1977 | + | + | + | — |
| | Avi | November, 1976 | + | + | + | — |
| | | April, 1977 | — | — | — | — |
| | Kendagl | November, 1976 | + | + | + | — |
| | Mur | November, 1976 | + | + | — | — |
| Banz | Ag. Coll. | November, 1976 | + | + | + | — |
| | | April, 1977 | + | — | — | — |
| | Baning | November, 1976 | + | + | — | — |
| | Kilipi | April, 1977 | + | + | — | — |
| | Kandipano | April, 1977 | + | + | — | — |
| | Dai | April, 1977 | + | — | — | — |
| Minj | Voc. Sch. | November, 1976 | — | — | — | — |
| Aiyura | Aiyura | November, 1976 | + | + | + | + |
| | Yarompa | April, 1977 | + | + | + | — |
| Kainantu | Kompiri | November, 1976 | — | + | — | + |
| | | April, 1977 | + | + | + | — |

Table 8 *continued*

| | | | | | | |
|---|---|---|---|---|---|---|
| Lae | Ag. Farm Unitech. | 1975 | + | + | — | — |
| | | April, 1977 | — | — | — | — |
| Port Moresby | U. P.N.G. | 1975 | — | + | — | — |
| | | 1976 | + | + | + | + |
| | | 1977 | + | + | + | — |

## CONCLUSIONS AND RECOMMENDATIONS

There are now a known number of diseases of winged bean and any selection or breeding programme must take the effects of diseases and pests into consideration, especially since the plants may be infected by diseases and pests at the same time. Resistance is the best solution, and sources of resistance should be sought after. The Papua New Guineans grow a multitude of lines with varying degrees of resistance and this is certainly to be recommended. Horizontal resistance would, therefore, appear to be of great importance especially since most lines are susceptible to at least two of the major diseases. The diseases can be controlled by pesticides but these would be uneconomic for subsistence growers and different fungicides are required for each disease. It must also be taken into account that disease may be desirable in certain places. Thus in Java, winged bean is traditionally infected with "false rust" and following disease development the young infected parts of the plant are steamed and eaten as a delicacy (Degener, 1945). Similar observations for the Sudanese area of Java are reported by Satrapradja and Animah-Lubis (1976). In surveys in the Highlands of Papua New Guinea we have found that local inhabitants do eat infected leaves and pods, but language difficulties make it extremely difficult to determine whether it has any effect on flavour. Thus studies on the biochemical changes to flavours and constitution of infected tissue is required.

The studies that were carried out in Papua New Guinea were made by people who were not engaged wholly on research and there is certainly a need for an injection of funds to enable further progress to be made by appointment of personnel who will work full-time on the diseases and pests. These are best studied under local conditions that it is not known what other diseases and pests will attack the winged bean when it is grown outside tropical areas. The two major fungal diseases appear to be host-specific and care should be taken that the propagules are not introduced into areas free of the disease.

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# Investigations of the Biology of *Synchytrium psophocarpi* (Rac.) Gaumann: The Cause of False Rust Diseases of the Winged Bean

*M. J. Drinkall*[1]

*Synchytrium psophocarpi* (Rac.) Gaumann is an obligate fungal endo-parasite causing false rust disease in the winged bean. The parasite is simple in structure consisting of sori, sporangia and zoospores. Sporangia of the parasite from Papua New Guinea were globose or ovate in shape and ranged in size from 12.5-27.0 (21.4) *um* diam., and 20.0 x 15.0 - 35.0 x 22.5 (25.2-19.4) *um*. Sporangia germinated at temperatures of 5-30°C and at 84-100% r.h., in the presence of free water; germination did not occur in humidities less than 100% in the absence of free water. Zoospores emerged after 40 min incubation and maximum germination occurred after 70 min. Sporangia exposed to the air lost their viability after 4 days; this increased to 24 days when stored in a sealed plastic box at 5°C. Live zoospores were pyriform and measured 5.0 x 2.5 to 10.0 x 5.0 (6.9 x 2.5 to 5.0 x 3.0 (3.34 x 2.5) *um*. Flagella length of recently emerged zoospores varied from 7.5 to 16.25 (12.98) um. Zoospores lost their motility after 30 min following emergence from the sporangium and encyst after a further 2-3 h; encysted zoospores are spherical and measure 3.0 to 6.0 (4.39) *um* diam. The zoospores retract their flagella by vesicular retraction.

## INTRODUCTION

The winged bean (*Psophocarpus tetragonolobus* (L.) DC.) has, until recently, been considered as a plant of only minor agricultural importance. This has resulted in a lack of quantitative data on pest and disease causing organisms that attack it. False rust is one of the major diseases of the crop in Papua New Guinea (PNG) (Price, 1976). It was first recorded in Java by Raciborski (1898) and later in the Philippines (Reinking, 1918, 1919; Sydow and Petrak, 1928; Baker, 1931), Malaya (Thompson and Johnson, 1953) and PNG (Shaw, 1963). Pospisil *et. al.* (1971) reported a disease in West Africa which was assumed to be false rust.

Some workers (Pospisil, *et. al.*, 1971; Masefield, 1973) have reported that there were no serious pests or diseases of the crop. Reinking (1918, 1919), however, stated false rust was a disease of economic importance in the Philippines while De Vera (1973) reported the disease caused a severe reduction of ooth tubers and pods in the Philippines. There is, however, no quantitative data available relating yield loss to disease severity. Both workers reported that infected pods were undesirable for use and were unsaleable in the market. On the other hand, in Java, winged beans are traditionally infected with the disease and are then steamed and eaten as a delicacy (Degener, 1945).

### Symptomatology

An early diagnostic symptom of the disease is the appearance of yellow galls. These galls appear on all the above ground parts of the winged bean, i.e., leaves, stems, flower buds and pods (Gaumann, 1927; De Vera, 1973). Severe galling and pod and leaf malformation frequently occurs.

### The Causal Agent

Raciborski (1898) first described the causal agent as an obligate fungal endoparasite belonging to the order Chrytridiales and erected the genus *Woroninella;* hence the fungus became known as *W. psophocarpi.* He described the zoospores as biflagellate and regarded the fungus as being intermediate between *Woronina* and *Synchytrium* (In Karling, 1964). Sydow and Sydow (1903) thought the organism was a rust fungus

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because of the cratershaped galls and renamed it *Uromyces psophocarpi*. Sydow (1914) later agreed with Raciborski's classification. Further investigation of *W. psophocarpi* and other species by Gaumann (1972) revealed their zoospores to be uniflagellate and he reduced the genus *Woronineella* to form a new sub genus in *Synchytrium*, hence the fungus is known as *S. psophocarpi*, sub genus *Woroninella* (In Karling, 1964).

The parasite is without mycelium simply consisting of sori, sporangia and zoospores and is classed as short cycled; sporangia are dispersed by wind following sorus membrane rupture (In Karling, 1964). Alicbusan (1965) reported dispersal occurred by wind, insect and other natural agencies. There is, however, no quantitative evidence to support these statements.

It is not known how the parasite survives in the absence of the winged bean host since attempts to infect alternate hosts have failed (Gaumann, 1927, Alicbusan, 1965) and the existence of resting spores has not been conclusively established.

## MATERIALS AND METHODS

Microscope cavity slides (75 x 25 x 3 mm) and 22 mm square coverslips were made grease free by washing with 'Pyroneg' (Diversey Pty. Ltd.), rinsed three times in tap water, followed by a final rinse in distilled water. They were then transferred to 95% ethanol and stored until required.

### Sporangia

Sporangia were removed from erupted sori on infected leaves with a mounting needle while viewing under a stereomicroscope (20x). Sporangia were transferred to a small drop of tap water which had been placed in the center of a coverslip by means of an Arnold Hand Micro applicator (Arnold, 1967) and a hanging drop preparation made according to the method of Ino and Ennomoto (1971). One hundred sporangia were measured at a magnification of 600x. This was repeated three times on sporangia from different sori.

### Germination of Sporangia

Sporangia were counted as germinated if they were empty, partially empty or showed zoospores actively emerging. Germination was tested by placing sporangia from erupted sori in cavity slides which were partially filled with sterile distilled water. These slides were then placed in slide racks and incubated at 100% r.h. in sealed plastic boxes which had been equilibrated for 24 h at 25°C.

### Effect of Temperature on Germination

The effect of temperature was measured by placing sporangia from a single sorus in seven cavity slides. A mark was made on the edge of each cavity and fifty sporangia were assessed for germination in each slide prior to incubation. This was repeated five times using sporangia from different sori. Each box of replicates was placed in incubators held at 5, 10, 15, 20, 25, 36 and 37°C and germination was assessed after 24, 48 and 72 h.

### Effect of Relative Humidity and Surface Wetness on Germination

The effect of relative humidity was investigated by placing saturated salt solutions in the plastic boxes to maintain the following relative humidities: $NaNO_2$, 66%; KBr, 84%; $ZnSO_4 \cdot 7H_2O$, 90%; $PbNO_3$, 95%; $H_2O$, 100%. The effect of surface wetness was investigated by placing one set of sporangia in cavity slides that did not contain water. Germination was assessed before and after 24 h incubation at 20°C. Four replicates were used for each treatment and fifty sporangia were counted in each replicate.

### The Germination Process and the Number of Zoospores per Sporangium

Sporangia were placed on a coverslip containing a drop of 1% carboxy methyl cellulose and a hanging drop preparation was made. The preparation was incubated at 25°C and the sequence of germination observed microscopically. The number of zoospores emerging from a single sporangium were counted on five separate occasions. These sporangia were all of the same size.

### The Rate of Germination

One hundred sporangia in each of four replicates were assessed for germination at 10 min intervals for the first 2 h, 4, 6 and 24 h after incubation at 25°C.

### Effect of Sporangial Age on Viability

One hundred sporangia from an unopened sorus, which had undergone protoplasmic cleavage, a recent

ly erupted sorus and one that had been open for some time were assessed for germination before and after 24 h incubation at 25°C. This was repeated eight times using sporangia from different sori.

**Effect of Storage on Viability of Sporangia**

Infected leaves and stems were removed from plants growing in the University Experimental Garden and placed in terylene net bags (1 mm² mesh) and air tight plastic boxes. One bag was placed in the field at the University of Papua New Guinea, 2 m above ground level, another bag was held at room temperature (25-28°C), one bag and one box were placed in a refrigerator held at 5°C and one bag and one box in a deep freeze held at −85°C. Outdoor measurements of temperature, relative humidity and rainfall were obtained from recording instruments at the University Meteorological Station. Room temperature and humidity were recorded on a thermohydrograph.

Sporangia from erupted sori were removed from each treatment on the day of collection (day 0) and 1, 2, 3, 4, 12, 16, 20 and 24 days later and assessed for germination after 24 h incubation at 20°C. Three replicates, each from different sori, were prepared and 100 sporangia were counted in each replicate.

**Number and Viability of Sporangia in a Single Sorus**

A single unopened sorus was removed from a leaf surface with mounting needles while viewing under a stereomicroscope (20x) and sporangia were teased out under distilled water. Germination of all the sporangia was assessed after 24 h incubation at 20°C. This was repeated twice using sori of the same diameter.

**Size of Fixed Zoospores and Flagella Length**

Sporangia were germinated in a drop of water and the emerged zoospores were fixed by exposure to 2% osmic acid for 1 min. They were then stained in a 0.04% solution of crystal violet, dried in a dessicator for 2 h, cleared in clove oil, washed in xylene and mounted in euparal (McLean and Cook, 1965). Measurements of 100 zoospores and 200 flagella were made at a magnification of 600x.

**Size of Live Zoospores**

Sporangia were germinated in a hanging drop. Zoospores which had ceased active swarming were measured under a magnification of 600x using phase contrast microscopy. The time between emergence from the sporangium and cessation of motility was recorded.

**Encystment of Zoospores and Observations on the Flagellum**

Sporangia were germinated in a hanging drop incubated at 25°C. The zoospores were fixed immediately after emergence by exposure to 2% osmic acid for 1 min and stained with a 0.04% solution of crystal violet. The procedure was repeated 1,2,3,4, and 5 h after germination. Two hundred zoospores were counted for each time interval and the number of zoospores with and without flagella was recorded. Measurements of 100 encysted zoospores were made at a magnification of 600x. Observations were made on live and fixed zoospores to determine whether the flagellum was retracted or shed.

## RESULTS

**Color, Shape and Size of Sporangia**

Immature sporangia consist of hyline hexagonal walls enclosing finely granulated pale yellow protoplasm which became darker and more coarsely granulated with maturity. The sporangia are either globose in shape measuring 12.5 to 27.0 (21.4) *um* or ovate measuring 20.0 x 15.0 to 35.0 x 22.5 (25.2-19.4) *um*. A few irregular shapes were also observed.

**Effect of Temperature on Germination**

The mean percentage germination after 24 and 48 h incubation is shown in Table 1. Germination did not occur at 37°C. Germination was significantly greater ($P = 0.05$) at 20 and 25°C than at 5 and 30°C. Germination increased after 48 h incubation for all temperatures except at 37°C and no further increase occurred after 72 h. Sporangia which failed to germinate at 37°C after 72 h did not germinate after subsequent transfer to 20°C for 24 h.

**Effect of Relative Humidity and Surface Wetness on Germination**

Sporangia germinated equally well at humidities of 84 to 100% but not at 66% when incubated 'wet' and only at 100% when incubated dry (Table 2).

**Table 1. The effect of temperature on germination of sporangia.**

| Temperature (°C) | Mean germination after 24 & 48 in incubation (angular transformed percentages) | |
|---|---|---|
| | 24th | 48th |
| 5 | 61.36 b | 64.38 |
| 10 | 63.54 ab | 70.19 |
| 15 | 70.41 ab | 81.33 |
| 20 | 71.77 a | 76.35 |
| 25 | 71.97 a | 74.96 |
| 30 | 62.5 b | 66.81 |
| 37 | 0 b | 0 |

Values for 24 h followed by the same letter are not significantly different (P = 0.05).

**Table 2. The effect of relative humidity and surface wetness on germination of sporangia.**

| Relative humidity % | Mean germination (angular transformed percentages) | |
|---|---|---|
| | + water | − water |
| 100 | 80.11 a | 15.34 |
| 98 | 72.66 a | 0 |
| 90 | 77.78 a | 0 |
| 84 | [illegible] a | 0 |
| 66 | [illegible] b | 0 |

Values for + water followed by the same letter are not significantly different (P = 0.05).

## Germination Process and the Number of Zoospores per Sporangium

The contents of ungerminated sporangia first become coarsely granular; this is followed by bulging of the sporangial wall. Zoospores are then differentiated and they begin to oscillate within the sporangium. The zoospores locate their exit by moving in a random circular motion. It is difficult to determine whether there is more than one exit or pore in the sporangial wall. After emerging from the sporangium the zoospores move around in an irregular manner. The number of zoospores that emerged from five sporangia all of 22.5 *um* diam., were 102, 122, 134, and 156. Following emergence of the zoospores the sporangial wall collapsed.

## Rate of Germination

Zoospores first began to emerge after 40 min incubation. This was followed by rapid germination for the next 30 min and only a few sporangia germinated with further incubation. A similar pattern occurred in all replicates.

## Effect of Sporangial Age on Viability

The mean percentage germination of sporangia from unopened and recently erupted sori was significantly higher (P = 0.05) than sporangia taken from old sori (Table 3).

**Table 3. The effect of sporangia age on viability.**

| Sorus | Mean germination (angular transformed percentages) |
|---|---|
| Unopened | 68.31 a |
| Recently opened | 62.7 a |
| Opened for some time | 14.67 b |

Values followed by the same letter are not significantly different (P = 0.05).

**Effect of Storage on Viability of Sporangia**

The viability of sporangia from bags kept in the field, at room temperature and 5°C decreased to zero after 4 days; those held in a sealed plastic box at 5°C remained viable for 13 days before declining and losing viability after 24 days. Sporangia stored in both bag and plastic box at −85°C lost viability after 24 h.

**Number and Variability of Sporangia in a Simple Sorus**

The number of sporangia counted from two unopened sori both of 160 *um* diam. was 4272 and 4890; a mean of 83% germinated.

**Size of Live and Fixed Zoospores, Flagella Length and Swarming Period**

Living zoospores were pyriform in shape and varied in size from 5.0 x 2.5 to 10.0 x 5.0 (6.9 x 4.6) *um*. Fixed zoospores assumed a spherical shape and varied in size from 2.5 x 2.5 to 5.0 x 3.0 (3.34 x 2.5) *um* which differed significantly ($p = 0.05$) from measurements of live zoospores. The flagella length ranged from 7.5 to 16.25 (12.98) *um*. This was significantly ($P = 0.01$) longer than the 8.0 *um* reported by Raciborski (1898). Some zoospores had ceased swarming 30 min after emergence from the sporangium.

**Encystment of Zoospores and Observations on the Flagellum**

Encysted zoospores were first observed 3h after emergence but flagellate zoospores were still present after 5 h (Table 4). Encysted zoospores varied in size from 3.0 to 6.0 (4.39) *um* diam.

**Table 4.** Encystment of zoospores with time.

| Time h (after germ.) | Flagellate zoospores | Encysted zoospores |
|---|---|---|
| 0 | 200 | 0 |
| 1 | 200 | 0 |
| 2 | 200 | 0 |
| 3 | 163 | 37 |
| 4 | 126 | 74 |
| 5 | 83 | 117 |

The zoospores retracted their flagella by a process of vesicular retraction. The process is completed within 10 min during which time the flagellum twitches and undulates and the zoospore may swim intermittently. A vesicle appears at the base of the flagellum which moves up towards the zoospore and is finally taken in through the body wall.

## DISCUSSION

The measurements of sporangia agree with those reported in Karling (1964) but are significantly smaller than those given by Alicbusan (1965).

The results indicated that temperatures between 10-25°C were more favourable for germination and that lower germination occurred at 5 and 30°C. The results differed from those of Alicbusan (1965) in that germination was not recorded at 37°C. Germination occurred equally well in relative humidities of 84-100% in the presence of a water film. The lack of germination in the absence of water except at 100% r.h. suggests that free water is essential for germination.

The minimum period for germination to take place in the presence of water was 40 min and most sporangia germinated within 60-120 min. These results are in agreement with those of De Vera (1973) and Alicbusan (1965). The proportion of sporangia that germinated after further incubation was low and indicated that most viable sporangia will germinate within 2 h provided conditions such as temperature and high rainfall experienced in parts of the highlands of PNG, where winged beans are traditionally grown, provide the necessary conditions which favour this rapid germination process.

The number of zoospores that emerged from each sporangium ranged from 102-156. These figures are less than the 200 reported by De Vera (1973) and significantly greater than the fifty reported by Alicbusan (1965). It is possible that the number of zoospores is dependent on the size of the sporangium.

The results indicated that sporangia from an unopened sorus, which had undergone protoplasmic cleavage, and a recently erupted sorus were more viable than sporangia taken from that which had erupted for some time. It appears that some maturation of sporangia must occur prior to the rupture of the sorus membrane. The loss of viability in sporangia from an old sorus may also be due to the loss of moisture or dehydration after exposure to the atmosphere. This is supported by the fact that viability of sporangia stored in porous bags declined to zero after 4 days whereas sporangia stored in a sealed container at 5°C remained viable for a maximum of 20 days. These results differed from those of Alicbusan (1965) who reported that sporangia remained viable for 6 months in the laboratory and 4 months in the field. These differences can be explained by the fact that he did not carry out any germination tests; his finding were only based on the colour and shape of sporangia. The rapid loss of viability does mean that sporangia are short lived and must be dispersed and reach an infection court within a few days after eruption of the sorus membrane.

The shape and size of live zoospores were in agreement with those reported by Raciborski (1898). Zoospores fixed in osmic acid become spherical and shrink in size. This effect of osmic acid had also been reported by Koch (1958). The flagellum was significantly longer than that stated by Raciborski (1898). It is not known whether his measurements were made on freshly germinated zoospores; zoospores retract their flagella prior to encystment and it is possible that this may account for the differences noted. It is also possible that there may be a different strain of the fungus as his material came from Java. The swarming of zoospores were observed to last for least 30 min. Some pairing of zoospores were also observed to take place. It is not known whether this is a result of fusion or incomplete cleavage in the sporangium. Similar observations have been made by Gaumann (1927) and De Vera (1973); pairing in other *Synchtrium* species have also been noted by Curtis (1921) and Karling (1955).

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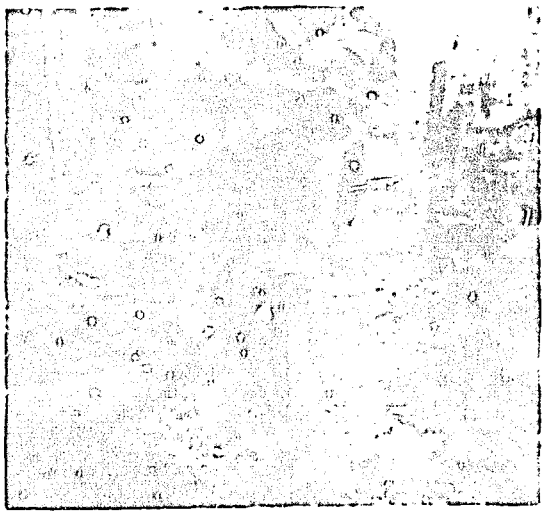

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*1 and 2 False rust or orange gall (Synchytrium psophocarpii on winged bean pods. 3 Orange gall infecting the stem.*

# Some Insect Pests Associated with Winged Bean in India

*K. Srinivasan, R. Rajendran* and *A. Satyanarayana*[1]

**The winged bean, *Psophocarpus tetragonolobus* was observed to be affected by a number of insect pests at various stages of crop growth, some of which have been identified and reported for the first time in India.**

**The gram pod borer, *Heliothis armigera* Hb. causes extensive damage by affecting the flowers and tender pods besides boring into mature pods consuming the seeds. Damage by the blue butterfly, *Catechrysops cnejus* F. to flowers is also observed. Other pests infecting pods and flowers are pod bugs, *Clavigrella horrens* D, *Clavigrella gibbosa*, S. and the green stink bug *Nezara viridula* Linn. The thrips *Megalurothrips distalis* (Karny) often becomes serious causing the drying of flowers. The plant lice, *Aphis craccivora* Koch. affects tender shoots, flower buds and young pods.**

**Genetic variability among the winged bean collections and differences in plant response to insect attack have also been observed.**

## INTRODUCTION

Although some information is available on the agronomy, botany, environmental requirements and biological variation of the winged bean, there has been no report on serious insect pests affecting this crop (Anon, 1975). Moreover several authors agree that this crop is relatively free of diseases and insect pests (Pospisil *et al.*, 1971 and Rachie, 1973).

In this paper, an attempt has been made to summarize the work done on the insect pests affecting this crop under South Indian conditions where literature cites its cultivation since 1799.

Work on the winged bean has been in progress for the past three years, at the experimental farm of the Indian Institute of Horticultural Research, Hessaraghatta, Bangalore. The crop was damaged by a number of insects, the description of which is given below.

## GRAM POD BORER

Gram pod borer, *Heliothis armigera* Hb. (Family: Noctuidae, Order: Lepidoptera). The eggs are spherical, about 0.5 mm in diameter, yellow when laid but turning brown as the embryo develops. The larva is a stout caterpillar of variable color but often greenish or brownish. The body is marked with longitudinal bands alternatively dark and pale, the pale bands down the sides of the body are particularly noticeable. The full grown larva is about 35 to 40 mm long. It pupates in an earthern cocoon in the soil. The early instar larvae feed on the tender parts and later bore into the pods. As the internal contents of the pods are devoured, the yield of green pods and seeds are considerably reduced. At least 20 to 30 percent of the pods were found to be affected by this pest in some of the lines.

The adult moth has a V shaped speck on the light brownish forewings and a dark border on the hind wings.

### Cathechrysops Cnejus F.

The larvae of blue butterfly, *Catechrysops cnejus* F. (Family: Lycaenidae, Order: Lepidoptera) was found to damage the flower buds and seeds inside the pod of the winged bean. The larvae are characteristically onisciform with both ends tapering and the enlarged sides concealing the legs. They have numerous secondary setae on their body. Although *Lampides boeticus* (L.) has been reported attacking the pods and flowers of other legumes in Senegal (Appert, 1964) and East Africa (Le Pelley, 1959), it was not found to occur in the Institute farm.

[1]**Indian Institute of Horticultural Research 255, Upper Palace Orchards, Bangalore — 560006. Contribution No. 630.**

## POD BUGS

Pod bug, *Clavigrella horrens* D. and *Clavigrella gibbosa* S. (Family: Coreidae, Order: Hemiptera) was found to infest the pods of the winged bean at times. These bugs were found to produce nauseous odours, making cultivation practices and harvesting inconvenient.

## GREEN STINK BUG

The green stink bug *Nezara viridula* (L.) (Family: Pentatomidae, Order: Hemiptera) was also found to be associated almost invariably in the developing pod and the feeding punctures cause local necrosis resulting in spotting and deformation. If attacked when young, the pods were found to shed. The eggs were found to be laid on the undersurface of the leaves in batches stuck together in rafts. The nymphs have five instars. The first stage nymphs remain clustered by the egg raft and do not feed; after moulting they disperse and start feeding. The adults are large green shield bugs measuring about 15 × 8 mm.

The occurrence of this bug has also been reported by Khan et al., (1974) in Papua, New Guinea.

## BEAN APHID

Bean aphid, *Aphis craccivorn* Koch. (Family: Aphididae, Order: Hemiptera), was found to affect tender shoots, flower buds and young pods. The adults are black or dark brown, variable in size, being from 1.5 to 2 mm long and antennae are about two thirds as long as the body.

## THRIPS

A species of thrips, (*Megalurothrips distalis* (Karny) Family: Thripidae, Order: Thysanoptera) was found to infest the flowers of winged bean causing drying and shrivelling.

## CONCLUSION

It has been found that *Heliothis armigera* Hb., *Cathechrysops cnejus* F. and *Megalurothrips distalis* to be major pests identified in winged bean causing extensive damage to flowers and pods. Other pests mentioned above seems to be of minor importance at present.

The insects in general were found to be controlled by monocrotophs (Nuvacron) 0.04% and by spraying quinalphos (Ekalux) 0.05%.

Though the insect pests associated with winged bean have been found and the nature of their damage diagnosed, work has to be initiated for finding out suitable insecticides for the control of major pests.

A survey of insects affecting winged bean in other places in India has to be conducted with special reference to its status.

Studies should be made to develop pest management programmes so that the use of insecticides could be avoided whenever possible.

Screening of cultivars for resistance to major insect pests should be done in collaboration with the plant breeders. Studies of collections in the Indian Institute of Horticultural Research Farm, already reveal extensive genetic variability and differences in plant response to insect attack.

To explore the possibilities of biological control of major pests, studies on the parasites and predators should be made with a feasibility for mass culturing and subsequent release in the field.

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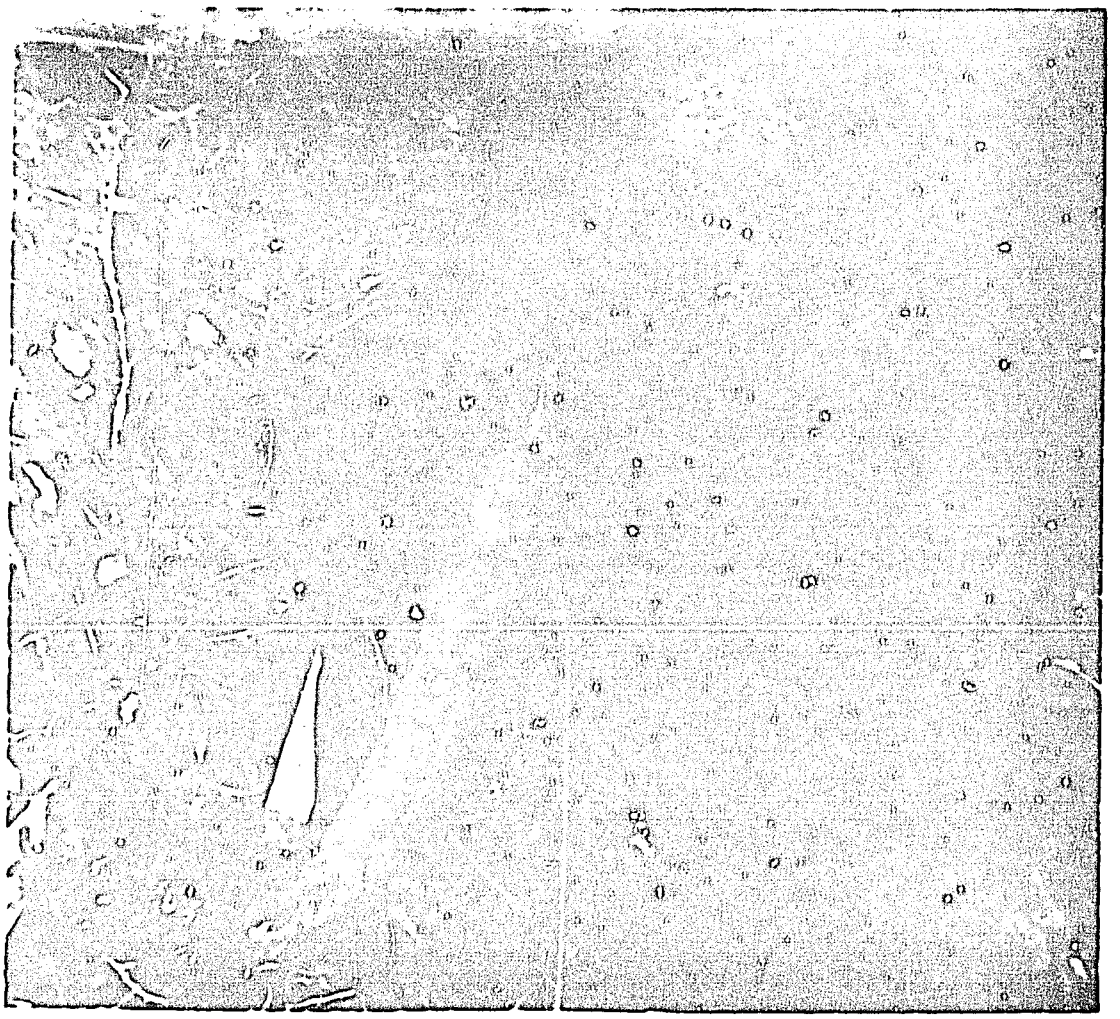

*Healthy pod and leaves (right) and virus infected pod and leaves (left)*

# Preliminary Observations on the Arthropod Fauna of Winged Bean at Kade, Ghana

*J. F. Abu* and *S. K. Karikari*[1]

From June 30, 1976 to November 15, 1977, immature and mature arthropods were collected from the vines of winged bean planted at the Agricultural Research Station, Kade Ghana. The arthropods were collected fortnightly by aspirators, hand-picking or insect nets and all immature stages were reared to adults in the laboratory. The arthropods have been classified mostly to families and are yet to be identified. However, a few of the insects have been identified to species level using a reference collection at the Faculty of Agriculture, University of Ghana, Legon. As indicated in Table 1, arthropod families representing 11 orders have been collected. The damage these arthropods do to the plants are being studied for effective control measures.

**Table 1. Arthropod Fauna of Winged Bean at Kade, Ghana.**

| Order | Family | Species Noted | Relative Frequency In Collection[1] |
|---|---|---|---|
| COLEOPTERA | Chrysomelidae (Alticinae) | *Podagrica sjostedti* (Jac.) | O |
| | Chrysomelidae (Alticinae) | *P. uniformis* (Jac.) | O |
| | Chrysomelidae (Alticinae) | Several species | VC |
| | Chrysomelidae (Galerucinae) | *Ootheca mutabilis* Sahlb | O |
| | Chrysomelidae (Criocerinae) | Few species | O |
| | Chrysomelidae (Hispinae) | Few species | R |
| | Lagridae | *Lagria villosa* F. | O |
| | Lagridae | *L. cuprina* Thoms | O |
| | Coccinellidae | *Epilachna chrysomelina* F. | R |
| | Scarabaeidae (Cetoniinae) | Few species | R |
| | Lycidae | Few species | R |
| | Cantharidae | Few species | R |
| | Cucujidae | Few species | R |
| | Carabidae | Few species | R |
| | Elateridae | Few species | R |
| | Curculionidae | Few species | R |
| DIPTERA | Agromyzidae | Few species | R |
| | Muscidae | Few species | R |
| | Syrophidae | Few species | R |
| LEPIDOPTERA | Ctenuchidae | Few Species | O |
| | Pyralidae | Few Species | R |
| | Noctuidae | Few Species | R |
| | Geometridae | Few Species | O |
| ORTHOPTERA | Mantidae | Few Species | O |
| | Blattidae | Few Species | R |
| | Acrididae | Few Species | O |

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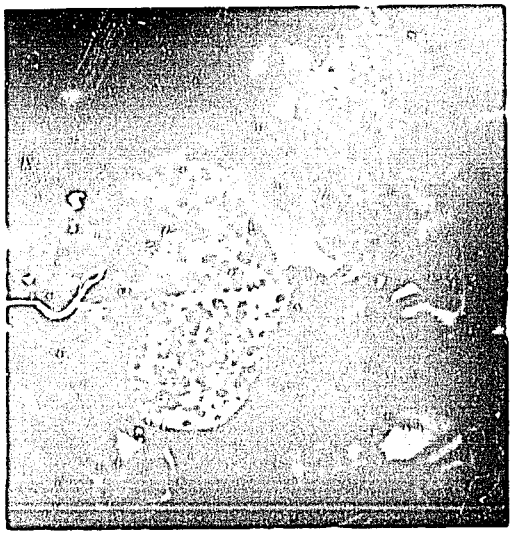
**Table 1.** *continued...*

| Order | Family | Species Noted | Relative Frequency In Collection[1] |
|---|---|---|---|
| | Tetrigidae | Few species | O |
| | Tettigoniidae | Few species | O |
| HEMIPTERA | Cydnidae | Many species | VC |
| | Cydnidae | *Brachyplatys sp* | VC |
| | Reduviidae | *Rhinocoris sp* | O |
| | Reduviidae | Many species | C |
| | Miridae | Few species | O |
| | Coreidae | *Riptortus sp* | VC |
| | Coreidae | Several species | O |
| | Pentatomidae | *Aspavia sp* | O |
| | Pentatomidae | Few species | O |
| | Lygaeidae | Few species | C |
| HOMOPTERA | Membracidae | Few species | O |
| | Flatidae | Few species | O |
| | Cicadellidae | Few species | C |
| | Cercopidae | Few species | C |
| | Derbidae | Few species | C |
| | Formicidae | Few species | O |
| | Apidae | Few species (mostly bumble bees) | |
| | | Few species (honey bees) | C |
| NEUROPTERA | Mantispidae | Few species | O |
| THYSANOPTERA | Tripidae | Leaf thrips | O |
| | | Flower thrips | VC |
| DERMAPTERA | — | Few species | O |
| ACARINA | Tetranychidae | Few species | C |

[1]O — Occasional VC — Very Common
C — Common R — Rare

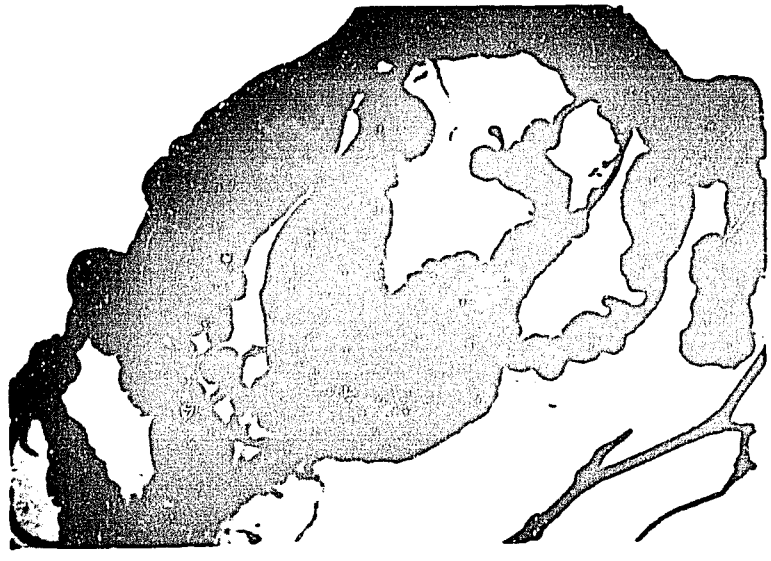
1.

2.



*1. Leaf spot (Pseudocercospora psophocarpus). 2. Powdery mildew. 3. Root knot caused by Meloidogyne incognita*

3.



# Utilization

- *The Role of the Winged Bean in Human Nutrition*
- *Comparative Nutritional and Clinical Aspects of the Winged Bean*
- *Nutritional Aspects of the Winged Bean*
- *The Winged Bean as a New Source of Protein for Rural Populations in the Ivory Coast, West Africa*
- *Utilization of Winged Bean for Thai Traditional Consumption*
- *Fermentation of the Winged Bean Seeds*
- *Household Preparation of Winged Bean Milk, Tofu, and Miso*
- *The Winged Bean in Livestock Feed with Particular Reference to the U.K. and E.E.C.*
- *Potential Markets for Winged Bean Oil Particularly in W. Europe*
- *The Proteins of Winged Bean Seed*
- *The Processing and Formulation of Weaning Foods Based on the Winged Bean*
- *A Simple Technique to Make Dried Winged Bean Seeds Edible*

# The Role of the Winged Bean in Human Nutrition

*Alan Claydon*[1]

**The winged bean plant has been used as a source of food for many centuries in the Old World tropics. All parts of the plant are edible and their usage in various geographical regions is discussed. The nutrient composition of these plant parts is presented along with the changes in composition which take place during some common methods of cooking. The inactivation of toxic factors in the winged bean is discussed with reference to some traditional processing methods. The future for industrial food processing of the winged bean is projected, especially in the light of the high quality oil and protein contained in the ripe seed. Some points are made on the dietary value of the winged bean as subsistence or home garden crop.**

## TRADITIONAL USE OF THE WINGED BEAN

The winged bean plant (*Psophocarpus tetragonolobus* (L.) (DC), has been used as a source of food and medicine in the Old World humid tropics, chiefly South and South East Asia and the Western Pacific. This use extends back over many centuries, the earlier written record being by Rumphius who lived in the South Moluccas between 1653 and 1702 (Rumphius, 1747). Traditional use of the winged bean has been described in the Mascarene Islands, Sri Lanka, India, Bangladesh, Burma, Indochina, Malaysia, the Philippines and Papua New Guinea (de Sornay, 1913; Burkill, 1906; Prain, 1903; Thompstone & Sawyer, 1914 ; Crevost & Lemarie, 1917; Burkill, (1936) 1966; Heyne, 1927; Merrill, 1912; Miklouho-Maclay, 1885).

Winged bean consumption is generally on a local basis. Large scale planting is seldom seen except in areas where a long-established tradition of cultivation exists, such as Burma and the Papua New Guinea highlands (Burkill, 1906; Khan et. al., 1977). In such areas, it seems that considerable use is made of the plant as a whole, for each part has nutritional as well as medicinal properties.

The food uses of the winged bean are described in the appendix to this paper, entitled 'Eating the Winged Bean'. The tender pods are the most popular part of the crop and the only part commonly eaten in most of Asia and Papua New Guinea. Young pods, chopped or whole, are used either raw or cooked in salad side dishes from South East Asia. Winged bean pods may be added to main dishes such as curries, stews and soups. Pods can also be stir-fried, deep fried or pressure cooked as in Papua New Guinea earth ovens or *mumu*(s).

The taste of winged bean pods is similar to that of most green beans. Immature winged bean seeds taste similar to garden peas and may be eaten raw or cooked. In some places they are consumed in preference to the whole pod. In Papua New Guinea, fibrous pods can either be steamed in a *mumu* pit or oil drum or baked in open fires. The seeds and the mucilage around them are scraped out of the pod and eaten (Hipsley & Kirk, 1965).

Fully ripe seeds are occasionally eaten in parts of Indonesia and Papua New Guinea. Sometimes farmers consume seeds saved for next year's planting during the early wet season when there is a general shortage of food as the new subsistence gardens contain only young plants. Seeds are steamed or boiled, after soaking in water overnight to loosen the seed coat and to shorten the time of cooking. Winged bean seeds are also baked (parched), either inside or outside the dry pod, and at times are stir-fried in animal fat or oil. The high temperature of frying breaks open the tough seed coat, and the peeled cooked seed makes a highly acceptable snack food. In West Java, *tempe*, a mold fermented cake, has been made from boiled, soaked winged bean seeds in the same way as using soyabeans.

Young winged bean leaves, shoots and flowers are popular additions to meals in some areas, providing color and flavor as well as nutrient. There is a fast fading tradition in West Java of deliberately infecting plants with the orange fungus *Synchytrium psophocarpi* (Rac.), known as 'false rust', which can cause the shoots, stems, leaves and pods to form turgid swellings or galls. When steamed these are regarded as a delicacy because they are crisp and juicy (Heyne, 1927). It is interesting to note that spontaneously infected leaves are highly prized also in the central highlands of Papua New Guinea.

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The use of winged bean tubers as food appears to be restricted to Burma and the Papua New Guinea highlands, although there are some rare occasions when tubers are used in countries during famines in remote subsistence garden communities. In Burma, fields of trailing winged been for tuber production have been observed (Burkill, 1906). The traditions of winged bean tuber cultivation in Papua New Guinea incorporates special techniques. The chosen tuber-producing varieties are grown on short stakes and are pruned periodically. Young shoots, flowers and pods which have been pruned are thereafter cooked or eaten raw.

Winged bean tubers are most often eaten cooked. In Papua New Guinea, tubers are sold in highland markets as baked, whereas in lower and upper Burma, tubers are sold either as raw, or boiled with rice straw (to color them red). In both countries the winged bean tuber fills the role of a valuable snack food which can be carried around and very easily peeled immediately before consumption.

However, with all its advantages, the winged bean is a food crop which has not achieved great importance in the diet as green vegetable, as grain legume or as root food. Large scale winged bean cultivation is labor intensive. In Papua New Guinea, the crop is more conveniently grown as a backyard crop along the garden fence or up the walls of a house, where pods can be picked easily throughout the long growing season. The availability of winged beans in local market tends to follow traditional planting season patterns. However, in the Papua New Guinea highlands a *mumu* pit is oftentimes seen with all parts of the winged bean plant cooking in it. The prices of winged bean pods and seeds in local markets are not high compared with similar foods, but winged bean tubers can command a much higher price than other tubers, which stimulates commercial production (Khan, et al., 1977).

## CHEMICAL COMPOSITION OF THE WINGED BEAN

Results of the first analysis on the chemical composition of the winged bean date from the turn of this century when Gresholl et al. (quoted by Masefield, 1973) found 29.8% protein and 15% oil in the seed, and when Hooper obtained the surprising result of 24.6% crude protein in a dried tuber sample (Hooper, 1902). Subsequent published results, appearing in Tables 1 and 2, confirm that the winged bean is a crop of high nutritional value. Differences between reported values must reflect not only differences in sampling and analytical methods, but more important, differences between environments and varieties, of which there are more than 122 pure lines in Papua New Guinea alone.

**Table 1. Collected results on the composition of the winged bean (grams per 100 g edible food, calculated on a fresh weight basis).**

| | | Moisture | Fat | Crude Protein | Total | Carbohydrates Fibre | Ash | |
|---|---|---|---|---|---|---|---|---|
| Seeds range[a] | | 6.7-24.6 | 15.0-20.4 | 29.8-37.4 | 31.5-38.0 | 5.0-12.5 | 3.6-4.0 | NAS, 1975 |
| Ripe seeds | Chimbu, PNG | 9.6 | 17.6 | 32.0 | 38.4 | 6.1 | 3.9[b] | Bailey, 1968 |
| White seeds | Port Moresby, PNG | 8.7 | 15.3 | 36.6 | 35.6 | 3.7 | 3.8 | Clayden, 1975 |
| Mixed ripe seeds | Goroka, PNG | 11.6 | 18.3 | 30.6 | 35.8 | 0.4 | 3.7 | Jaffe & Korte, 1976 |
| Ripe seeds | | 14 | 16.0 | 33.0 | 37 | 5.0 | — | Platt, 1962 |
| Dried seeds | | 9.7 | 17.0 | 32.8 | 36.5 | | 4.0 | FAO/UNDHEW, 1972 |
| Ripe seeds | Nigeria | — | — | 27.5-40.2 | | — | — | Luse, 1975 |
| White seeds | Ghana | 9.0 | 17.0 | 31.2 | 33.0 | 6.6 | 3.3 | Watson, 1971 |
| Brown seeds | Ghana | 10.5 | 16.5 | 32.4 | 31.2 | 6.0 | 3.4 | Watson, 1971 |
| Dry shelled seeds | Ghana | 9.7 | 18.1 | 37.3 | 25.2 | 5.4 | 4.3 | Cerny et al. 1971 |
| Air dried seed meal | Malaysia | 10.9 | 15.1 | 35.5 | 26.6 | 8.0 | 3.7 | Wong, Kai Choo, 1975 |
| Dry seeds | Philippines | 9.7 | 17.0 | 32.8 | 36.5 | 5.2 | 4.0 | Inst. of Nutr. 1957 |
| Shelled seeds | Philippines | 6.54 | 13.11 | 41.86 | 31.22 | 5.27 | | Padilla & Solisen, 1953 |
| Defatted seeds range from different varieties | Java, Madura & Bali | — | — | 25.87-41.21 | — | — | — | Citroekusuma, 1977 |
| Immature cooked | New Guinea | 79 | 3.9 | 8.1 | 8.1[c] | — | — | Hipsley & Clemente, 1947 |
| Immature pods range | | 76.0-92.0 | 0.2-0.3 | 1.9-2.9 | 3.1-3.8 | 1.2-2.6 | 0.4-1.9 | NAS, 1975 |
| Dried pods (6-34 days after Greening) | Nigeria | (5) | — | 32.9-21.1 | — | — | — | IITA, 1975 |
| Green pods | Trinidad | 91.8 | 0.2 | 1.9 | 3.1 | 2.6 | 0.4 | Purseglove, 1968 |
| Pods | Malaya | 92.1 | 0.2 | 2.4 | 4.6 | — | — | Willimott, 1949 |
| Young Pods | Malaysia | 93.0 | 0.3 | 1.9 | 2.3 | 0.9 | 0.5 | Wong, Kai Choo, 1975 |

**Table 1.** *continued*

| | | Moisture | Fat | Crude Protein | Carbohydrates Total | Carbohydrates Fibre | Ash | |
|---|---|---|---|---|---|---|---|---|
| Young pods | Philippines | 75.92-91.58 | 0.27 | 2.94 | 3.80 | 1.21 | 0.77-1.86 | Brown, 1954 |
| Pods | Philippines | 91.7 | 0.3 | 2.7 | 5.6 | 1.3 | 0.7 | FNRC, 1964 |
| Young pods | S. Vietnam | 93.5 | 0.3 | 2.1 | 3.2 | 1.7 | 0.9 | Vuilard, Goudou, 1956 |
| Immature beans & young pods raw | | 89.5 | 0.1 | 1.9 | 7.9 | 1.6 | 0.6 | FAO/USDHEW, 1972 |
| Immature beans & young pods boiled | | 92.2 | 0.1 | 1.4 | 5.9 | 1.2 | 0.4 | FAO/USDHEW 1972 |
| Seeds from immature pods | Port Moresby | 35.8-88.1 | 0.8-10.4 | 0.5-2.6 | — | — | 1.0 | Claydon, in press |
| Mucilage surrounding seeds | Port Moresby | 91.0 | | 1.4 | — | — | 0.5 | Claydon, in press |
| Immature pods without seeds | Port Moresby | 91.4-83.8 | | 0.4-3.4 | — | — | — | Claydon, in press |
| Unripe pods (2-3 weeks old range) | Bogor, Indonesia | 88.4-94.5 | | 1.2-3.1 | — | — | — | Citroreksoko, 1977 |
| Unripe pods with seeds | Port Moresby | 84.3-89.4 | 0.2-1.2 | 1.4-3.2 | — | — | 0.5-1.0 | Claydon, in press |
| Pods | Philippines | 90.4 | 0.2 | 2.9 | 5.8 | 1.3 | 0.7 | Inst. of Nut., 1957 |
| Raw or cooked beans | | — | trace | 1.8 | 4.8 | — | — | Church & Church, 1971 |
| Stems & Leaves | Malaya | 78.9 | 1.0 | 6.3[d] 4.8[e] | 7.9 | 4.1 | 1.8 | Teik, 1951 |
| Leaves (range) | | 64.2-77.7 | 0.7-1.1 | 5.7-15.0 | | | | NAS, 1975 |
| Dried leaves (up to 2 weeks after sprouting) | Nigeria | (5) | | 39.2[d] 27.8[e] | | — | — | IITA, 1975 |
| Leaves | Port Moresby | 77.7 | 1.1 | 5.7 | | — | — | Claydon, 1975 |
| Leaves from plants 2-3 months old | Port Moresby | 75.2-80.5 | 1.0-1.9 | 5.4-7.1 | | — | 1.0-2.1 | Claydon, in press |
| Leaves, raw edible portion | | 85.0 | 0.5 | 5.0 | 8.5 | — | 1.0 | FAO/USDHEW, 1972 |
| Dried flowers | Nigeria | 5 | | 22.4 | — | — | — | IITA, 1975 |
| Flowers | Port Moresby | 84.2 | 0.9 | 5.6 | — | — | — | Claydon, 1975 |
| Flowers (range) | | 54.9-65.2 | 0.5-1.1 | 12.2-15.0 | 27.2 | 17.0 | 0.9 | NAS, 1975 |
| Dried tubers | Burma | 9.0 | 1.0 | 24.6 | 56.1 | 5.4 | 3.9 | Burkill, 1906 & 1966 |
| Mature tubers | Malaysia | 16.1 | 0.5 | 18.3 | 53.9 | 8.1 | 3.1 | Wong, Kat, Choo, 1975 |
| Fresh tubers | Port Moresby | 56.5 | 0.4 | 10.9 | 30.5 | 1.6 | 1.7 | Claydon, 1975 |

[a]Result dating from 1903 to 1971.
[b]Calculated from dry weights.
[c]Calculated from values given by Platt, 1961.
[d]Crude
[e]Digestible
See also results given in Table 4.

The winged bean as green vegetable, especially the leaf, is a good dietary source of provitamin A, vitamin C, minerals and protein. As presented in Tables 1 and 2 there is a large range of values quoted for the composition of pods. This in part depends on their stage of maturity and the development of the seeds. As the protein and energy contents of the whole pod increase, the pod case becomes more fibrous and less edible. Further research is being done to find the optimum stage of pod maturity in terms of nutritive value and food acceptability.

In overall composition the winged bean seed most closely resembles the soyabean as shown in Table 3. The comparison relates not only to oil and protein but also the essential minerals, calcium and iron, and the first three B vitamins.

There seem to be very few root foods which compare in protein content with the winged bean tuber. The reason for this might be the extremely heavy root nodulation and nodule activity which the plant possesses (Masefield, 1961). The compositions of most other legume tubers, for instance those of the yam bean (*Pachyrhizus erosus* (L.) Urban) and kudzu bean (*Pueraria lobata* (syn. *P. thunbergiana* (Sieb. and Zucc. Benth.) resemble those of non-leguminous root crops, as shown in Table 4. The African yam bean (*Sphenostylis stenocarpa* (Hockst.) Harms.) is a possible exception like the winged bean with its high tuber protein content (Ranchie, personal communication).

Table 5 shows changes in composition of edible parts of the winged bean due to the three common methods of cooking. As with most grain legumes, the winged bean seed absorbs its own weight in water as a result of soaking and boiling. There appears to be little nutrient loss on removal of the seed coat after soaking and boiling, yet it represents about 13% of the total seed weight at that stage.

**Table 2. Further results on the composition of the winged bean (milligrams per 100 g fresh edible food recalculated where necessary on the same weight basis).**

| | | K | P | Ca | Mg | Na | Fe | Zn | Vit.A[g] | B1 | B2 | Niacin | C | E | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Seed (range) | | 1100-1200 | 320 | 204-370 | 120-204 | 20-56 | 9.6-11.8 | | | 1.4 | 0.2 | – | – | | NAS, 1975 |
| Ripe seed[a] | Chimbu, PNG | 1010 | 260 | 340 | 110 | 20 | | – | – | – | – | – | – | | Bailey, 1968 |
| Whole seed | Port Moresby | 1100 | 450 | 230 | 255 | 64 | 11 | 3.1[b] | – | – | | – | – | | Claydon, 1975 |
| Mixed ripe seeds | Goroka, PNG | | 500 | 215 | | | 18 | – | – | 1.05 | 0.33 | 3.09 | – | – | Jaffe & Korte, 1976 |
| Ripe seed | | | | | | – | – | – | – | 0.08 | – | – | trace | – | Platt, 1962 |
| Dried seed | | | 200 | 80 | 109 | 2.0[c] | – | – | – | – | – | – | – | | FAO/USDHEW, 1972 |
| White seed | Ghana | 410 | 210 | – | – | – | 15 | – | – | – | – | – | – | | Watson, 1971 |
| Brown seed | Ghana | 370 | 240 | – | – | 3 | – | – | – | – | – | – | – | – | Watson, 1971 |
| Dry skinned seed | Ghana | | – | – | – | – | – | – | – | 1.39 | 0.18 | – | – | 22.8[d] | Cerny et al., 1971 |
| Immature seeds | | – | – | – | – | – | – | – | – | – | – | – | – | – | |
| cooked | New Guinea | – | – | – | – | – | – | – | – | – | – | – | 37 | | Hipsley & Clements, 1947 |
| Immature pods | | – | – | – | – | – | – | – | – | – | – | – | – | – | |
| (range) | | – | 60 | 63-330 | – | – | 1.3-1.7 | – | 900 | 0.06 | 0.12 | 0.5 | 22-37 | – | NAS, 1975 |
| Dried pods (6-14 | | – | – | – | – | – | – | – | – | – | – | – | – | | |
| DAF) | Nigeria | – | 800-400 | 2000-600 | – | – | 12.4 | – | – | – | – | – | – | – | IITA, 1975 |
| Pods | Malaya | – | 31 | 7 | – | – | 0.2 | – | 300 | 0.06 | – | – | 6 | – | Willimott, 1949 |
| Young pods | Philippines | – | 26 | 236 | – | – | 12[e] | – | – | – | – | – | – | | Brown, 1954 |
| Pods | Philippines | 205 | 36 | 64 | – | 3 | 0.1 | – | 545 | 0.24 | 0.09 | 1.20 | 15 | – | FNRC, 1964 |
| Young Pods | S. Vietnam | 143 | 30 | 40 | 16 | 2 | 1.98 | – | 416 | 0.15 | 0.07 | 0.77 | 3 | | Vaillard Goudou, 19__ |
| Immature beans | | – | – | – | – | – | – | – | – | – | – | – | – | – | |
| and young pods | | – | – | – | – | – | – | – | – | – | – | – | – | | |
| raw | | 205 | 48 | 53 | – | 3 | 0.2 | – | 567 | 0.19 | 0.08 | 1.0 | 21 | – | FAO/USDHEW, 1972 |
| Immature beans | | – | – | – | – | – | – | – | – | – | – | – | – | | |
| and young pods | | – | – | – | – | – | – | – | – | – | – | – | – | – | |
| boiled | | 152 | 36 | 39 | – | 2 | 0.1 | – | 64.2 | 0.09 | 0.7 | 0 | 0 | | FAO/USDHEW, 1972 |
| Unripe pods with | | – | – | – | – | – | – | – | – | – | – | – | – | – | |
| seeds | Port Moresby | 37-100 | – | 17-28 | – | 5-10 | 0.3-0.6 | 0.1-0.3 | 50-820 | – | – | – | 17-25 | – | Claydon, in press |
| Seed from pods | | | – | – | – | – | – | – | – | – | – | – | – | | |
| (above) | Port Moresby | 120 | – | 48 | – | 1 | 0.2 | 0.1 | 250 | – | – | – | 13-25 | – | Claydon, in press |
| Mucilage from | | | – | – | – | – | – | – | – | – | – | – | – | – | |
| pods (above) | Port Moresby | 100 | – | 10 | – | 1 | 0.1 | 0.1 | 400 | – | – | – | 22 | | Claydon, in press |
| Pods | Philippines | 205 | 37 | 63 | – | 3.1 | 0.3 | – | 595 | 0.24 | 0.09 | 1.2 | 19 | – | Inst. of Nut. 1957 |
| Raw or cooked | | | | | | | | | | | | | | | |
| beans | | – | 37 | 57 | – | – | 0.5 | – | 330 | 0.22 | 0.089 | 0.7 | – | – | Church & Church, 1971 |
| Stems and leaves | Malaya | – | 52 | 260[e] | – | – | – | – | – | – | – | – | – | – | Teik, 1951 |
| Dried leaves | Nigeria | – | 600-300 | 500-1200 | – | 10-12 | – | – | – | – | – | – | – | – | |
| Leaves from | | – | – | – | – | – | – | – | – | – | – | – | – | | |
| plants (2-3 | | – | – | – | – | – | – | – | – | – | – | – | – | | |
| months old) | | – | – | – | 11-18 | – | – | 0.5-1.4 | 9730-19300 | 0 | – | – | 55-128 | | |
| Leaves, raw | | – | 81 | 134 | – | – | 6.2 | – | 5240 | 0.28 | – | 29 | – | – | FAO/USDHEW, 1972 |
| Dried flowers | Nigeria | – | 500 | 300 | – | – | 10 | – | – | – | – | – | – | – | IITA, 1975 |
| Tubers (range) | | – | 64 | 40 | – | – | 3.0 | – | – | – | – | – | – | – | NAS, 1975 |
| Fresh tubers | Port Moresby | 550 | 30 | 25 | 23 | – | 0.5 | 1.3[f] | – | – | – | – | 26 | – | Claydon, 1975 & 1976 |

[a]Calculated from dry weight figures.
[b]Sr: 380, Mn: 25 (mg).
[c]Pyridoxine 0.11 mg, folic acid 25.6 mcg.
[d]Calculate from tocopherol content in the oil.
[e]Originally expressed as oxides.
[f]Sr: 21, Mn: 10 (mg).
[g]Vitamin A (carotene) contents expressed in international units.

The changes in composition of pods, leaves and flowers during boiling are not only due to absorption of water but also leaching of soluble carbohydrates, proteins, amino acids, minerals and vitamins as well as thermal decomposition of ascorbic acid. Short-time cooking methods for vegetables such as stir-frying assist retention of nutrient and reduce the amount of ascorbic acid breakdown. For seeds and tubers, which require much longer periods of cooking, there is some benefit in keeping the outer covering on while processing.

Table 3. Composition of four important tropical grain legumes.

| | Winged bean[a,c] | Soyabean[b] (dried) (yellow varieties) | Peanut[b] | Cowpea[b] |
|---|---|---|---|---|
| 1 *MATURE SEEDS* (grams per 100 g fresh edible weight) | | | | |
| Moisture | 8.7 | 10.2 | 7.3 | 11.5 |
| Total energy (mj) | 1.61 | 1.61 | 2.29 | 1.43 |
| Fat | 15.3 | 17.7 | 45.3 | 1.6 |
| Crude protein | 36.6 (N × 6.25) | 35.1 | 23.4 | 22.7 |
| Carbohydrates | 35.6 | 32.0 | 21.6 | 61.0 |
| Fibre | 3.7 | 4.2 | 2.1 | 4.2 |
| Ash | 3.8 | 5.0 | 2.4 | 3.2 |
| 2. *MINERALS* (milligrams per 100g fresh weight) | | | | |
| Potassium | 1100 | 1504 | 662 | 688 |
| Phosphorus | 450 | 546 | 357 | 382 |
| Magnesium | 255 | 236 | 185 | 53 |
| Calcium | 230 | 226 | 58 | 110 |
| Iron | 10.8 | 8.5 | 2.2 | 6.5 |
| 3 *VITAMINS* (milligrams per 100g edible portion) | | | | |
| Thiamine | 1.05 | 0.66 | 1.00 | 0.59 |
| Riboflavin | 0.33 | 0.22 | 0.13 | 0.22 |
| Niacin | 3.09 | 2.2 | 16.8 | 2.3 |

[a]Claydon, 1975.
[b]FAO, USDHEW, 1972.
[c]Jaffe & Korte, 1976.

Table 4. Composition of some tropical root foods.

| | Winged bean[a] | Kudzu bean (*Pueraria lobata*) (syn. *thunbergiana*) | Yam bean (*Pachyrrhizus erosus*)[b] | Yam (white) (*D. alata*)[b] | Sweet Potato (white)[b] |
|---|---|---|---|---|---|
| (a) *PROXIMATE COMPOSITION* (grams per 100g edible food) | | | | | |
| Moisture | 56.5 | 68.6 | 87.4 | 76.4 | 72.3 |
| Energy (Mj) | 0.63 | 0.47 | 0.19 | 0.36 | 0.45 |
| Protein (crude) | 10.9 (N × 6.25) | 2.1 | 1.6 | 1.9 | 1.0 |
| Fat (crude) | 0.4 | 0.1 | 0.2 | 0.2 | 0.3 |
| Carbohydrate (total) | 30.5 | 27.8 | 10.3 | 19.9 | 25.6 |
| Fibre | 1.6 | 0.7 | 1.3 | 0.6 | 0.8 |
| Ash | 1.7 | 1.7 | 0.5 | 1.6 | 0.7 |
| (b) *MINERALS and VITAMINS* (milligrams per 100g edible food) | | | | | |
| Calcium | 25 | 15 | 18 | 38 | 21 |
| Iron | 0.5 | 0.6 | 0.8 | 1.1 | 0.9 |
| Ascorbic acid | 26 | — | 15 | 6 | 21 |

[a]Claydon, 1975 and 1976.
[b]FAO/USDHEW, 1972.

**Table 5. Effect of cooking on the nutrient composition of edible parts of the winged bean plant.**

| (per 100g edible portion) | Moisture % | Fat g | Protein g | Carbohydrate (total) | Ash g | Calcium mg | Iron mg | Ascorbic acid mg |
|---|---|---|---|---|---|---|---|---|
| *SEED* ripe | | | | | | | | |
| whole, raw | 11.4 | 18.5 | 33.0 | 34.1 | 3.0 | 280 | 8.0 | — |
| whole, soaked[1] & boiled[2] | 55.0 | 10.0 | 17.9 | 15.5 | 1.6 | 161 | 3.0 | — |
| soaked,[1] boiled[2] & skinned | 52.8 | 11.5 | 20.6 | 13.3 | 1.8 | 174 | 3.1 | — |
| *POD* whole, 7-14 days after flowering | | | | | | | | |
| raw | 89.6 | 0.4 | 2.7 | 6.7 | 0.6 | 80 | 2.3 | 20 |
| boiled[3] | 90.4 | 0.4 | 2.5 | 6.2 | 0.5 | 59 | 1.3 | 4 |
| steamed[3] | 90.5 | 0.4 | 2.3 | 6.2 | 0.6 | 74 | 1.7 | 9 |
| stir-dried[4] | 84.7 | 2.8 | 3.3 | 8.5 | 0.7 | 100 | 2.9 | 8 |
| *LEAF* top 3 sets, from plants 2-3 months old | | | | | | | | |
| raw | 78.1 | 1.6 | 8.1 | 10.8 | 1.4 | 205 | 3.2 | 73 |
| boiled[5] | 85.5 | 1.5 | 5.8 | 6.5 | 0.7 | 125 | 1.4 | — |
| steamed[5] | 81.6 | 1.6 | 7.2 | 8.5 | 1.1 | 155 | 1.8 | — |
| stir-fried[4] | 62.4 | 13.9 | 11.8 | 10.3 | 1.6 | 240 | 3.7 | 44 |
| *FLOWER* fully opened from plants 2-3 months old | | | | | | | | |
| raw | 87.5 | 0.5 | 2.8 | 8.4 | 0.8 | 67 | 1.7 | 5 |
| boiled[5] | 93.1 | 0.4 | 1.9 | 4.2 | 0.4 | 45 | 1.6 | 3 |
| steamed[5] | 86.9 | 0.5 | 2.9 | 8.9 | 0.8 | 60 | 1.5 | 2 |
| stir-fried[4] | 72.9 | 8.9 | 4.2 | 12.8 | 1.2 | 102 | 2.6 | 4 |
| *TUBER* (Claydon, 1976) | | | | | | | | |
| raw | 63.2 | — | — | — | — | — | — | 26 |
| steamed[6] | 63.6 | — | — | — | — | — | — | 19 |

NOTES:

[1]24 hours at room temperature.
[2]30 minutes in 5× sample weight of water.
[3]15-20 minutes (in 5 × sample weight water, where boiled). Excess water drained off.
[4]7 minutes in shallow layer of edible oil. Excess fat removed from surface.
[5]as in 3 with 5 minutes cooking.
[6]42 minutes steamed with skin on, then peeled.
All samples except tubers, taken from plants of one pure variety (UPS 1227 grown at Waigani, Papua New Guinea from July to October 1977.

## TOXIC FACTORS IN THE WINGED BEAN

Many legume species contain a variety of toxic and pharmacologically active compounds, especially in the seed. Some factors of this type have already been found in the winged bean seed. In order to find out more about toxic factors present in the whole winged bean plant and ways to remove or destroy them, it is necessary to look at some of the traditional methods of processing the plant for human consumption, and also some of its medicinal uses. A brief summary of toxic compounds, toxic effects and medicinal uses reported in the Asia-Pacific region appears in Table 6.

Table 6. Toxic compounds and medicinal uses of the winged bean[a]

| | Leaves | Immature Pods | Ripe Seed | Tubers |
|---|---|---|---|---|
| Medicinal Usage | (Indonesia)<br>a) Eye and ear infections[b]<br>b) Boils (when mixed with adas pulosari cetatet)<br>(in anaemia)<br>c) Dyspepsia (in the morning)<br>d) Toothache<br>(Malaysia)<br>e) Smallpox | (Sri Lanka)<br>a) Diabetes<br>(Indonesia)<br>b) Good for the blood<br>c) Slimming food | (Indonesia)<br>a) Cleansing the blood[f]<br>b) Venereal disease[f] | (Burma)<br>a) Vertigo (poultice)<br>(Indonesia)<br>b) Thrush (boiled with lump sugar) |
| Toxic effects reported | (Indonesia)<br>Too many raw leaves produce dizziness, sea and flatulence | (Indonesia)<br>Too many raw pods produce dizziness, nau flatulence | (Indonesia)<br>Raw seeds toxic to rats and they are avoided by humans<br>Too many cooked seeds (roasted) produce dizziness heavy head feeling | (Burma)<br>Cooked tubers eaten with cocoa or chocolate produces severe intoxication<br>(Papua New Guinea<br>Raw tubers can produce nausea |
| Toxic factors found | Cyanide reported in stems[d] | Trypsin inhibitor in developed seeds only[e] | Trypsin inhibitor[i]<br>Hemagglutinin[j]<br>Cyanide (low content)[k]<br>Saponins[l] | |

[a]Claydon, in press. Some of this information needs corroboration Hayne, 1927.
[b]Hayne, 1927.
[c]Burkill and Haniff, 1980.
[d]Teik, 1951.
[e]Sohonie & Bhandarkar, 1954.
[f]Sunarjono, 1972.
[g]Claydon, 1975.
[h]Cerny et. al., 1971.
[i]Renkonen, 1948.,
[j]Schertz et. al., 1960.
[k]Bhatia and Allen, 1962.
[l]Balasubramanian, personal communication.

The eating of raw, ripe winged bean seed by humans appears to be undesirable. Jaffe and Korte (1970) observed 100% mortality in rats fed diets containing raw winged bean flour with or without added methionine. Pancreatic hyperplasia and low spleen weights were recorded, and similar effects were obtained from diets using raw kidney bean (*P. vulgaris*) flour. The hemagglutinin, trypsin inhibitor and amylase inhibitor activities in the winged bean were found to be lower than those in the kidney bean. Another rat feeding experiment using raw winged bean seed in nutritionally balanced diets reported symptoms of renal failure, possible liver cirrhosis and general malnutrition in all but control groups (Claydon, unpublished).

Strong non specific hemagglutinating activity has been noted in winged bean seeds by Renkonen (1948) and Schertz et al. (1960). Bhatta and Allen (1962) found out that winged bean agglutinating extract reacted with all blood groups tested except one which was H antigen deficient. Sohonie and Bhandarkar (1954) reported finding trypsin inhibitor activity in winged bean pods, but only in developed seed inside and not in the outer tissues.

Winged bean seed trypsin inhibitor seems to be reasonably heat-resistant. Sohonie and Bhardarkar's acid-extracted inhibitor lost very little of its activity after 1 hour in boiling water and it still retained almost half its activity after 30 minutes autoclaving at 15 pounds pressure (121°C). Cerny et al. (1971) completely destroyed trypsin inhibitor activity in raw ripe winged bean seed by autoclaving at 130°C for 10 minutes, or by soaking the seed in water for 30 minutes. It is worthy to note that this study found dry heat unsatisfactory for complete removal of trypsin inhibitor activity. Some current thought, however is that trypsin inhibition is without much nutritional significance because of lack of conclusive evidence of its effects in humans (Liener, 1973).

Cyanide has been reported in the stems of the winged bean plant (CSIR, 1962) and it has also been found in the ripe seed (Claydon, 1975). The amount liberated from the seed (5 mg%) is about twice the amount in raw peas but only a third the amount found in 'safe' varieties of lima bean (*Phaseolus lunatus* L.)(Liener, 1973). The presence of saponins in the winged bean seed is currently being investigated (Balasubramanian, personal communication).

There seems to be very little more information available on toxic and pharmacologically active factors present in the seed or in other parts of the winged bean plant. Perhaps the lower digestibility of the seed carbohydrates in relation to that in some other grain legumes (Rathfelder, 1977) might offer some possible explanation for toxic effects reported from eating the seed.

## PRESERVATION AND PROCESSING OF THE WINGED BEAN

There has been very little preservation and processing of the winged bean, due perhaps to its restricted cultivation and its generally low dietary importance compared with some other available foods. The storage of winged beans is limited only to the seed and this is usually for the purpose of next year's crop if the winged bean is grown seasonally. In Papua New Guinea, winged bean tubers are sometimes stored temporarily in the field before being sold in the market. They are not stored for future consumption in the village, like yams, although it has been shown that winged bean tubers can be stored in an almost fresh state for up to 2 months (Claydon, 1976). There appears very little if any village or commercial storage, preservation or processing of winged bean pods, except for their use in pickles in South India (Kesavan, personal communication). There might perhaps be a local or export market for young winged bean pods or immature seeds locally processed in bottles or cans in other regions.

Ripe seeds have been traditionally processed in West Java to make *tempe*, a mold-fermented cake which is more often made with cooked soybean seeds. Investigations are currently being made into the production of other traditional soyabean processed products like *tahu* (bean curd) and soyabean 'milk' from winged bean seeds.

Another important topic of research should be the use of ripe winged bean seed as a source of edible oil and high-protein human food or animal feed. Winged bean seeds contain about as much oil and protein as soyabean seeds. The composition and properties of winged bean seed oil compared with soyabean and groundnut oils are given in Table 7. It is apparent that winged bean oil contains a very acceptable amount of unsaturated fatty acids, especially linolenic acid (18:2). In contrast to soybean oil, the content of linolenic acid (18:3) is low in winged bean oil, giving it greater potential stability. Furthermore, Cerny et al. (1971) have reported a higher content of tocopherol antioxidants in crude winged bean oil than in soyabean or maize oils.

**Table 7.** Composition and properties of winged bean seed oil as compared with soya and groundnut oils.

| Fatty acid | | Winged bean | | | Soya[c] | Groundnut[c] |
|---|---|---|---|---|---|---|
| | | P.N.G.[a] | | Other | | |
| | (% saponifiable oil) | (1) | (2) | varieties[b] | | |
| Myristic | 14:0 | 0.3 | 0.4 | 0.1 | 0.1 | 0.4 |
| Palmitic | 16:0 | 9.0 | 9.8 | 8.9-9.7 | 11.0 | 10.0 |
| Palmitoleic | 16:1 | 0.6 | 0.3 | 0.8 | 0.1 | 1.7 |
| Stearic | 18:0 | 6.9 | 6.7 | 5.7-5.9 | 4.0 | 4.0 |
| Oleic | 18:1 | 41.6 | 36.6 | 32.3-39.2 | 25.0 | 61.0 |
| Linoleic | 18:2 | 28.6 | 31.3 | 27.2-27.8 | 50.0 | 18.0 |
| Linolenic | 18:3 | 1.0 | 1.1 | 1.1-2.0 | 8.0 | — |
| Arachidic | 20:0 | 2.2 | 1.5 | 2.0 | 0.4 | 0.9 |

Table 7. *continued*. . .

| Fatty acid (% saponifiable oil) | | Winged bean P.N.G.[a] (1) | (2) | Other varieties[b] | Soya[c] | Groundnut[c] |
|---|---|---|---|---|---|---|
| Gadoleic | 20:1 | | | | | |
| and | | 3.0 | 2.6 | 2.5 | — | 1.1 |
| Parinaric | 18:4 | | | | | |
| Behenic | 22:0 | 6.1 | 8.9 | 13.4-15.5 | 0.3 | 2.5 |
| Lignoceric | 24:0 | 1.0 | 1.7 | — | — | 1.0 |
| Iodine value | — | 95.0 | — | 82.1[d] | 125-128 | 84-102 |
| % Unsaponifiable matter | — | 2.4 | 2.9 | — | 1.0-1.5 | 1.0 |
| Saponification value | — | — | — | 176 | 188-195 | 188-196 |
| % Oil | — | 16.2 | 20.4 | 15.0-20.4 | 17.7 | 48.4 |

[a]Claydon, 1978.
[b]NAS, 1975.
[c]Hildith & Williams, 1964.
[d]Agenolli, 1929.

Winged bean oil contains a very unusual fatty acid, parinaric (cl8:4; 9c, 11t, 13t, 15c), which seems not to have been isolated before from legume seeds (Hilditch & Williams, 1964). Though it is readily identifiable in the u.v. spectrum , its concentration is probably much lower than the figure given in Table 7, which refers to the more common fatty acid, gadoleic (C20:1). It is also unusual for a legume oil to contain such a high amount of behenic acid (C22:0). This saturated acid has not been reported to be toxic and it is found mainly in the unsaponifiable fraction, which is lost during the refining of crude edible oil.

Table 8. Composition and nutritive value of winged bean seed protein as compared with soybean.

| Amino acid (% whole protein) | Winged Bean (a) | (b) | (c) | (d) | (e) | Soyabean (a) | (b) |
|---|---|---|---|---|---|---|---|
| Arginine | 6.5 | 6.6 | 7.5 | — | — | 7.0 | 7.1 |
| Histidine | 2.7 | — | 2.9 | — | — | 2.5 | 2.6 |
| Lysine | 8.0 | 7.4 | 7.6 | — | 9.6 (Total) | 6.6 | 6.2 |
| Tyrosine | 3.2 | — | -- | — | — | 3.2 | — |
| Tryptophan | — | 1.0 | — | — | 0.75 | 1.2 | — |
| Phenylalanine | 5.8 | 4.8 | — | — | — | 4.8 | — |
| Cystine | 1.6 | 2.6 | 1.6 | 1.7 | 1.17 | 1.2 | 2.0 |
| Methionine | 1.2 | — | 1.1 | 1.4 | — | 1.1 | 1.3 |
| Serine | 4.9 | 5.2 | — | — | — | 5.6 | — |
| Threonine | 4.3 | 4.5 | — | — | — | 3.9 | — |
| Leucine | 9.0 | 8.6 | — | — | — | 7.6 | — |
| Isoleucine | 4.9 | 5.1 | — | — | — | 5.8 | — |
| Valine | 4.9 | 5.7 | — | — | — | 5.2 | — |
| Glycine | 4.3 | — | — | — | — | 3.8 | — |
| Alanine | 4.3 | — | — | — | — | 4.5 | — |
| Proline | 6.9 | 7.6 | — | — | — | 5.4 | — |
| Glutamic acid | 15.3 | 15.8 | — | — | — | 18.5 | — |
| Aspartic acid | 11.5 | 12.5 | — | — | — | 8.3 | — |

| Cooked winged bean[a] | Cooked Winged bean + maize[c] | Cooked winged bean + 0.3% methionine[f] | Cooked winged bean[e] | Cooked winged bean + 0.3% methionine |
|---|---|---|---|---|
| P.E.R. 2.1 | 2.7 | 3.5 | 1.6 | 2.8 |
| N.P.U. 55 | 66 | (NPR) 4.4 | — | — |

[a]Cerny et al., 1971 & 1973.
[b]Kapsiotis, 1968.
[c]Carpenter, personal communication.
[d]Claydon, unpublished.
[e]Jaffe & Korte, 1976.
[f]Tobin, 1975.

The composition and nutritive value of winged bean seed protein is shown in Table 8. The amino acid profile of the winged bean seed, like that of many other legume seeds, shows a primary limitation in the essential sulphur amino acids, methionine and cystine. But the overall essential amino acids composition of the winged bean is very similar to that of the soyabean which has a much higher chemical score and nutritive value than most other legumes.

The biological value of cooked winged bean seed protein has been assessed using rats (Cerny et al., 1971; Tobin, 1975; Jaffe and Korte, 1976) and chickens (Wong, 1975) and it was found to be quite similar to that of the soyabean. In Ghana, children with Kwashiorkor were successfully fed with cooked winged bean seed flour in part replacing skim milk on maize-skim milk diets (Cerny & Andy, 1973). On the basis of such favorable results, the addition of winged bean flour to children's diets has been encouraged in countries such as Hongkong and Papua New Guinea (Fry, 1965; Clark et al. 1975).

The sweet, nutty taste of cooked winged bean seeds was shown to be well accepted in Ghana. Perhaps processed winged bean products will be even more readily accepted in countries where the winged bean plant is already known.

## DISCUSSION AND FUTURE OUTLOOK

In the humid tropics where it is grown, the winged bean is regarded as a popular vegetable and snack food. It is a crop capable of producing virtually all types of food, from salad greens to a pulse high in protein and energy, and to an unusually nourishing tuberous root.

Due to its labour intensive cultivation requirements, the winged bean is mostly grown by villagers on a small scale in subsistence gardens and home gardens or beside large scale cultivated crops. Its dietary importance is therefore expected to be low. However, because of its outstanding nutritional advantages the winged bean is well suited to humid tropics and ought to be cultivated here more extensively. The vegetative parts of the winged bean are rich in vitamins, minerals and protein; the seed is very high in protein, oil, minerals and vitamins, and the tuber is much higher in crude protein than other roots which are often staple foods. There are numerous ways of cooking and serving these plant parts in order to make them acceptable to a wide range of tastes.

In the case of one commodity, the tuber, some subsistence gardeners have even turned to larger scale commercial cultivation. With the development of improved varieties of seed, large scale cultivation of the winged bean for general purposes may develop more quickly. The benefits of the winged bean plant as food should then be extended over a wider range of people with the marketing of fresh or locally processed winged bean products. Ripe winged bean seed might then be used commercially as a locally grown substitute for items such as other gram legumes, edible oils, high protein products and snack foods which are very expensive but necessary imports in several developing countries. The export of winged bean products and winged bean is perhaps just another step further.

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*Household preparation of winged bean seeds in the Ivory Coast.*

## APPENDIX A. EATING THE WINGED BEAN

The winged bean plant, *Psophocarpus tetragonolobus* (L.) DC, has been cultivated as a food crop for many centuries in the humid tropical belt from the Mascare Islands through South East Asia to the eastern Pacific. It is, therefore, to be expected that a wide variety of traditional ways of preparation of the winged bean exists. Every part of the plant is potentially edible with or without processing.

This report brings together some of the culinary practices associated with the winged bean in different parts of the world. It also includes some more recent information and suggestion on the possibility of local or commercial processing in order to make all parts of the winged bean plant more acceptable and available to a wide range of tastes.

An index and key to recipes and suggestions appears below:

**Index to Recipes and Suggestions on Eating the Winged Bean**

| | Raw Alone | Raw Mixed | Cooked Alone | Cooked Mixed | Processed Currently | Suggestions |
|---|---|---|---|---|---|---|
| | | | — page — | | | |
| 1. Shoots | 275 | 275 | 275 | 275 | — | 275 |
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| 4. Immature Pods | 276 | 276 277 | 277 | 277-279 | 279 | 279 |
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### 1. Shoots

1.0 Tender shoots from the top of the winged bean stem(s) and side shoots which appear on the base of the stem in the later life of the plant probably due to *S. psophocarpi* inflation are eaten raw in parts of Indonesia and Papua New Guinea. They are almost always green and their taste is pleasant and slightly sweet.

1.1 Winged bean shoots may be found in mixed dishes of raw vegetables as given in section 4.1.

1.2 Winged bean shoots are most often boiled, but they may also be steamed or stir-fried if served as a cooked green vegetable.

1.3 Shoots of the winged bean may be added to vegetable soups (e.g. in Thailand) *mumu*(s) (Papua New Guinea) or boiled or fried in a curry. See section 4.3 for detail.

1.4 No processed product reported.

1.5 The use of sprouted winged bean seed should be investigated and its nutrient composition determined. No toxic substances have so far been reported in winged bean shoots or sprouts.

### 2. Leaves

2.0 Young leaves are sometimes eaten raw in South East Asia and Papua New Guinea. In Papua New Guinea the top three sets of leaflets are most often chosen for food. Leaflets lower down may be too tough and are then unsuitable for consumption. Young leaves are attractive in flavour, dark green in colour and contain large amount of vitamins, minerals and protein.

2.1 Winged bean leaves may be added to mixed raw vegetable dishes of the type given in section 4.1.

2.2 Winged bean leaves are most often boiled, but they may also be steamed or stir fried if presented as a cooked green vegetable. No detailed information on the preparation of 'false rust' infected leaves is available.

2.3 Leaves of the winged bean may be used in vegetable and fish soups and stews, *mumu*(s), and curries. See section 4.3 for details.

2.4 No processed product reported.

2.5 Winged bean leaves may be cooked like spinach in a variety of European and Oriental ways.

**Flowers**

3.0 Some flowers may be picked from the winged bean plant in order to prevent the plant collapsing under an undue weight of pods, or to encourage it to produce better tubers. Flowers can be eaten raw; their taste is sweet and their colours range from white and blue to red and deep purple.

3.1 Winged bean flowers may be added to mixed dishes of raw vegetables, as given in section 4.1.

3.2 Winged bean flowers are very often cooked by frying in oil. The taste of shallow-fried winged bean flowers is reminiscent of mushrooms. In Thailand, winged bean flowers may be mixed with flour and fried in the same way as *Sesbania roxburghii*, Merr. flowers are fried. They may also be mixed with egg and fried. Winged bean flowers may be gently steam-cooked, but if they are boiled they tend to lose their attractive colour and become very soggy.

3.3 Flowers of the winged bean can be found mixed with other vegetables in Papua New Guinea *mumu(s)*.

3.4 No processed product reported.

3.5 Winged bean flowers might perhaps be dried, crushed and used as colouring to be sprinkled on top of foods. Unfortunately they have no distinctive smell.

**4. Immature Pods.**

4.0 Young or immature pods remain tender until about 2 weeks after the corresponding flowers opened. Once the pods reach their maximum length, they very quickly become too stingy to eat raw. The seeds inside the immature pod are not formed and are still juicy. The colour of the pod and the seeds inside is normally green but varieties which are purple or green with purple wings are known in some areas such as the Papua New Guinea highlands. Immature winged bean pods have a distinctive flavour which is similar to other green beans.

4.1 Immature winged bean pods may be eaten raw, either whole or chopped. They are also used in salad-side dishes such as those given below:

**YAM TAENG (Thailand)**

Cut a short cucumber into small pieces and finely dice about 100 grams of young winged bean pods. Place the vegetables in a salad bowl and add 2 tablespoon of ground dried prawns, 1 tablespoon of ground roast peanuts and 1/2 a shallot, finely chopped. Mix together 1 teaspoon of sugar with salt, the juice of 2 Limes or 1/2 a lemon, 2 teaspoon *nam plaa* (fish sauce) and a pinch of ground chili (if desired), toss this dressing with the other ingredients and garnish with fried garlic, mint of coriander sprigs and soaked fresh chilies.

**SOM TOM (Thailand)**

Prepare a salad dressing from brown sugar (3 teaspoons); ground black pepper (2 teaspoons), ground chili (1 teaspoon), *nam plaa* (fish sauce) (1 dessert spoon), crushed garlic (3 cloves) and the juice of 1 lemon or limes. Toss about 225 grams of finely shredded vegetables (winged beans, cucumber, green pawpaw, celery and cabbage) and 2 firm tomatoes, quartered, in the dressing about and serve on a bed of lettuce leaves.

**NAM PRIK PAK (Thailand)**

Pound together one tablespoon of *kapi* (shrimp paste) with 1 to 3 cloves of garlic, 5 to 7 small red chilis, 1 teaspoon of sugar, 2 teaspoons of lemon juice and 1 teaspoon of *nam plaa* (fish sauce). Place this well-mixed sauce in the middle of a large plate and arrange winged bean pods and other vegetables, cut in strips, around the sauce.

**ASINAN (Indonesia)**

Mix chopped winged bean pods with bean sprouts, shredded cabbage and strips of unpeeled cucumber in a salad bowl. Toss with a dressing made from distilled vinegar, a little white sugar, a few fried prawns, salt and chili powder. Serve on a bed of lettuce leaves and sprinkle with roughly ground roasted peanuts. *Lalab* and *rumbah* are Indonesian side dishes like asinan containing winged bean pods and other raw vegetables.

4.2 Immature winged bean pods are very often eaten as cooked plain vegetable. They are usually chopped down the length of the pod and boiled, steamed or stir or deep-fried. Young winged bean pods may be cooked whole in mumu(s) (See section 4.3). Young winged bean pods may be found in a variety of cooked

mixed dishes such as soups, curries and sambal(s) all through South Asia, and stews and *mumu*(s) of Papua New Guinea.

4.3 Immature winged bean pods are also prepared and mixed with other foodstuffs as in the following:

**SAYUR ASAM (Indonesia)**

Prepare a stock by boiling 1/2 a shallot, chopped, 2 fresh red chilis, 1 curry leaf, 1/2 teaspoon of brown sugar (if desired), 2 cloves of garlic (crushed), a little fried meat or prawn and 1/2 cm. of *terasi* (Indonesian shrimp paste or blachan) in 0.8 litres (1-1/2 pints) of water for 10 minutes. Add a combination of the following vegetables (raw peanuts, soaked kidney beans, young corn on or off the cob, young chopped winged beans, french beans or long beans (cowpeas), diced aubergines and sliced courgettes (zuchinni) and when they are lightly cooked add about 100 m. tamarind water. Stir, return to the boil and serve.

**YAM STEW (Papua New Guinea)**

Boil together peeled yam (taro or sweet potato) with green leaf vegetables such as sibika (*Abelmoschus manihot*) or cassava leaves, winged bean pods, long beans (cowpeas), river fish and salt if available, in water or coconut cream diluted with 2 volumes of water.

**DAMBALA MALLUN (Sri Lanka)**

Wash and slice young winged bean pods (*dambala*) after removing strings if necessary. Add salt and (a little) water, and boil gently. Remove from the heat and crush some onions, green chili and coconut together. Add these to the boiled winged bean and simmer until the coconut smells cooked.

**GADO-GADO (Indonesia)**

Boil and slice some waxy potatoes and hard boil one egg. Deep fry some pieces of *tahu* (soyabean curd) until brown and crisp. Slice and lightly cook some young carrots and very lightly boil or blanch some chopped winged beans or long beans (*kacang panjang*) or french beans, mungbean or soyabean sprouts and shredded cabbage. Arrange all the vegetables with some thick strips of unpeeled cucumber and slices of hard boiled egg on a flat plate Prepare the gado-gado peanut sauce by first frying about 225 g raw peanuts in 2 tablespoons of oil, preferably coconut oil. Remove the cooked peanuts and use the rest of the oil to fry separately in the following order: 7 small, whole fresh chilis with seeds removed; 3 cloves of garlic, smashed and roughly chopped; and 1 teaspoon of *terasi* (shrimp paste). Blend and finely grind the chillis, garlic and *terasi* and then add the peanuts and grind roughly. Add 0.3 litres (1/2 pint) of coconut cream, 1-2 teaspoons of brown sugar and blend thoroughly. Transfer the mixture into a sauce pan, add 1 slice of fresh *laos* (Galanga root) or 1/2 teaspoon laos *laos* powder and 2 curry leaves, bring to boil and cook until the sauce thickens enough to be poured. Removed the sauce from the heat, add 1 teaspoon of lemon juice of white vinegar and pour over the vegetables on the plate. Garnish with finely chopped celery and fried chopped spring onions.

**URAB (Indonesia)**

Mix 200 grams of grated fresh coconut 1/2 clove of garlic, smashed and chopped, 1/2 teaspoon of fried *terasi*, 2 sliced fresh hot chilies and brown sugar and salt to taste. Allow to stand for a few minutes and then toss with about 300 grams of lightly cooked vegetables (winged beans or other green beans sliced into 2-3 cm lengths, bean sprouts, celery and diced choko (chayote, *Sechium edule*) until well mixed. Served straight away.

**PECAL (Indonesia)**

Arrange heaps of lightly cooked vegetables such as chopped young winged bean pods, shredded cabbage, diced choko (chayote), sliced waxy potato and halved hard-boiled eggs, and serve accompanied by *pecal* sauce in a separate bowl. This sauce is made by roughly mixing 50 grams fried peanuts, roughly ground; 1/2 teaspoon ground chili powder, 1/2 clove of garlic, smashed and chopped, 1/2 a shallot, finely chopped, 1/2 teaspoon of fried *terasi* (shrimp paste), 1 teaspoon of brown sugar and 4 tablespoons of water.

## DAMBALA CURRY (Sri Lanka)

Wash and thinly slice some winged beans, and a little saffron, salt and curry powder, some chopped onions and green chilis, and cook with a little water until it boils. Remove from the heat, and in a separate pan heat up some oil. Cut a few onions, green chilis, rampe (lemon grass) and *karipinta* (curry leaves) and fry them in the oil until the onions are golden brown. Add the boiled winged beans and some coconut milk and simmer on a low heat for a few minutes.

## KAENG PHET PLAA (Thailand)

Prepare the kaeng phet sauce by pounding together 1 garlic clove, 5 shallots, 5 small red chilis, 3 small pieces of *kah* (galanga or *laos*), 2 pieces of cut lemon grass, 1-3 sliced *bai makrut* (bergamot or lime) leaves. Add 1 teaspoon of *kapi* (shrimp paste or *terasi*) and form a fine paste. Fry the *kaeng phet* sauce in coconut milk for about 20 minutes, then add 10-20 fish balls (*plaa*) and fry for a further 5 minutes. Add chopped winged bean pods, green chilis, more *bai makrut* and more coconut milk or cream and simmer until the curry thickens.

## MUMU (Papua New Guinea)

*Mumus* in Papua New Guinea are basically of two types, below ground and above ground. In the highland areas a *mumu* is usually cooked below ground in a pit. This pit is lined first with banana leaves and a stick is placed upright in the centre. A number of large stones previously heated for some hours in a fire are placed over the bottom of the pit and some banana or other thick leaves are placed on them. All food to be cooked (unpeeled sweet potatoes, taro, yam or cooking banana, leafy vegetables, winged bean pods (mature or immature), shoots, flowers, leaves and tubers if available, other vegetables like chokos (chayotes), and occasionally meat or fowl) is wrapped in banana leaves in packages of various sizes and placed on top of the leaves. More leaves may be used to cover them. When the pit is full, the centre stick is removed and some water poured into the hole made by the stick. The pit is then sealed with leaves and soil and the food is allowed to cook by steam pressure for some hours.

In the Papua New Guinea lowlands, a *mumu* is most often cooked on the ground. Hot stones are arranged in a circle on the fireplace. Then a structure is built on top of them with smaller stones and banana leaf-wrapped packages of food to be cooked (staples like yam, sweet potato, taro, bananas and cassava, leafy vegetables, winged bean pods, chokos and possibly meat or fowl). The cooking time is usually shorter as the heat is more direct.

## DAMBALA SAMBOL (Sri Lanka)

Wash and cut young winged bean pods and fry in deep fat in small quantities until crisp. Cut up a quantity of onions and a few green chilis. Mix well with some salt and lime. Serve the fried winged beans with this mixture on top.

## TORD MUN (Thailand)

Thinly slice young winged bean pods with chopped *bai makrut* (bergamot or citrus leaves) and mix with sticky fish and kaeng phet sauce to make a smooth paste. This may be fried and eaten with cucumber and a mixture of peanut sauce, vinegar and hot sugar syrup.

## FRIED WINGED BEAN POD WITH EGG (Thailand)

Fry some cloves of garlic in oil, add chopped winged bean pods and fry for a further 2 minutes. Break and beat an egg into the mixture, add some *nam plaa* (fish sauce) and cook about 5 minutes more until the egg thickens.

## TUMIS (Indonesia)

Fry 1 finely sliced shallot, 1 clove of garlic, smashed and chopped, 2 fresh chilis, finely sliced and with seeds removed, 1 teaspoon of powdered *laos* (galanga) or fresh *laos*, 1 stem finely sliced lemon grass and 2 curry leaves until soft. Add 225 g of sliced winged bean pods, or other beans *mange tous* peas, shredded cabbage or green pawpaw, choko etc., and stir-fry until lightly cooked and still crisp. Add a little dark soy sauce and salt to taste, stir again and serve.

**SAMBAL GORENG SAYRAN (Indonesia)**

Blend and pound 3 cloves of garlic, 2 chopped shallots, 1 teaspoon of *terasi* (shrimp paste) 1 teaspoon of *laos* (galanga) powder and 2 teaspoons of chili powder (or fresh seedless chilis) into a paste adding enough vegetable oil to keep it smooth. Fry the paste in a shallow pan until it is brown and smells aromatic. Add 0.41 (three quarters pint) of coconut cream, 3 curry leaves and 1 teaspoon of sugar and stir. Add 450 grams (1 lb) of chopped winged bean pods (or other beans, cabbage or waxy potato) and simmer, uncovered, until it is cooked. Add 1-2 tablespoons of tamarind water and salt to taste. Stir until the gravy is thick and dark.

This dish can also be made with ripe tomatoes, chopped and fried in the oil after the spices. These would replace the tamarind water and the sugar, and perhaps the *terasi*.

4.4 Young winged bean pods have been processed into a pickle in Tamil Nadu, South India (Desavan, personal communication).

4.5 Because of their interesting shape and good nutrient content immature winged bean pods should be bottled or canned in developing countries for local consumption and export. Where sufficient technology is available, winged bean pods might be quick dried and/or frozen like other green beans.

**5. Full-Grown Pods**

5.0 Full grown winged bean pods will probably be too fibrous to eat raw. However, the still unripe seeds inside and the mucilage around them are sometimes eaten raw in limited quantities in parts of Papua New Guinea.

5.2 Fully grown winged bean pods which are still green or purple and not dry are sometimes steamed in oil drums or a *mumu* or baked in an open fire in Papua New Guinea. The cooked unripe seeds and the mucilage will be scraped out of them and eaten. The seeds taste like peas and the mucilage is juicy and slightly sweet.

**6. Immature Seeds**

6.0 Young or immature winged bean seeds from soft or fibrous pods are eaten raw in some areas, sometimes in preference to the pod cases themselves. The color of the seed coat may be light green to purple depending on variety and maturity; the seed cotyledons are colored from cream to green and taste like peas.

6.1 Immature winged beans seeds are sometimes used in salad-side dishes like *pecal* and *lablab* in Indonesia (see section 4.1).

6.2 Immature seeds from winged [illegible] pods may be eaten boiled, steamed or stir fried in places such as Papua New Guinea and Indonesia.

6.3 Immature winged bean seeds may be cooked in soups and dishes like *gado gado* (see 4.3).

6.4 No processed product is reported.

6.5 Immature winged bean seeds may be used as a substitute for peas in areas where peas are not readily available. Young bean seeds may be canned, bottled, quick dried or frozen.

**7. Ripe Seed**

7.0 The consumption of raw ripe winged bean seed has not been reported. Furthermore it should not be encouraged because of its definite toxic effect on rats. However, no information is available at this moment on the relative toxicities of different colored varieties (see 7.2).

7.2 In parts of Indonesia and Papua New Guinea, ripe winged bean seeds are sometimes boiled after soaking to loosen the tough seed coat. After soaking overnight in water which is then discarded, the cooking time can be reduced from 2-3 hours to 30 minutes. The produce has a sweet, nutty or beany taste. Whole ripe winged bean seeds have been baked or parched either inside or outside the dry pod in parts of Indonesia and Papua New Guinea. In these places, ripe winged bean seeds are occasionally shallow-fried in hot animal fat or vegetable oil. The high temperature of frying breaks open the tough seed coat and the decorticated fried seed then makes an acceptable nutty-tasting snack food.

As a guide to safe processing, more information should be obtained on the efficiency of removal of toxic factors in the ripe seed with subsequent screening of seed varieties, as has been the case with lima bean (*Phaseolus lunatus*).

7.3 Cooked ripe winged bean seeds are sometimes mixed with cooked rice in a dish called *sangrai* from West Java.

7.4 In West Java, ripe winged bean seeds have been used in place of soyabeans to make the mould fermented cake tempe. In winged bean *tempe* making the ripe seeds are first soaked overnight and then decorticated (skinned) using abrasion. The seed cotyledons are soaked again overnight and then boiled for 1 hour. The drained boiled seeds are left to cool slightly and then inoculated with the spores of selected strains of *Aspergillus niger* or *A. oryzae* taken from a previous batch of *tempe* or applied as a dried flour based culture with the help of suitable leaf such as one from the plant *Hibiscus tiliaceus*. When the seeds are spread completely with mould spores they are then wrapped in banana leaves or especially aerated plastic bags and left in a sufficiently ventilated environment at about 25°C for about 36 hours until a thick coating of white mould appears in between and on top of the seeds. This *tempe* can be eaten boiled or fried as accompaniment to meals.

7.5 Experiments are already under way in Thailand and Malaysia to investigate the possibility of producing *tahu* (soya bean curd) — like winged bean curd, and winged bean milk as an alternate to soyabean milk. Research into the extraction of edible oil from winged bean seed and the use of the defatted high-protein flour in human food and animal feed should also be promoted.

## 8. Tubers

8.0 It has been reported that winged bean tubers have sometimes been eaten raw. But at present there is insufficient information available on the toxic factors they contain and on the toxic effects they produce. Raw winged bean tubers have a brown colored skin and the flesh inside is white or cream, and firm and juicy with a distinctive nutty, earthy flavor.

8.2 Winged bean tubers are often boiled whole. After 30-45 minutes the tubers soften and their peel can then be removed easily. In Burma peeled tubers are often boiled with rice straw to color them red and they are eaten with a sauce made from oil and salt.

In Papua New Guinea whole tubers are frequently wrapped in banana leaves or in a bamboo tube and cooked in a *mumu* pit or an open fire. The tubers will then be peeled and eaten as a snack or part of a meal without any sauce accompaniment.

Peeled tubers do not fry very well.

8.4 No preservation of processing of winged bean tubers is reported. The storage time of fresh raw tubers has been shown to be at least two months in conditions of low temperature (13.5°C) and high relative humidity (82%). At higher temperatures and lower relative humidities winged bean tubers tend to become very dry and hard. Cooked tubers are inclined to go mouldy very quickly.

# Comparative Nutritional and Clinical Aspects of the Winged Bean

*Karel Cerny*[1]

## INTRODUCTION

In the statement No. 22 "On Upgrading Human Nutrition Through the Improvement of Food Legumes" in 1973, the Protein-Calorie Advisory Group of the United Nations System drew the attention of scientists to Leguminosae. The comprehensive statement recommends urgent research attention to six major species of food legumes: dry beans, pigeon peas, cowpeas, chick peas, broad beans and peas; and the two leguminous oilseeds, peanuts and soybeans. If this list had been worked out somewhat later, the winged bean (*Psophocarpus tetragonolobus* (L) DC) would have probably also been included

It is surprising that a plant which has been grown and eaten for centuries in various countries of South East Asia and New Guinea has not attracted, until recently, more attention of agriculturists and nutritionists. The first analysis of the composition of the winged bean was probably that of Greshoff *et. al.* (Masefield, 1973) who at the turn of the century, found 29.8% protein and 15% oil in the seed. Since then, more reports confirmed the promising properties of this plant. Unfortunately, information that could arouse more interest was scattered, with perhaps few inceptions, in reports that were not easily accessible to the wide scientific public. Therefore, the work done by the *ad hoc* panel of experts and the subsequent publication of the small booklet "The Winged Bean: A High Protein Crop for the Tropics" by the U.S. National Academy of Sciences in 1975, contributed greatly to the present international recognition of this plant.

The report submitted here attempts to summarize most of the available information and comment on some of the properties of the edible parts of this plant from the point of view of human nutrition.

## FLOWERS

Flowers of many plants are eaten, especially in the tropics, but most of them do not play a very important role in human nutrition. They are mostly used as spices, condiments and candies, or for food coloring.

The winged bean flowers are known to be consumed in various ways. They may be eaten raw, added to salads, or fried in oil and with a resembling taste of mushrooms (NAS, 1975). In the highlands of Papua New Guinea, the flowers are cooked together with the pods, leaves and stalks of the winged bean. Flowers of winged bean is still being used as food coloring (Claydon, 1975). However, reports from Java indicated that the practice is not currently observed (Sastrapradja and Aminah Lubis, 1975).

Very little information is available on the composition of the winged bean flowers. The only analysis carried out so far has been of Claydon (1975), the results of which are presented in Table 1.

Table 1. Composition of winged bean flowers (in 100 g edible portion).

| | Winged Bean[a] | Banana[b] | Squash[b] | *Sesbania-agati*[b] |
|---|---|---|---|---|
| Moisture (%) | 84 | 91.3 | 94.8 | 89.0 |
| Fat (g) | 0.9 | 0.2 | 0.2 | 0.4 |
| Crude Protein (g) | 5.6 | 1.6 | 1.3 | 1.6 |
| Carbohydrates (g) | 3.0 | 5.7 | 2.9 | 8.5 |

[a]Claydon, (1975).
[b]Food Composition Table for Use in East Asia (1972).

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## IMMATURE PODS

Perhaps all reports on the use of the winged bean as food agree that it is the young, green pods that are the most relished part of the plant. The green pods containing the young seeds make a tender, crunchy vegetable that can be eaten raw or included in salad or cooked in other recipes. In West Java (Sastrapradja and Aminah Lubis, 1975), the green pods are eaten fresh or steamed as *lahlah*, or cooked with other vegetables in *sayur asem*, a favorite sour soup served with rice. In the highlands of Papua New Guinea, not only the young pods are eaten but, also pods that have already become slightly fibrous. These are cooked with the seeds inside the pod, together with other ingredients, in the traditional ground stone oven *mumu* (Khan and Claydon, 1975). In Thailand, Philippines, Vietnam, Malaysia and other countries, the young pods are most often eaten cooked with chillies (National Academy of Sciences 1975; W. K. Choo, 1975). In Bangladesh the pods are fried and eaten with fish or meat (National Academy of Sciences, 1975).

**Table 2.** Composition of immature pods of the winged bean (in 100 g of edible portion).

| | Winged Bean[a] | Cowpea[b] | Kidney Bean[b] | Hyacinth Bean[b] |
|---|---|---|---|---|
| Moisture (%) | 76-93 | 88.3 | 90.6 | 87.5 |
| Fat (g) | 0.1-3.4 | 0.2 | 0.2 | 0.3 |
| Crude Protein (g) | 1.9-3.0 | 3.0 | 2.1 | 3.1 |
| Carbohydrate (g) | 1.1-7.9 | 7.9 | 6.4 | 8.2 |
| Fiber (g) | 0.9-2.6 | 1.6 | 1.3 | 1.9 |
| Ash (g) | 0.4-1.9 | 0.6 | 0.7 | 0.9 |
| Calcium (mg) | 53-236 | 44 | 50 | 75 |
| Phosphorous (mg) | 26-60 | 45 | 48 | 50 |
| Sodium (mg) | 3 | 6 | 8 | 5 |
| Potassium (mg) | 205 | 233 | 250 | 279 |
| Iron (mg) | 0.2-12.0 | 0.7 | 0.7 | 1.2 |
| Vitamin A (I.U.) | 340-595 | 225 | 110 | 160 |
| $B_1$ (mg) | 0.06-0.24 | 0.12 | 0.07 | 0.08 |
| $B_2$ (mg) | 0.08-0.12 | 0.11 | 0.08 | 0.13 |
| Niacin (mg) | 0.5-1.2 | 1.0 | 1.8 | 0.5 |
| Ascorbic acid | 21-37 | 22 | 16 | 16 |

[a]Ranges of values reported by Brown (1954); Institute of Nutrition, Philippines (1957); Purseglove (1968); Food Composition Table for Use in East Asia (1972); NAS (1975); W. K. Choo (1975).

[b]Food Consumption Table for Use in East Asia (1972).

The composition of the green pod is shown in Table 2. Most of the values correspond well to those found in green pods of other legumes, such as cowpeas, kidney beans or *lahlah* beans. However, the calcium content (236%) as reported by Brown (1954), and the iron content (12 mg%) as given by the Institute of Nutrition, Philippines (1957), would appear to be well above the average. The vitamin A is also high. This could make the green pod a valuable contribution to the diets of the young.

## LEAVES

A large variety of leaves is used for food by tropical populations, although they are usually looked down on as "poor man's food" (Nicolls *et. al.*, 1961). Some are good sources of protein and most of them, especially the dark green ones, are rich in vitamin A precursors and other vitamins and minerals.

The crude protein compares very favorably with that of cassava and many other dark green tropical leaves. Platt (1962) gives the average value for the protein content in this type of leaves as 5 per cent. According to the National Academy of Sciences (1975), as much as 15 per cent protein could be recovered from leaves of a winged bean cultivar (Table 3).

The calcium content, especially the values reported by Teik (quoted by Claydon, 1975), also appeared to be promising. The high carotene content of the winged bean leaves can be regarded of special importance. The vitamin A value as determined in fresh and relatively young leaves of a cultivar grown in the greenhouse

of the Institute of Tropical and Subtropical Agriculture in Prague, Czechoslovakia, amounted to more than 20,000 I.U. (Svabova and Cerny, 1977). The seeds of this cultivar were originally brought to Czechoslovakia from Ghana.

**Table 3. Composition of winged bean leaves (in 100 g fresh weight).**

| | Winged bean[a] | Cassava[b] | Amaranthus spp. | Taro[b] |
|---|---|---|---|---|
| Moisture | 75.0-85.0 | 81.0 | 89.3 | 81.4 |
| Calories | 47.0 | 60.0 | 26.0 | 61 |
| Fat (g) | 0.5-1.1 | 1.3 | 0.1 | 1.0 |
| Crude Protein (g) | 5.0-7.6 | 6.9 | 3.6 | 4.1 |
| Carbohydrates (g) | 3.0-8.5 | 9.2 | 4.5 | 11.9 |
| Fiber (g) | — | 2.1 | — | 1.2 |
| Ash (g) | 1.0-2.9 | 1.6 | 2.5 | 1.6 |
| Calcium (mg) | 113-260 | 144 | 154 | 162 |
| Phosphorus (mg) | 52-81 | 68 | 74 | 69 |
| Iron (mg) | 6.28 | 2.8 | 2.9 | 1.0 |
| Vitamin A (I.U.) | 3,145-20,833 | 9,000-13,000[c] | 6,545 | 5,535 |
| Thiamine (mg) | 0.286 | 0.16 | 0.04 | 0.13 |
| Ascorbic acid (mg) | 14.5-29.0 | 82 | 23 | 63 |

[a]Ranges of values from Food Composition Tables for use in East Asia (1972); Claydon; Svabova and Cerny (1977).
[b]Food Composition Table for Use in East Asia (1972).
[c]Terra (1964).

## TUBEROUS ROOTS

Some of the varieties of the winged bean are known to produce high yields of tuberous roots. The tubers are said to have a pleasant and slightly sweet taste, ivory white flesh and firm texture resembling that of an apple.

In the highlands of Papua New Guinea the roots of the winged bean are usually served wrapped in banana leaves or in bamboo, steamed in the *mumu* over or in oil drum. The tubers is a popular and highly accepted food among the village population (Khan and Claydon, 1975). In Burma, cooked tubers are peeled and eaten like potatoes, by children, often with a sauce made from vegetable oil and salt (NAS, 1975). In Malaysia however, they are consumed very seldom (Wong Kai Choo, 1975), and in Indonesia, the use of the tubers for food has not been observed at all (Sastrapradja and Aminah Lubis, 1975).

The composition of nutrients in the winged bean tuberous roots, as determined by Claydon (1975), appears to be very satisfactory (Table 4). Protein content of the winged bean is at least five times higher than that in yam and ten times higher than that found in the cassava root. In some of the cultivars, as much as 15% protein was found in the roots, calculated on a fresh weight basis (NAS, 1975). Not only is the protein content high, but the tuberous roots are also rich in carbohydrates. The nutrient content combination of the bean makes the tuberous winged bean unique among tropical root crops. The values for calcium, phosphorus and iron compare well with those found in most tropical tubers.

**Table 4. Composition of the winged bean tuber (in 100 g edible portion).**

| | Winged Bean[a] | Cassava[b] | Sweet Potatoes[b] | Taro[b] | Yam[b] |
|---|---|---|---|---|---|
| Moisture (%) | 56.5 | 65.5 | 70.7 | 75.4 | 71.8 |
| Calories | 150 | 135 | 115 | 94 | 108 |
| Fat (g) | 0.4 | 0.2 | 0.3 | 0.4 | 0.1 |
| Crude Protein (g) | 10.9 | 1.0 | 1.2 | 2.2 | 2.0 |
| Carbohydrate (g) | 30.5 | 32.4 | 27.1 | 21.0 | 25.1 |
| Fiber (g) | 1.6 | 1.0 | 0.8 | 0.8 | 0.5 |
| Ash (g) | 1.7 | 0.9 | 0.7 | 1.0 | 1.0 |

**Table 4.** *continued*

| | Winged Bean[a] | Cassava[b] | Sweet Potatoes[b] | Taro[b] | Yam[b] |
|---|---|---|---|---|---|
| Calcium (mg) | 25.0 | 26 | 36 | 34 | 22 |
| Phosphorus (mg) | 30.0 | 32 | 56 | 62 | 39 |
| Iron (mg) | 0.5 | 0.9 | 0.9 | 1.2 | 1.0 |
| Manganese (mg) | 10 | — | 387 | 263 | — |
| Zinc (mg) | 1.3 | — | 2.0 | — | 1.1 |

[a]Claydon (1975).
[b]Food Composition Table for Use in East Asia (1972).

The only investigation on the amino acid composition of the winged bean tuber protein is probably that of Wong Kai Choo (1975).

The winged bean tuber, although very rich in crude protein, appears to have an amino acid pattern that cannot be regarded as satisfactory (Table 5). The chemical score calculated from amino acid contents, has only 28 mg/g N when based on the S containing amino acids. Other essential amino acids appear to be present also in inadequate amounts. The total aromatic amino acid content represents only 47% and that of valine is 49% of the levels suggested in the provisional amino acid scoring pattern (FAO/WHO, 1973). Values of lysine and tryptophan were not determined. The range of value for individual amino acids can be very large, of course. Thus, for example, in the cassava root, the range for methionine is between 31 and 179 mg/g N and that for cystine between 25 and 154 mg/g N (FAO, 1972). Therefore, a single analysis of the amino acid composition of the winged bean tuber protein cannot be regarded as representative.

**Table 5.** Amino acid composition of the winged bean tuber protein (mg/g N).

| Amino Acid | Winged Bean[a] | Cassava[b] | Sweet Potato[b] | Taro[b] | Yam[b] |
|---|---|---|---|---|---|
| Isoleucine | 171 | 175 | 230 | 219 | 234 |
| Leucine | 229 | 247 | 340 | 460 | 404 |
| Lysine | — | 259 | 214 | 241 | 256 |
| Methionine | 48 | 83 | 106 | 84 | 100 |
| Cystine | 14 | 90 | 69 | 163 | 72 |
| Total S cont. | 62 | 173 | 175 | 247 | 172 |
| Phenylalanine | 106 | 156 | 241 | 316 | 311 |
| Tyrosine | 72 | 100 | 146 | 226 | 210 |
| Threonine | 195 | 165 | 236 | 257 | 225 |
| Tryptophan | — | 72 | — | 88 | 80 |
| Valine | 150 | 209 | 283 | 382 | 291 |
| Arginine | — | 683 | 307 | 552 | 477 |
| Histidine | — | 129 | 84 | 110 | 118 |
| Alanine | 113 | 235 | 298 | 344 | 265 |
| Aspartic Acid | 594 | 406 | 825 | 788 | 691 |
| Glutamic Acid | 406 | 1009 | 541 | 7[illegible] | 777 |
| Glycine | 137 | 160 | 234 | 331 | 220 |
| Proline | 106 | 172 | 219 | 276 | 249 |
| Serine | 171 | 204 | 255 | 413 | 330 |
| Chemical Score[c] | 28? | 56 | 63 | 71 | 75 |
| Limiting Amino Acid | S cont.? | Leucine | Lysine | Lysine | Lysine |

[a]Choo (1975), recalculated to mg/g N.
[b]FAO (1970).
[c]Calculated according to the privisional amino acid scoring pattern (FAO/WHO, 1973).

## MATURE SEEDS

For human nutrition, the mature dry seeds represent probably the most valuable part of the winged bean. However, consumption of mature seeds in regions where the winged bean is grown, is not so popular as eating the immature pods. In New Guinea, though mature seeds are sometimes roasted and eaten as a snack,

this practice is not very popular. According to Claydon (1975), seeds in New Guinea is mainly for planting. In West Java, mature seeds are seldom used for food (Sastrapradja and Aminah Lubis, 1975). In Central Java, the seeds can be seen in large quantities in the markets. They are either cooked and consumed directly, or fermented. Sometimes they are eaten after parching. In Bangladesh, according to Dillard (quoted in the Winged Bean Flyer, 1975), the seeds are cooked, mixed with sugar and eaten like nuts. They taste like potatoes.

Since the first analysis of the composition of the winged bean seeds carried out by Greshoff *et. al* (quoted by Masefield, 1973), more results were published, all of them confirmed the very high protein and fat content. Reports published during the last decade are those of Bailey (1968), Cerny et al. (1971), Claydon (1975), Wong Kai Choo (1975) and Jaffe and Korte (1976). The nutrient content in raw, mature, dry seeds are summarized in Table 6.

**Table 6. Composition of major nutrients in mature winged bean seeds (in 100 g edible portion).**

| | Winged Bean[a] | Soybean[b] | Peanut[b] | Cowpea[b] | Chick-pea[b] |
|---|---|---|---|---|---|
| Moisture % | 8.7-14.0 | 10.2 | 7.3 | 11.5 | 11.0 |
| Calories | 375-410 | 400 | 548 | 340 | 362 |
| Fat g | 15.0-18.3 | 17.7 | 45.3 | 1.6 | 5.6 |
| Crude Protein g | 29.8-37.4 | 35.1 | 23.4 | 22.7 | 19.4 |
| Carbohydrates g | 25.2-38.4 | 32.0 | 21.6 | 61.0 | 60.9 |
| Fiber g | 3.7-9.4 | 4.2 | 2.1 | 4.2 | 2.5 |
| Ash g | 3.3-4.3 | 5.0 | 2.4 | 3.2 | 3.1 |

[a]Ranges of values reported by Platt (1962), Bailey (1968), Watson (1971); Cerny et. al. (1971); Masefield (1973); Claydon (1975); Jaffe and Korte (1976).

[b]Food Consumption Table for Use in East Asia (1972).

The crude protein content compares well with that of the soybean and higher than in most other legumes. With the exception of the soybean, none of the eight species recommended by PAG (1973) as food legumes can compare the winged bean, in this respect.

Crude fat is present in amounts which are also very close to those of the soybean. The values for carbohydrates are given as total carbohydrate by difference. The actual availability therefore will be lower as in other legumes. As shown in Table 7, the mature seeds is also a good source of minerals.

**Table 7. Composition of minerals and vitamins in mature winged bean seeds (in 100 g edible portion).**

| | | Winged Bean[a] | Soybean[b] | Peanut[b] | Cowpea[b] | Chick-pea[b] |
|---|---|---|---|---|---|---|
| Calcium | mg | 215-340 | 226 | 58 | 110 | 114 |
| Phosphorus | mg | 210-500 | 546 | 357 | 382 | 387 |
| Sodium | mg | 20-64 | 5 | 5 | 6 | 10 |
| Potassium | mg | 370-1100 | 1504 | 662 | 658 | 1006 |
| Magnesium | mg | 110-255 | 236 | 185 | 53 | 108 |
| Iron | mg | 3-18 | 8.5 | 2.2 | 6.5 | 2.2 |
| Manganese | mg | 25 | 1.2 | 1.6 | — | — |
| Zinc | mg | 3.1 | 3.8 | 1.9 | -- | — |
| Thiamine | mg | 0.08-1.39 | 0.66 | 1.00 | 0.59 | 0.46 |
| Riboflavine | mg | 0.18 | 0.22 | 0.13 | 0.22 | 0.20 |
| Pyridoxine | mg | 0.11 | 0.82 | — | 0.42 | 0.54 |
| Folic acid | mg | 25.6 | 210.0 | 124.0 | 439.0 | 163.0 |
| Ascorbic acid | mg | Trace | 0 | 0 | 1.0 | Trace |
| Tocopherol | mg | 22.8 | 21.0 | — | — | — |

[a]Ranges of values reported by Bailey (1968); Watson (1971); Cerny et. al. (1971); Food Composition Table for Use in East Asia (1972); Claydon (1975); Choo (1975); Jaffé and Korte (1976).

[b]Food Composition Table for Use in East Asia (1972).

[c]In full-fat four (Souci *et. al.* 1962).

The calcium content is similar to that of the soybean, but is higher as compared to other legumes. Phosphorus, the intake of which should be at least equal or perhaps twice as great as the calcium intake, is also present in favorable amounts. Values given for iron range from 3 mg (Platt 1962), to 18 mg (Claydon, 1975). Winged bean becomes only a valuable source of iron if the average value is close to the latter figure. The possible limitations in actual availability of calcium, iron and also zinc, owing to impaired absorption in the presence of phytates, holds true, also for the winged bean.

Although there is no direct evidence of manganese deficiency in humans, there is reason to believe that its functions are equally essential as they are in other mammals. According to Naravana Rao (1972), the average manganese content in dried legume seeds is 20.2 mg of the edible portion. Thus, bean seeds seem to be well within the average range.

Single determination of vitamins have revealed that thiamine and riboflavin are present in amounts comparable to those found in other legumes. The tocopherol content appears to be very favorable. The importance of adequate intake of this vitamin in the diets of the population groups in developing countries has been sufficiently demonstrated. The suspected interrelationship between tocopherol deficiency and the development of anemia in malnourished children and the ability of this vitamin to spare vitamin A (by protecting it from oxidation in the gut and by increasing its absorption, utilization and storage) deserve to be mentioned in this connection. Table 8 presents available data on the amino acid composition of protein of the winged bean seeds.

**Table 8. Amino acid composition of protein in mature winged bean seeds (mg/g N).**

| Amino Acid | Winged Bean[a] | Soybean[b] | Peanut[b] | Cowpea[b] | Chick-pea[b] |
|---|---|---|---|---|---|
| Isoleucine | 306-350 | 284 | 211 | 239 | 277 |
| Leucine | 462-564 | 486 | 400 | 440 | 468 |
| Lysine | 413-600 | 399 | 221 | 427 | 428 |
| Methionine | 75-87 | 79 | 72 | 73 | 65 |
| Cystine | 73 | 83 | 78 | 68 | 74 |
| Total S cont | 160-193 | 162 | 150 | 141 | 139 |
| Phenylalanine | 214-362 | 309 | 311 | 323 | 358 |
| Tyrosine | 195-200 | 196 | 244 | 163 | 183 |
| Threonine | 269-287 | 241 | 163 | 225 | 235 |
| Tryptophan | 47-63 | 80 | 65 | 68 | 54 |
| Valine | 242-306 | 300 | 261 | 283 | 284 |
| Arginine | 400-440 | 452 | 697 | 400 | 588 |
| Histidine | 169-183 | 158 | 148 | 204 | 165 |
| Alanine | 230-269 | 266 | 243 | 257 | 271 |
| Aspartic acid | 719-781 | 731 | 712 | 689 | 725 |
| Glutamic acid | 856-1154 | 1169 | 1141 | 1027 | 991 |
| Glycine | 259-269 | 261 | 349 | 234 | 251 |
| Proline | 425-431 | 343 | 272 | 244 | 263 |
| Serine | 306-327 | 320 | 299 | 268 | 318 |
| Total estimated Amino Acid | 2308-2923 | 2457 | 2026 | 2309 | 2426 |
| Chemical Score[c] | 72 | 74 | 65 | 64 | 63 |
| Limiting Amino Acid | S cont | S cont | Lysine Threonine | S cont | S cont |

[a]Ranges of values reported by Kapsiotis (1968); Cerny et. al. (1971); Choo (1975); Jefée and Korte (1976). Recalculated to mg/g N.

[b]FAO (1970).

[c]Calculated according to the provisional amino acid scoring pattern, (FAO WHO, 1973).

The values are expressed as ranges only of amino acids as estimated by different authors. The number of

analyses is not yet sufficient to allow statistical evaluation and to express the values as means. The differences are sometimes high, probably owing not only to the variety of the material tested, but also to the different analytical procedures, which include both column chromatographic as well as microbiological methods.

The composition of the essential amino acids compares well with that of the soybean and appears to be superior to other legumes especially its lysine content. Even the lowest value that has been reported is higher than that found in the soybean, and its average content is probably higher than that in any of the other legumes presented in Table 8. This makes the winged bean seed a valuable food legume and a good supplement to lysine-deficient cereals.

Methionine and cystine are probably the limiting amino acids. The values given for the range of the total content of the S containing amino acids were calculated as the range of values given by authors for the total of both amino acids. The chemical score based on the lowest value for the S containing amino acids and calculated according to the provisional amino acid scoring pattern recommended by FAO WHO (1973) is 72, which is only slightly lower than the corresponding value for the soybean.

When considering only the lowest values of the range for the individual amino acid, tryptophan and perhaps valine appear to be next limiting. The chemical score for both amino acids would be approximately 78%. Tryptophan could become limiting in mixtures with ordinary maize. The winged bean — cassava meal mixture is one of the few examples of mixtures where valine could become limiting, but only when cassava meal would provide more than 40% of the total protein content of the mixture.

Histidine, which is essential for infants is found in quantities sufficient to make the protein of the winged bean seeds adequate for use in feeding infants, at least as far as its amino acid composition is concerned. All the other essential amino acids are also present in adequate amounts.

## Fatty Acid Composition in the Seed Oil

The mature seeds of the winged bean are known to be rich in fat. The fatty acid composition in the winged bean seed oil is shown in Table 9. Values found in some other commonly used vegetable oils are given for comparison.

**Table 9. Fatty acid composition in the winged bean seed oil (% by dry weight).**

| Fatty Acid | | Winged Bean[a] | Peanut[b] | Olive[b] | Soybean[b] | Sunflower[b] |
|---|---|---|---|---|---|---|
| Myristic | C 14 0 | 0 06 | 0 1 | — | — | — |
| Palmitic | C 16 0 | 8 9 9 7 | 11 0 | 14 0 | 11 0 | 8.0 |
| Palmitoleic | C 16 1 | 0 83 | — | 2 0 | — | — |
| Stearic | C 18 0 | 5 7 5 9 | 3 0 | 2.5 | 4.0 | 3.0 |
| Oleic | C 18 1 | 32 3 39 0 | 46.0 | 68 0 | 25.0 | 20.0 |
| Linoleic | C 18 2 | 27 2 27 8 | 31 0 | 13 0 | 50 0 | 67.8 |
| Linolenic | C 18 3 | 1 1 2 0 | 1 5 | 0 7 | 8 0 | 0.5 |
| Parinaric | C 18 4 | 2 5? | — | — | — | — |
| Arachidic | C 20 0 | 2 0 | 1.5 | 0 5 | 0.4 | 0.5 |
| Behenic | C 22 0 | 13 4 15 5 | 3.5 | 0 2 | 0.3 | 0.2 |
| Lignoceric | C 24 0 | — | 1 5 | — | — | — |
| Total saturated | | ± 30 | 21 | 17 | 16 | 12 |
| Total unsaturated | | ± 70 | 79 | 83 | 84 | 88 |

[a]Cerny et al. (1971), National Academy of Sciences, (1975).
[b]Drew Chemical Corp. (1970).

Based on the percentage of the three most common fatty acids found in vegetable oils, palmitic, oleic and linoleic, the winged bean seed resembles the peanut. The palmitic acid content of both is very similar, as it is also in the soybean and sunflower oils. Both the winged bean and the peanut oils contain more oleic acid than linoleic acid. The same is also true with the olive oil, but the difference between the two fatty acids is much greater. In the soybean and sunflower oils, the percentages of oleic and linoleic acids are reversed. Linoleic and arachidic acids are found to be present in the winged bean seed in amounts which are also similar to those in the peanut oil. Both oils possess relatively high, long chain saturated fatty acid contents. In the peanut oil, behenic acid appears to be even much higher. In one analysis using gas chromatography (Cerny *et. al.*, 1975),

an unusual fatty acid was found. On the basis of relative retention times, it was tentatively identified as $C_{18}$ tetraenoic acid, known as parinaric acid. Further analyses will be needed in order to confirm or to refuse this single finding.

### Measurements of PER and NPU of the Seed Protein

In the study conducted by Cerny *et al.* (1971) in Ghana, the protein of the winged bean seeds was tested in young growing albino rats measuring the PER and NPU by the method of Miller and Bender (1955). The consumption of diets and the results obtained with rats are shown in Table 10.

**Table 10. PER and NPU of diets containing winged bean seeds measured with rats[b].**

| Diet | | Protein content of diet (%) | | | | | |
|---|---|---|---|---|---|---|---|
| No. | Source of Protein | Winged Bean | Groundnut | Maize | Skim milk[a] | PER[c] | NPU[d] |
| 1 | Skim milk | — | — | — | 10.0 | 3.04 | 73.2 |
| 2 | Winged bean | 10.0 | — | — | — | 2.14 | 55.0 |
| 3 | Groundnut | — | 10.0 | — | — | 1.53 | 46.2 |
| 4 | Winged Bean + maize | 7.3 | — | 2.7 | — | 2.70 | 65.7 |
| 5 | Groundnut + maize | — | 7.1 | 2. | — | 1.92 | 54.7 |
| 6 | Skim milk | — | — | — | 16.0 | 2.37 | — |
| 7 | Winged bean | 16.0 | — | — | — | 2.00 | — |
| 8 | Winged bean + maize | 11.7 | — | 4.3 | — | 2.20 | — |
| 9 | Winged bean + maize + skim milk | 9.1 | — | 3.3 | 3.6 | 2.35 | — |
| 10 | Winged bean + maize + 0.3% dl methionine | 11.7 | — | 4.3 | — | 2.38 | — |
| 11 | Groundnut + maize | — | 11.4 | 4.6 | — | 1.82 | — |

[a]Difference between diets
significant: 1 v. 2  2 v. 4  4 v. 5  7 v. 8  8 v. 11
not significant: 1 v. 4  6 v. 8  6 v. 9  6 v. 10  8 v. 9  8 v. 10

[b]Data from Cerny *et al.*, 1971.
[c]Protein Efficiency Ratio.
[d]Net Protein Utilization.

Dry winged bean seeds were soaked in water for 24 hours. Their coats were removed and the seeds were steamed in an autoclave (live steam) for 30 minutes at 100°C. This method of heat-processing proved to be the most efficient for the inactivation of the trypsin inhibitor. The seeds were then dried at 55 to 60°C in a cabinet dryer and ground into flour. Groundnuts processed in the same way, ordinary whole-maize flour obtained from the local market and skim milk powder of good quality were also used. A series of diets was prepared in which the protein content was adjusted to a 10% level for assessing NPU and to a 10 or 16% level for assessing PER.

At the 10% protein level, both the PER and the NPU values of the winged bean seeds were found to be superior to those of the groundnut. Statistically significant differences were observed when comparing the winged bean-maize and groundnut maize mixtures. Whereas the PER values for skim milk and the winged bean differed significantly, the difference between the values for skim milk and for the winged bean-maize mixture was not significant.

At the 16% protein level, the differences in the PER values for skim milk, for the unsupplemented winged bean-maize mixture, and for the mixtures containing supplements of either 10% skim milk powder or 0.3% DL-methionine were not significant. The PER value of the winged bean-maize mixture were not significant. The PER value of the winged bean-maize mixture, however, was significantly higher than that of the groundnut-maize mixture.

Jaffeé and Korte (1976), also conducted biological assays in growing rats using a sample of winged bean seeds. The results of their experiments are summarized in Table 11.

**Table 11. PER, *in vivo* digestibility and relative organ weights of rats after consuming diets containing winged bean seeds.[c]**

| Diet | PER | Digestibility (%) | Weight of pancreas (in per cent of body weight) | Weight of spleen (in per cent of body weight) |
|---|---|---|---|---|
| Raw seeds | a | 61.5 | 0.3881 | 0.1040 |
| Raw seeds + 0.3% methionine | b | — | 0.03501 | 0.1011 |
| Seeds autoclaved at 112°C for 20 min | 1.6 | 81.0 | 0.3541 | 0.2055 |
| Seeds autoclaved at 118°C for 20 min. + 0.3 % methionine | 2.8 | — | 0.3121 | 0.2535 |
| Casein control | 3.0 | 91.7 | 0.2614 | 0.2335 |

[a]All animals died between day 14 and 15; weight change day/animal — 3.6 g.
[b]All animals died between day 5 and 10, weight change day/animal — 6.7 g.
[c]Data from Jaffeé and Korte, 1976.

The PER value of 1.6 obtained from seeds that had been autoclaved at 112°C for 20 minutes was greatly enhanced by supplementation of the diet with 0.3% methionine. The digestibility, too, was considerably improved by autoclaving. Weights of pancreas and spleen expressed in per cent of the body weight also indicated that the best results were achieved with diets that had been autoclaved and supplemented with methionine.

**Natural Toxic Substances in the Mature Seeds**

Data on the presence of toxic factors in the winged bean seeds, until recently, is very scanty. The first report on the presence of a trypsin inhibitor in raw seeds was probably that of Sohonie and Bhandarkar (1954), who stated that the activity of the acid extracted inhibitor could not be affected by one hour boiling water and, that only partial inhibition, to the extent of 61%, could be achieved by autoclaving the seeds for 30 minutes at 121°C. The haemagglutinating activity of the raw seeds was observed by Renkonen (1948), later by Schertz *et al.* (1960), and by Bhatia and Allen (1962).

More recently, Cerny *et al.* (1971), reported that the degree of elimination of the trypsin inhibitor activity varied considerably when dry or wet heat were used. Fig. 1 shows that maximum elimination, practically zero activity of the trypsin inhibitor, could be achieved by boiling 30 minutes the seeds which had been previously soaked in water for 10 hours. The same effect, though insignificantly lower, was reached by exposing the seeds to direct steam in an autoclave for 10 minutes at 130°C. Under similar conditions, temperature at 120°C resulted only in reduction of the anti-tryptic activity by less than a third. Application of dry heat for autoclaving the seeds (Fig. 2) did not affect the trypsin output of urine in the experimental groups which was approximately 50% lower during the first half, and by 80 to 90% lower during the second half of the experimental period, than that observed in casein fed animals.

On post-mortem examination, weights of liver and spleen were found to be only slightly control. The thymus was less than 25% of control, but the kidneys were about one third heavier than those of the casein fed rats. Several other pathological changes were observed in coat, musculature and fat, liver, gut and in the genitals of the animals. There were no signs of presence of tumors.

In another experiment carried out with one day-old Hubbard broiler chicks (Choo, 1975), the toxicity of the raw seeds was also proven. In the experimental diets, the winged bean seeds, either raw or autoclaved at 121°C for 15 minutes, were substituted for the soybean meal to replace its protein content either by 100% or by 50% only. Chicks fed on a diet of 50% autoclaved winged bean seeds (substituted for 50% of the soybean meal protein) had a satisfactory growth rate and feed conversion. These indicators were significantly poorer when all the protein supplied by the soybean meal was replaced by that of the winged bean seeds.

## Clinical Testing of the Mature Seeds in Malnourished Children

The data from chemical analyses and biological assays using adequately cooked seeds in rats were in compliance with the guidelines of the Protein Calorie Advisory Group of the U.N., the major prerequisites for carrying out feeding trials in children.

Seventy two children who had admitted to the Princes Marie Louise Hospital in Accra, Ghana, with moderate or severe kwashiorkor were included in the study (Cerny and Addy 1973). The experimental group of children were composed of twelve children with moderate and twenty four children with severe kwashiorkor. The control group consisted of equal number of children of the same age and sex and with similar clinical, somatometric and biochemical measurements. The ages of the children ranged between 12 and 48 months, most of them being between 18 and 36 months.

Treatment of kwashiorkor was begun in all children with the routine diet based on skim milk and calcium *caseinate* (Casilan), which was offered during the acute phase of the illness until all edema had subsided and until the first weight increments could be recorded. Then either the experimental or the control diet was substituted gradually for the skim milk — Casilan mixture. The composition of the experimental and control diets is shown in Table 12.

**Table 12. Composition of diets fed to malnourished children using winged bean seeds.**

| Ingredient | | | Content in porridge | | |
|---|---|---|---|---|---|
| Food | Amount (g) | Protein (g) | Fat (g) | Carbo-hydrate (g) | Energy (k) |
| | | | **Experimental diet** | | |
| Winged bean flour[a] | 65 | 24 | 12 | 16 | 1122 |
| Maize flour | 96 | 9 | 4 | 66 | 1406 |
| Skim milk (dried) | 20 | 7 | Trace | 10 | 284 |
| Ground nut oil | 22 | — | 22 | — | 829 |
| Sucrose | 43 | — | — | 43 | 720 |
| Total | 245 | 40 | 38 | 135 | 4361 |
| | | | **Control diet** | | |
| Maize flour | 50 | 4 | 2 | 35 | 728 |
| Skim milk (dried) | 100 | 36 | 1 | 50 | 1478 |
| Ground nut oil | 35 | — | 35 | — | 1319 |
| Sucrose | 50 | — | — | 50 | 836 |
| Total | 235 | 40 | 38 | 135 | 4361 |

[a]Cerny et al., 1971.

Both diets were designed to provide the same amounts of protein, fat and carbohydrate. In the control diet, skim milk provided 90% of the protein and only 10% of the protein was derived from maize. In the experimental diet only 17.5% of the protein content was supplied by skim milk and 82.5% was of vegetable origin (60% from the winged bean and 22.5% from maize). Maize was used because it represented the most important cereal in Southern Ghana. In both diets the maize was of the fermented type such as it is used in *akasa* or *koko* a favourite local fish for small children.

The acceptance of the experimental diet was very good. The children apparently like the sweet, nutty taste of the winged bean seeds that had the flavor, so familiar to them, of the fermented maize. Only one child took the diet reluctantly and, owing to poor weight gains, the diet had to be discontinued after 10 days. No gastrointestinal upsets such as abdominal distention or excess flatus were recorded. In most of the children of the experimental group diarrhea ceased sooner, though the stools tended to be more bulky. Relapses of diarrhea, which sometimes occur during treatment of kwashiorkor, were observed in six children of the control group but none in the experimental group.

Some of the somatometric measurements on admission and the mean daily weight gains of children recorded at the end of the experiment are summarized in Table 13.

**Table 13. Somatometric measurements and gains in weight in children fed on experimental and control diets.[a]**

| | Moderate kwashiorkor | | Severe kwashiorkor | |
|---|---|---|---|---|
| | Experimental diet (12) | Control diet (12) | Experimental diet (24) | Control diet (24) |
| Age (months) | 26.8 | 26.7 | 27.8 | 27.9 |
| Body wt (kg) at the start of expt | 8.54 | 8.53 | 7.14 | 7.35 |
| Body length (mm) | 773 | 774 | 761 | 763 |
| Daily wt gain (g) | | | | |
| Per child | 51 | 58 | 69 | 72 |
| Per kg body wt | 6.0 | 6.8 | 9.7 | 9.8 |

[a]All values are in means: number of subjects in parenthesis. Data from Cerny and Addy (1973).

When the mean daily weight gains attained by children fed on the two diets were compared, it was seen that the weight gains were only slightly lower in the experimental groups. The difference, though statistically insignificant, was more marked between the two groups of children with moderate kwashiorkor. Significantly higher weight gains were observed in children with severe kwashiorkor than in children with moderate kwashiorkor, both in the experimental and the control groups.

The biochemical investigations, which were carried out in children at the beginning and at the end of the experiment (some of them also on the 14th day of treatment), included haemoglobin concentration, total serum proteins, serum protein fractions, the amino acid imbalance ratio in serum and hydroxyproline: creatinine index in urine. There was a minimum difference between the experimental and the control groups of children for all measurements, but it is statistically insignificant (Cerny and Addy, 1973).

**Questions Arising from the Results of Evaluation of the Seed Protein**

The results of the clinical tests have shown that the winged bean seeds are suitable for use as a milk substitute in treatment of children suffering from kwashiorkor. When evaluating the nutritive quality of a protein, the results obtained in humans, especially in small children, can be considered meaningful. However, some of the discrepancies which arises when comparing the results of the preclinical and clinical tests of the winged bean protein deserve our attention.

Table 14 summarizes the data wherein the protein quality of the winged bean seeds and of the winged bean maize mixture (not supplemented with milk) can be predicted.

**Table 14. Evaluation of protein quality of cooked winged bean seeds and of the winged bean-maize mixture.**

| | Winged Bean | Winged bean, 73% + Maize, 27% (relative protein content) | Cow's milk |
|---|---|---|---|
| Chemical Score[a] | 72 | 77 | 95 |
| NPU/rats[b] | 55 | 66 | 82 |
| Relative NPU/rats[c] | 61 | 73 | 91 |
| Limiting amino acid | S containing | Tryptophan | S containing |
| Safe level of intake, child age 1 to 3 years | | | |
| on chem. score (g/kg/day) | 1.65 | 1.55 | 1.19 |
| on relat. NPU (g/kg/day) | 1.76 | 1.46 | 1.19 |

[a]Values are calculated according to FAO/WHO (1973).
[b]Values from Cerny and Addy (1973).

The values for the relative NPU obtained in rats with the cooked seeds alone (relative NPU 61), and with the winged bean maize mixture (relative NPU 73), can be regarded as satisfactory. The difference between the two values for relative NPU is higher than that between the values for the two diets based on the scoring system (chemical score 72 and 77 respectively).

The S containing amino acids are limiting in the winged bean seed. This was clearly demonstrated in the experiments of Jaffé and Korte (1976), when supplementation with methionine resulted in a considerable increase of the PER value of autoclaved seeds. The situation may be different, however, in the winged bean maize mixture. Ordinary maize is known to be deficient in tryptophan and its high content of leucine apparently further increases the need for tryptophan. Kapsiotis (1968) reported 63 mg tryptophan/gN in the seed protein, whereas Jeffe and Korte (1976), found only 43 mg/gN. It has been established that, with the increasing protein level in the diet tested, there is a fall of sensitivity in measuring protein quality. Nevertheless, it was interesting to observe that, at a 16% protein level, supplementation of the winged bean maize mixture neither with methionine nor with the skim milk rich in tryptophan, resulted in an increase of the PER value measured in rats, that would be statistically significant. Although more analyses are needed to get more precise information on the tryptophan content, it would appear that maize, owing to its low content of this amino acid, is not the ideal cereal to be mixed with the winged bean seeds.

The differences in results obtained in biological assays carried out with rats and chicks are not easy to interpret. The toxic effects of the raw seeds, at least of the varieties tested, seem to have been clearly demonstrated. The question arises, however, of the differences in results also when heat processed (autoclaved) seeds were used. Several varieties of the winged bean were subjected to testing. The variety which gave the best results in biological assays with rats as well as in malnourished child was originally from New Guinea and continually cultivated in Ghana for several seasons. Therefore, certain differences in the inherent properties cannot be ruled out. It seems more likely, however, that it was the way of heating the seeds, with regard to the degree of destruction of the trypsin inhibitors as shown earlier in this paper, that may be responsible for the different results. Another toxic component which appears to be universally distributed among legumes, phytohaemaglutinins, have been responsible for intoxication of humans from time to time (Jaffe, 1969). Complete destruction of phytohaemagglutinins requires, preliminary soaking in water prior to autoclaving of cooking of the seeds (Liener, 1973). It was this procedure which was used in feeding trials conducted in Ghana with rats as well as children and was probably responsible for the better results.

In conclusion it can perhaps be said that, based on the value of the relative NPU obtained on rats fed adequately with cooked seeds, the safe level of protein intake in a child aged 1 to 3 years would appear to be 1.8 g of protein of the winged bean seed alone (5.0 of edible portion) and 1.6 g of protein of the winged bean maize mixture (7.7 g of edible portion), per kg body weight per day. It is important to recognize, however that these calculations, especially those based on the scoring system, are not applicable to infants.

Clinical testing of a protein in malnourished children may be connected with limitations which are not always fully realized. In a malnourished child the body weight gains need not be a criterion sufficiently sensitive for differentiating proteins on the basis of quality. Other criteria of the protein efficiency, such as serum albumin regeneration, do not always go hand in hand when using vegetable and milk protein, although gains in body weight may be equally good (Narasinga Rao, 1975). In addition, there seems to be more discrimination between the two major dietary proteins, at least at the beginning of the feeding trials, in well nourished children, as compared with children suffering from protein energy malnutrition (Cerny *et al.*, 1968).

**Problems of Feeding Dry Legumes to Small Children**

The question that has been repeatedly raised is that of the quantity of legumes that can be used in human feeding, especially in small children. The two factors of major concern are probably those of digestibility and of increased flatulence.

Digestibility of legumes is determined in the first place by their inherent characteristics. There is not only great variation among species, but even without each species certain varieties may be more difficult to digest than others. Properly cooked legumes are known to produce less gas than those which had been inadequately cooked, thus suggesting the presence of a heat labile factor. The true mechanism of increased flatus production with diets containing legumes, however, is not yet known. The required cooking time may be 3 to 4 hours in some legumes while others are ready to eat in half that time. Of interest is the report by Bhatia et al., (1967), that cooking pulses and beans with papain can cut cooking time by nearly 50%.

The maximum amount of legumes that can be tolerated by a small child is not easy to define as it depends on many factors other than the inherent properties of the legume itself. In small children, digestibility is connected with intestinal adaptability to every newly introduced food. As pointed out by Jelliffee and Jelliffee (1973) this phenomenon may be applicable to legumes too.

It seems, however, that the problem of digestibility and especially that of flatus production in connection with feeding legumes to young children has been somewhat overestimated. There are numerous reports by authors who were unable to observe any gastrointestinal disturbances or presence of meteorism. Thus, for example, the amount of 6 g of edible portion of the winged bean flour was very well tolerated by malnourished Ghanaian children. The daily intake of 6 g of winged bean flour per kg body-weight represents approximately 2.0 g of protein intake per kg body weight. This can be considered, especially in regions where some cereal is the staple food, a valuable contribution to the diet.

The problem of adaptation to a newly introduced food, such as legume, could be observed in a group of well-nourished Czech infants who, after several months on powdered whole milk (PWM) were put on a home-made formula with full-fat soy bean flour as the major source of protein. Despite very good acceptance, the weight gains were at first lower than those attained by children fed PWM. As can be seen from Fig. 3, it took the children of the experimental group almost three months to get adapted to the new food, but later their monthly weight gains exceeded those observed in the control group. After six months, on completion of the experiment, there was an even steeper decline in weight gains during the first month when PWM was again substituted for the soybean flour mixture, though it took the children a shorter period to get re-adapted to PWM (Cerny *et al.*, 1968).

We agree therefore with Jelliffee and Jelliffee (1973) that one of the practical approaches to safe feeding legumes to small children is to introduce them at first in dilute form, increasing the content of pulse as the child gets used to this new food.

**Further Research on Utilization of the Winged Bean Seed as Food**

It is only understandable that research, aimed at utilization of the winged bean seeds in forms other than flour or unprocessed paste, is being conducted especially in countries where the various well established ways of processing soy beans have a long tradition.

In Thailand, nutritionists at the Applied Scientific Research Corporation have prepared winged bean "milk" which, according to them, has a good appearance, with none of the "beany" taste of soy bean "milk," but with a "green" smell.

In Malaysia, according to Choo (1977, personal communication) various products were prepared using winged bean seeds. The "milk, with added sugar, had also an acceptable appearance and was nutritively comparable to soybean "milk." It was found, however, not to be very acceptable to local consumers because of its "stronger beany" flavor. In the various curds which differed very little with regards to texture and appearance from those prepared from soy beans, the flavor of the winged bean seeds could also be detected by the consumers.

This confirms the well-established experience that, when introducing a new food, the food preferences are very often the major obstacle to be overcome. In this respect it was interesting to observe that the winged bean seeds cooked into soft paste were not only readily eaten by Ghanaian children, but were acceptable (though with some reserve as to their "doubtful" nutritive value rather than taste) also to the accompanying mothers of the hospitalized children, whereas cooked soybeans were not. It should be pointed out that neither winged beans nor soybeans are used as food by the Ghanaian. The results of trials conducted in Malaysia are encouraging wherein winged bean fermented products such as sauce and *tempe* where prepared. Investigations of adding winged bean flour to bread (up to 9%) as well as to use it in biscuit making are also looked into.

There is one more problem connected with using the winged bean seed as food, especially for small children, that should deserve maximum attention of food technologists. Before cooking, the relatively tough coats of the seeds have to be removed. Seeds that had been cooked with their skins were quite unacceptable to small children even when mashed into a fine paste, not to speak of the increase of bulk and of indigestible matter in the formula. Manual dehulling of the seeds, however, is more time consuming than soybeans.

As shown in Fig. 4, soaking in water at 22°C, maximum swelling of the winged bean seeds takes place within the first 10 hours. After 16 hours, the uptake of water comes practically to a standstill. Unlike soy

beans, where manual skinning can be done by rubbing small handfuls of the previously soaked beans between the fingers and palms, the winged bean seeds have to be taken one by one and the pressure that has to be exercised by the fingers in order to remove the cost is higher. Preliminary trials conducted in Prague with dehulling of the seeds by mechanical means, using some of the procedures applicable to soy beans, have not given satisfactory results. The losses were too high. It must be pointed out, however, that, owing to the small amount of seeds available, not all of the possible procedures were tested.

**Future Prospects of the Winged Bean and the Need to Assess its Nutritive Qualities**

The potential of the winged bean for improving the human diet, especially that of the vulnerable population groups in developing countries, calls for maximum attention of all involved branches of science. The diversity of varieties of this species and hence possible differences in the inherent properties and nutritive value indicate that the task facing nutritionists is certainly not a small one. Although the winged bean is basically not a new food legume, it is felt that, in spite of considerable data accumulated on the nutritive qualities of this plant, many questions need to be elucidated. Some of the already conducted measurements will have to be repeated in order to reach more reliable average values.

Four major parts of the winged bean can be considered of importance for direct human consumption: the leaves, the young pods with immature seeds, the tuberous roots and the mature seeds.

The young leaves with their high protein content could provide raw material for extraction of lead protein as has been long advocated in other leaves by Pirie (1952). In developing countries, however, the most beneficial use of the winged bean leaves could be obtained by including them into multimixes for the "transitional", that is for a child from about six months to two years of age (Jelliffee, 1976). The very high content of Vitamin A precursors can be regarded of special value in the prevention of vitamin A deficiency which is widely prevalent in the densely populated countries of southern and eastern Asia and also in part of Africa, the Middle East, and Latin America (WHO, 1976).

The young pods, though less rich in protein, could also serve as a valuable item in diets of small children. The empirical proof of their safety even in raw state as food for adults was given, since no adverse effects have been recorded despite widespread consumption. More information should be gained, however, on their equally safe utilization in the diet of young children.

The tuberous roots of the winged bean can hardly be called "starchy" because of their high protein content. The amino acid composition, however, as recorded by a single analysis, does not appear to be satisfactory. It remains to be hoped that future determinations will prove the winged bean tuber protein to have a more adequate essential amino acid pattern. This is especially important since starchy roots such as cassava, sweet potato and yam, are frequently used as a food for small children in regions where cereal is the staple food. The winged bean tubers, if grown in larger quantities, could become a valuable component in the diets of the children. More information will also be needed, based on biological assays, clinical tests and chemical analyses including detection of possible toxic factors.

It can be expected that the major role in utilizing the winged bean as a food will be played by the *mature seeds*, although food prejudices and preferences cannot be underestimated. The resemblance with the soybean is so close that is tempting to assume that the winged bean could develop into an important food legume. Many problems, other than nutritional, will have to be solved before this target can be reached. But there are questions which involve the nutritive properties of the seeds that also remain to be answered.

The satisfactory quality of the seed protein, at least of the varieties tested, seems to have been demonstrated by chemical, biological as well as clinical measurements. Data on the presence of toxic components, however, are not yet complete. The toxicity of raw seeds appears to be higher than that of the soybeans. Experiments carried out with raw seeds by Claydon (1975) and those of Jaffé and Korte (1976), indicate the possible presence of natural toxic components other than trypsin inhibitors and haemagglutinins. The usual way of preparing legumes at the household level, i.e. by cooking the beans after soaking overnight, has been shown to be adequate for detoxifying the seeds. For processing larger quantities however, suitable methods which would ensure maximum elimination of the toxic factors, without causing damage to the essential amino acids, will have to developed.

The high fat content of the seeds makes the winged bean a prospective plant to be used for extraction of oil. From what is known at present, the fatty acid composition appears favorable though slightly lower in unsaturated fatty acid content as compared with some other edible oils. Two of the fatty acids, however, present a problem which calls for more investigation.

The oil of the winged bean seed contains relatively high amounts of behenic acid. This long chain saturated fatty acid with twenty two carbon atoms and with the melting point of 80°C is related to erucic acid which has one double bond. The adverse effects of erucic acid have been shown in many experiments. Although, there is not clear evidence as yet on possible toxic properties of behenic acid, its high amount of the winged bean seed oil must be regarded with caution. Nevertheless, despite poor digestibility of this acid, no untoward effects were recorded in malnourished children who were fed full fat winged bean flour which supplied 1.2 g of the seed oil, i.e. 160-180 mg of behenic acid per kg body weight per day. It has been established, however, that young children can digest relatively high loads of long chain saturated fatty acids. The efficiency of breaking down these acids diminishes with increasing age. This does not mean to say that high levels of long chain saturated fatty acids could be recommended in diets of small children.

The presence of behenic acid need not be looked upon with too much concern as regards consumption of whole cooked seeds or full fat winged bean flour. The quantity of behenic acid consumed in this way could hardly be large enough to produce untoward effects on the nutritional status. In the peanut seed, owing to a high fat content, the arachidic (C 20:0), behenic (C 22:0) and lignoceric (C 24:0) acid content amounts sometimes to 6.5% (Drew Chemical Corporation, 1970). When the two oilseeds are compared with respect to content of saturated fatty acid with twenty carbon atoms and above, 100 g of peanut seed contain up to 3.1 g of these fatty acids, of which more than a half is behenic acid, whereas 100 g of winged bean seed contain approximately 2.6 to 2.9 g of arachidic and behenic acids. The presence of behenic acid, together with the high level of tocopherols can be expected to act favourably by increasing resistance to the development of rancidity of the full fat winged bean flour.

The situation is different, however, when evaluating the oils of the two seeds. There, the arachidic and behenic acid content in the winged bean oil appears to be more than twice as high as the content of arachidic, behenic and lignoceric acids together, in the peanut oil. Biological assays with small animals as well as in humans will have to be conducted therefore in order to assess the possible implications resulting from the relatively high content of behenic acid in the winged bean seed oil.

The fatty acid fraction tentatively identified as parinaric acid on the basis of relative retention times presents another problem. Parinaric acid can be found in a number of species of tropical evergreen trees, such as *Parinarium laurinum*, in kernels of the edible drupes (Eckey, 1954). The seeds of balsam (*Impatiens balsamina*) and of other species of this genus as well as of certain aquatic plants (*Iris* spp., *Nymphaea alba*) also contain parinaric and other fatty acids with similar characteristics. Parinaric acid is unique among the vegetable oil fatty acids because it has four double bonds and also because all four double bonds are conjugated. It contains either two cis and two trans, or one cis and three trans ethylenic groups. When exposed to light or an isomerizing catalyst it is converted into the beta form which possesses an all trans configuration (Markley, 1960).

The evidence of the presence of parinaric acid in the winged bean seed oil, however, must be taken *cum grano salis*, particularly because conclusions were drawn from relative retention times only. Since polyunsaturated fatty acids with conjugated bonds as well as those possessing trans configurations are regarded as undesirable for human nutrition because of their atherogenic properties, the need for positive chemical identification of the presence of this component, if any, is therefore evident.

The mature winged bean seeds have been shown to provide suitable materials for preparation of food products, such as milk, curd, sauce, *tempe* and others, by using procedures similar to those applied to soybeans. Acceptance and nutritional qualities of these products should be tested not only in regions where soybean is popular but also in regions where soybean is unknown and difficult to cultivate but where the winged bean can be expected to give satisfactory yields.

The possibility of using winged bean flour in vegetable protein rich substitutes of milk for children has been already documented. More trials in children are needed, however, using both full fat and defatted flour in combination with other cereals in order to choose the most suitable mixture. The necessary prerequisite for production of larger quantities of winged bean flour is to invent suitable methods of dehulling the dry seeds.

It is obvious that, for the winged bean to develop from a backyard into a commercial crop, agricultural research will have to go a long way. There is probably little doubt that the nutritional potential of this plant deserves such an effort. It has to be emphasized that nutritional research should not only cover all the promising varieties but also new varieties.

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**APPENDIX 1. Fig. 1-4.**

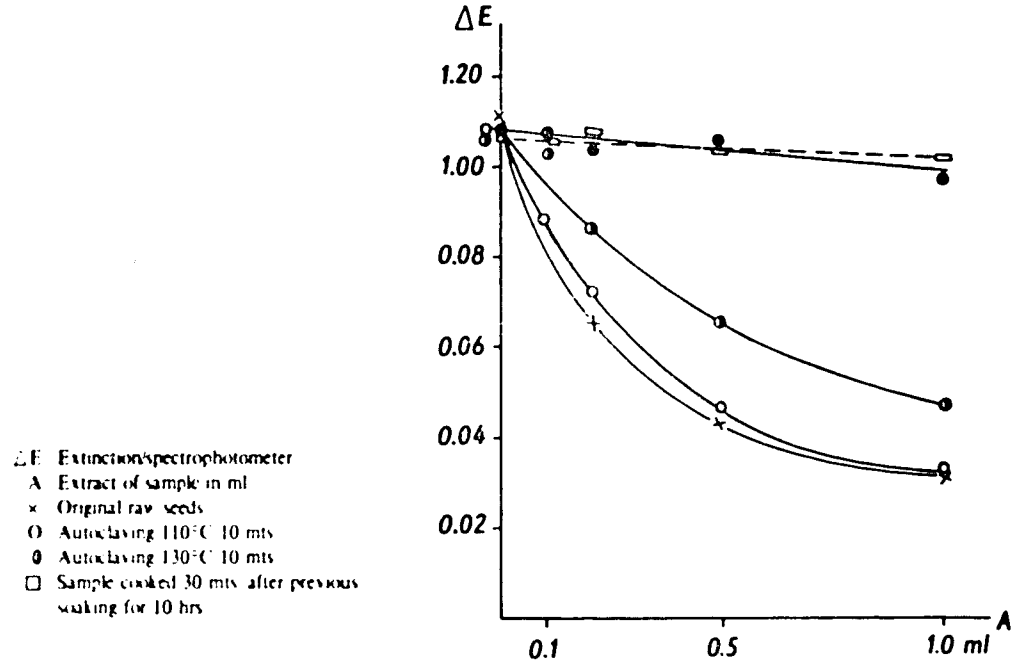


**Fig. 1. Changes in trypsin inhibitor activity of winged bean seeds (wet heat).**

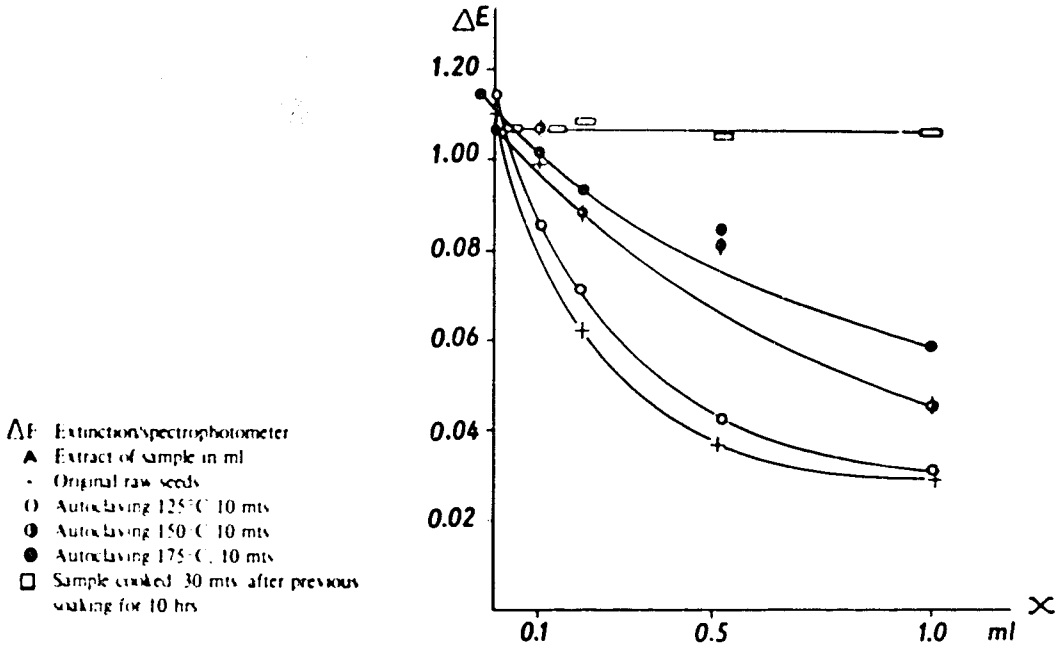


**Fig. 2. Changes in trypsin inhibitor activity of winged bean seeds (dryheat).**

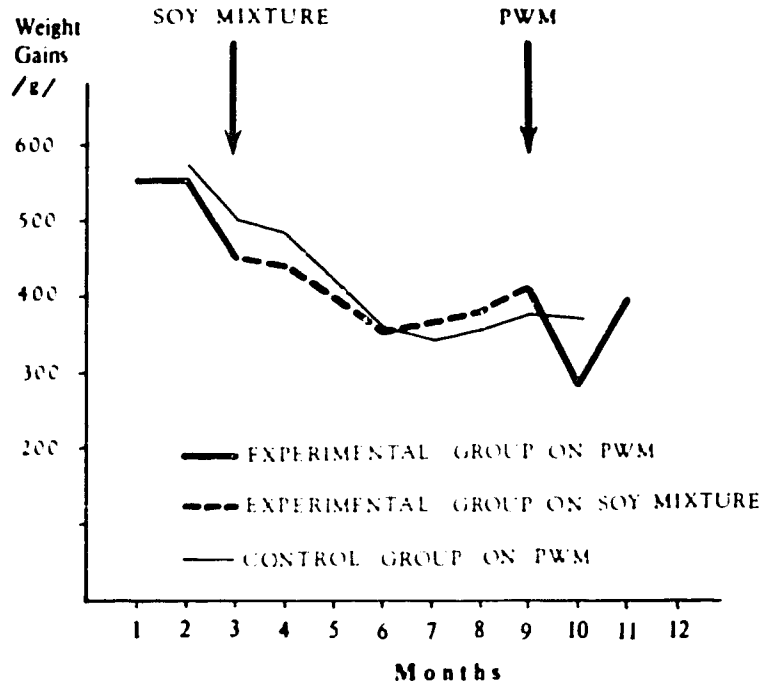


**Fig. 3. Monthly weight gains of well nourished children with respect to altering the diets (PWM—Soybean Flour-PWM)**

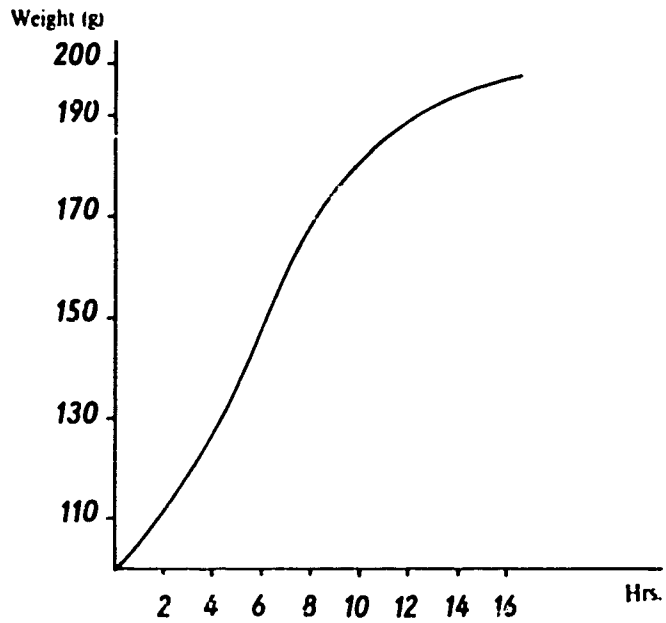


**Fig. 4. Swelling of winged bean seeds at 22 + 2°C.**

# Nutritional Aspects of the Winged Bean

*Thomas E. Ekpenyong* and *Raymond L. Borchers*[1]

**A series of studies has been conducted to establish the nutritional characteristics of the winged bean. Protein, lipid and mineral composition were identical to that of soybean and better than that of Great Northern and Pinto beans. The different parts of the plant are very high in protein with roots containing about 12%. The seeds are rich in oil and have more unsaturated fatty acids, with oleic acid predominating.**

**The amino acid composition of the different parts of the plant is of extreme nutritional significance. Time of hydrolysis had no significant effect on the amino acid profile. Methionine is the limiting amino acid in winged beans. Lysine, leucine and phenylalanine + tyrosine were higher in winged bean than soybean. Autoclaving the meal before hydrolysis reduced lysine and leucine levels in winged bean but increased the level of the sulfur-containing amino acids as well as threonine, phenylalanine + tyrosine and tryptophan. Based on FAO, again lysine, isoleucine, leucine, valine, phenylalanine + tyrosine were superior in winged bean compared to soybean. The predicted PER (uncorrected) was 2.13 for raw winged bean and 2.29 for soybean. The C-PER was 1.68 and 1.86 for winged bean and soybean respectively. Autoclaving improved these values, giving a PER (uncorrected) of 2.83 and C-Per of 2.38 as compared to 2.66 for casein.**

**Extraction and precipitation of the proteins with water, hydrochloric acid, sodium chloride and sodium hydroxide showed that sodium hydroxide gave the highest percent yield of proteins extracted. Nitrogen solubility of the winged bean was seen to be strongly pH-dependent. The amount of protein extracted at alkaline pH (pH 12) was greater than that at either neutral or acidic pH. The minimum points of nitrogen dispersion was at pH 4 corresponding to the highest amount of protein precipitated, the apparent isoelectric point.**

**Processing methods had various effects on fat content, protein level and *in vitro* digestibility. Autoclaving reduced fat content while dry heat and oven heating had no significant effects. Autoclaving, and to a lesser extent dry heat, were very effective in increasing *in vitro* digestibility. Soaking seeds overnight in water before cooking improved *in vitro* digestibility. Ether-extracted meal had a slightly increased *in vitro* digestibility. Compared to autoclaving, the difference was not significant.**

**Preliminary results indicate that the extract of raw beans shows some trypsin inhibitor activities. This inhibitory effect can be inactivated by heat.**

## INTRODUCTION

Grain legumes are important sources of dietary proteins and oils. They form one of the main protein supplies of people in areas where animal protein sources are either scarce or very expensive. The recent FAO publication (1964) has demonstrated the world need for increased food supplies. Legumes are among the oldest of crop plants both in the Old and New Worlds and their remains have been found in cave sites dating back to more than 6,000 years ago (Aykroyd and Doughty, 1964). Legumes can play an increasing role in meeting protein needs in areas of food scarcity and widespread malnutrition. Besides the major commercially important legumes there are other lesser known tropical legumes lacking adequate scientific information and whose full potentials have not been exploited. One of these little known legumes is the winged bean, *Psophocarpus tetragonolobus (L.) DC.*

The winged bean is a little known tropical legume with a promising future. There are about 8 species of *Psophocarpus*. The origin of *Psophocarpus* has not been fully established. Historically, the record of Rumphius who lived at Amboina in the Moluccas between 1653 and 1702, along with other records, have indicated the fact that the Arabs introduced the winged bean from Africa (Merrill, E.D., 1903; 1917; 1923). *Psophocarpus tetragonolobus* is a cultivar and others are indigenous to Africa. It grows as an escape in Burma (Burkill, 1906) and the Philippines (Agcaoili, 1929). The species *P. tetragonolobus* is a twinning perennial grown as an annual with tuberous roots and pods with longitudinal wings. It has been suggested that this species was introduced into Asia from Madagascar or Mauritius (Burkill, 1935). Dalziel (1955) has shown that

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it is indigenous to tropical West Africa. Of recent an equally unconvincing and sketchy data points to New Guinea as the most likely center of geographical origin, or at the minimum a center of germplasm diversity (Hymowitz and Boyd, 1977).

Today, the species is grown widely in the higher rainfall belt of West Africa. It has been grown and eaten for a long time in Southeast Asia and Melanesia (Burkill, 1966; Purseglove, 1968). In tropical Asia, it was grown in small areas for its green pods (Masefield, 1973) and only in Burma was it grown as a field crop (Burkill, 1966). It is grown in the southern part of India especially around Poona and Mysore. It is grown as a vegetable crop in Malaysia and the Philippines where they are sold in fairs and markets (Milsum and Grist, 1941; Brown, 1954). With the turn of the century, it found its way into the West Indies (Purseglove, 1968). In New Guinea it is cultivated in the highlands (Powell, 1974) and the coastal markets of Port Moresby, Lae Rabaul and Madang as quoted by Claydon (1975) from Koddy (1975).

The winged bean has been known and described by different people with different names. It has been called the four-angled bean, Goa bean, Murukayari in India, see kok tau in China, asparagus pea in England, averrhoea bean, four-cornered bean, Manila bean and princess pea (Purseglove, 1968; Masefield, 1973). Field observations have shown that this legume has tremendous potential of agricultural interest due to its capacity in forming nitrogen-fixing root nodules (Thompstone and Sawyer, 1914, Masefield, 1952, 1957, 1973 Walsh, 1958).

**Uses of the Winged Bean**

Like the soybean, the seeds of the winged bean have long been known to be high in protein and oil (König and Bömer, 1903; Burkill, 1906; Ageaoili, 1929; Tindall, 1968; Pospisil *et al.*, 1971). In fact, unlike the soybean the entire plant is consumed because each part of the plant has nutritional and medicinal properties (Burkill, 1966). The dry seeds contain 32 to 37% protein, 15 to 18% oil with 71% of the fatty acids being unsaturated (Bailey, 1968; Claydon, 1975; Masefield, 1973; Platt, 1962). The nutritive value is similar to soybean, has similar amino acid composition though with a higher Lysine level. Like soybean, it is deficient in methionine (Cerny *et al.*, 1971; Lierner, 1972; Kapsiotis, 1968). The seeds are rich in tocopherol and some minerals (Rachie, 1974; Watson, 1971; Brown, 1954; Claydon, 1975).

The mature seeds are either cooked or roasted and never eaten raw. The duration of soaking prior to cooking is an important factor in length of cooking time as well as digestibility. The seeds from immature pods are also widely consumed.

In Southeast Asia, the young green pods are eaten as green vegetables or added to other dishes without the occurrence of adverse effects. In New Guinea, old pods are steam cooked, the seeds and viscid material surrounding them are removed and eaten (Hipsley and Kirk, 1965). In some parts of Nigeria, seeds of some other legumes are pre soaked overnight with addition of sodium bicarbonate. This pre soaking plus addition of soda render the beans very soft. In Ghana, it has been shown that even in the raw state, the seeds have a sweet, nutty flavor and this, too eliminates any elaborate home preparation (Cerny *et al.*, 1973).

The flowers and leaves of the winged bean are eaten raw or cooked, added to salads, fish and prawn soups and are known to contain one of the highest amounts of protein of any known forage legumes (Claydon, 1975; NAS, 1975; Jaffe and Korte, 1976).

The foliage is rich in protein, about 25.6% (Masefield, 1961). The leaves are consumed by man as in Malaysia where they are used as vegetables (Burkill, 1935). It could also be used as green fodder, as a forage crop for animals and the haulms fed to livestock (Masefield, 1973).

The roots of the winged bean are of special interest. The analysis of Hooper in 1902 (quoted by Burkill, 1906) showed that a sample of dried roots contained 9% water and 24.6% protein. This is unique in itself and widespread consumption could help in containing the problem of protein deficiency diseases in the humid tropics where root tubers — yam, cocoyam, cassava, potato — with average contents of 4 to 5% protein form the staple diet of the people. The roots are used predominantly in Burma (Herklots, 1972) and the South Pacific Islands and several Asian countries. The tuberous roots are firm in consistency, slightly sweet in taste (Burkill, 1906); eaten raw or boiled (Burkill, 1906; Fairchild, 1923; Thompstone and Sawyer, 1914).

Medicinally, the plant has a roborant effect (Stopp, 1963); the leaves are used in the treatment of smallpox and the roots used as a poultice to cure vertigo (Massart, 1895). The beans have been used as a milk substitute in the treatment of kwashiorkor in children (Cerny *et al.*, 1973).

**Problems**

Like other legumes, it is beset with some problems that call for intensive and coordinated research.

Besides the presence of such anti-nutritional factors like the trypsin inhibitor (Sohonie and Bhandarkar, 1952; Cerny *et al.*, 1971) it also contains phytohemagglutinins which cause yet undetermined nutritional disorders and nonspecific haemagglutination (Renkonen, 1948; Toms and Western, 1971). It is possible, as has been suggested (Cerny *et al.*, 1971) that the phytohemagglutinins are destroyed by cooking. Immature seeds can however be eaten raw without adverse effects.

The present study was designed to determine the biochemical and nutritional characteristics of the winged bean. Of particular interest were the amino acid contents of the different parts of the plant; protein extraction and precipitation; the effects of different processing methods on the *in vitro* digestibility and other different processing methods on the *in vitro* digestibility and other useful nutritional indices.

## MATERIALS AND METHODS

The winged bean variety, Tpt-2 obtained from the International Institute of Tropical Agriculture in Nigeria was used in this study. Some of the seeds were planted in clay pots from which we collected the different samples for further analysis.

### Composition

The samples were homogenous. Proximal analysis was performed by the AOAC methods (1970). Mineral analysis was performed using the Perkin-Elmer Atomic Absorption Spectrophotomer. Phosphorus was determined using the Beckman Model DU Spectrophotometer.

Amino acid analyses were determined on all samples by the method of Spackman *et al.* (1958). A comparison was made between using an 18 hr and a 24 hr vacuum hydrolysis respectively at 110°C for all amino acids except tryptophan, which was determined using $Ba(OH)_2$ hydrolysis following the method of Pataki (1968). Cystine and methionine were determined as cysteic acid and methionine sulfone by a performic acid oxidation followed by an acid hydrolysis according to the method of Moore (1963). All hydrolysates, both acid and alkaline, were analyzed on a Beckman-120C Amino Acid Analyzer and data were computed automatically (Cavins and Friedman, 1968).

### *In Vitro* Protein Digestibility

The method used was a newly developed method by Hsu *et al.* (1977) which was a modification of that of Maga *et al.* (1973) and Rhinehart (1975). A multi enzyme solution consisting of trypsin, chymotrypsin and peptidase was selected.

The enzymes were purchased from Sigma Chemical Company. The enzymes were trypsin (Type IX) with 14,190 BAEE units/mg protein, bovine pancreatic chymotrypsin (Type II) with 60 units/mg powder and porcine intestinal peptidase (Grade III) with 40 units/mg powder.

The different samples were finely ground to pass through an 80 mesh screen. They were then dissolved in glass distilled water. Fifty milliliters of aqueous protein suspension (6.25 mg protein/ml) in glass-distilled water were adjusted to pH 8.0 with 0.1 N HCl and/or NaOH, while stirring in a 37°C water bath for 15 minutes. The multi enzyme solution (1.6 mg trypsin, 3.1 mg chymotrypsin and 1.3 mg peptidase per ml) was maintained in an ice bath and adjusted to pH 8.0 with 0.1 N HCl and/or NaOH. Five ml of the multi enzyme solution were added to the protein suspension which was being stirred at a constant temperature of 37°C. The pH drop on addition of the multi enzyme solution was recorded automatically every 2 minutes, over a 10 minute period using a recording pH meter.

The multi enzyme solution was prepared fresh daily and preserved in an ice-bucket during the tests. The activity was determined using a casein of known *in vivo* apparent digestibility.

### C-PER Model

Based on previous experience, Kendrick *et al.*, (1976) have constructed a mathematical model to provide estimates of protein quality based on the amino acid contents and *in vitro* digestibilities of protein samples. The output of the model includes expressions of protein efficiency ratios (PER) and is termed "computed" PER (C-PER) to distinguish the model values from PER data derived from *in vivo* rat feeding trials.

### Extraction Method.

The nitrogen extractability was determined by dispersing 2 g winged bean flour (WBF) in 30 ml of deionized water, adjusting the pH to between 2-12 with 1 N HCl or 1 N NaOH and shaking in a 25°C water bath for 30 min. The pH of the mixture was readjusted, if necessary, and then centrifuged at 1000 X G for

30 min at room temperature. The mixture was then filtered with a Whatman No. 1 filter paper. Duplicate 10 ml aliquots of the filtrated extracts were analyzed for their nitrogen contents using the Kjeldahl method (AOAC, 1970).

The influence of different pH, different solvents (water, sodium chloride, sodium hydroxide and hydrochloric acid) on the extraction and precipitation characteristics of WBF compared to some other legumes was also determined. The nitrogen precipitation was determined by extracting the WBF (2 g:30 ml extractant) at pH 9 for 20 min at 25°C.

## RESULTS AND DISCUSSION

In a report by Masefield (1973) it is indicated that Greshoff *et al.* found 29.8% protein and 15% oil in the seed and Hooper obtained a value of 24.6% protein in a dried root sample. In our analysis as shown on Tables 1 and 2, the raw seeds had approximately 36% protein as compared to 39% for soybean. When the seeds were defatted, the percent protein increased to 39%. We did not obtain as high a protein content (11.6%) in the roots as did Hopper (26.4%). There is a possible explanation for this. In our sample the roots did not develop any nodules. It is possible that Masefield (1973) in reporting the analysis of Hooper did not emphasize the fact that the analysis was done on tuberous roots with plenty of nodules. The oil content in the winged bean seeds compares favorably with that of soybean (15.8 vs. 16.1). We obtained higher level of fiber in the seeds compared to other legumes studied and in the leaves, winged bean contained more oil and more fiber than any of the other legumes. In terms of the essential minerals, calcium and iron, the levels of these minerals are higher in the winged bean than in the soybean. Differences that might exist between our report and previous ones could reflect not only differences in sampling and analytical techniques but more importantly the fact that the portion of each component of the ash residue may be influenced by variety, soil conditions, climate, agronomic practices and age of the beans prior to analyses. It is feasible that geographical location could contribute in a large measure to differences in ash content among varieties. Since the number of differences varieties and the quantity of such varieties at our disposal was very limited these environmental factors and their effect on oil and protein metabolism vis a vis total ash accumulation in the seed, could not be investigated.

**Table 1. Composition of the winged bean seed and other legumes.**

| | Winged Bean | Soybean | Great Northern | Pinto |
|---|---|---|---|---|
| Moisture (%) | 10.4 | 8.2 | 10.4 | 10.4 |
| Protein (%) | 35.9[a] | 39.0 | 22.9 | 21.0 |
| Oil (%) | 15.8 | 16.1 | 2.4 | 1.9 |
| Carbohydrates (%) | 23.9 | 25.4 | 50.6 | 54.6 |
| Fiber (%) | 9.2 | 4.7 | 8.5 | 7.2 |
| Ash (%) | 4.9 | 6.6 | 5.1 | 5.0 |
| **Minerals** | | | | |
| (mg/100g) | Winged bean | Soybean[b] | | |
| Calcium | 275 | 226 | | |
| Phosporus | 310 | 546 | | |
| Potassium | 117 | — | | |
| Iron | 10.2 | 8.5 | | |
| Sodium | 35 | — | | |
| Manganese | 178 | — | | |

[a]Raw seeds, 35.9% protein; defatted, 39% protein; roots, 11.6% protein.
[b]FAO, Rome, 1972.

**Table 2. Composition of the leaves of winged bean as compared to other legumes.**

| | Winged Bean | Soybean | Great Northern | Cowpeas | Red Kidney |
|---|---|---|---|---|---|
| Moisture % | 75.8 | 83.3 | 85.3 | 87.5 | 93.8 |
| Protein % | 28.1 | 30.3 | 29.2 | 22.4 | 29.1 |
| Oil % | 10.2 | 7.8 | 7.5 | 7.5 | 9.5 |
| Fiber % | 12.2 | 11.1 | 8.9 | 10.9 | 11.1 |
| Ash % | 10.4 | 9.4 | 10.4 | 11.3 | 11.7 |

***In Vitro* Digestibility.**

The result of *in vitro* digestibility of the different parts of the winged bean is presented in Table 3. *In vivo* fat feeding trials have been used as common parameters for estimating protein digestibility. Although the amino acid content of protein sources is equally important in assessing the nutritive value of a protein source, the primary factor that evaluates the availability of the amino acids is the digestibility. *In vivo* rat studies are time consuming and expensive. The *in vitro* of Hsu *et al.*, (1977) used here is rapid and reliable.

**Table 3.** ***In vitro*** **digestibility of the different parts of the winged bean.**

| Sample | % Protein | 0 min | 2 min | 4 min | 6 min | 8 min | 10 min | % Digestibility |
|---|---|---|---|---|---|---|---|---|
| Raw seeds | 37.6 | 8.00 | 7.95 | 7.94 | 7.93 | 7.92 | 7.91 | 67.3 |
| Immature pods | 17.1 | 7.99 | 7.85 | 7.79 | 7.74 | 7.71 | 7.66 | 71.8 |
| Mature pods | 16.6 | 8.00 | 7.74 | 7.67 | 7.62 | 7.58 | 7.55 | 73.8 |
| Young Leaves | 27.0 | 8.00 | 7.90 | 7.84 | 7.80 | 7.76 | 7.73 | 70.5 |
| Mature leaves | 14.6 | 8.00 | 7.93 | 7.89 | 7.85 | 7.82 | 7.79 | 69.4 |
| Above ground no pods | 12.4 | 8.00 | 7.95 | 7.91 | 7.88 | 7.85 | 7.83 | 68.7 |
| Entire plant | 19.3 | 8.04 | 7.96 | 7.92 | 7.89 | 7.84 | 7.66 | 71.8 |
| Roots no nodule | 11.6 | 8.00 | 7.95 | 7.92 | 7.90 | 7.87 | 7.85 | 68.4 |

**Regression equation = 210.464-18.103X.**
**Where "X" = pH of protein suspension after 10 min digestion with multi-enzyme solution.**

Our results in Table 3 show that mature pods had the highest percent digestibility and raw seeds had the lowest, 73.8% and 67.3% respectively. Fig. 1 shows a plot of pH versus the incubation time in minutes. It has been shown by Hsu *et al.* (1977) that there is an advantage in the use of a multi-enzyme system in that it avoids under-predicting the digestibility of proteins containing the trypsin inhibitor like the soybean and winged bean.

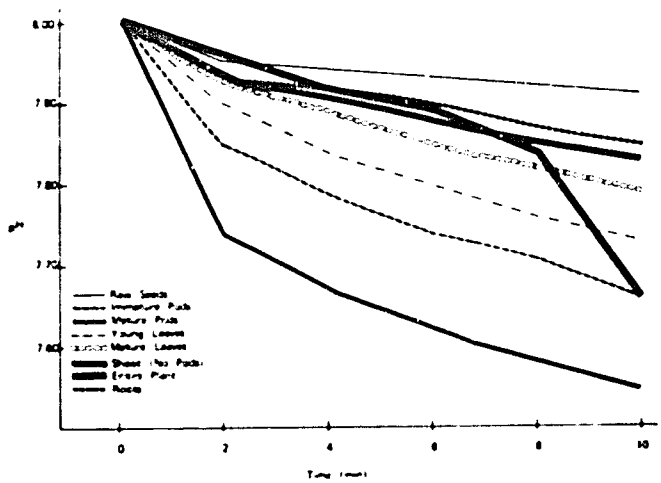

**Figure 1.** ***In Vitro*** **Digestibility of the Winged Bean.**

The effect of soaking and cooking times on *in vitro* digestibility of beans of the winged bean as compared to soybean. Equal weights of the winged bean and soybean were soaked and cooked for different period of time. The final cooked beans were then dried at room temperature and milled to a fine powder and then evaluated for their *in vitro* digestibility as previously described. Our results show that soaking overnight before prolonged cooking as compared to short soaking time with at least cooking for one hour did not show any significant difference in the case of the winged bean. Cooking of beans after soaking is a common practice in those areas where legumes form part of the diet. Our results show that whereas raw seeds gave a digestibility of [illegible]%, cooking of both soybean and winged bean for anything above one hour improved the digestibility by over 20%. This is in agreement with the work of Dutra de Oliveira (1975) who found that digestibility was increased by cooking. Our time of cooking is in disagreement with the results of Breines *et al.* (1975) who found 10 minutes to be adequate for home cooking of beans. Our experience elsewhere is to the fact that cooking for only 10 minutes after soaking does not render the beans soft enough for consumption. Our results are also supported by earlier published reports on other legumes (Brevighieri, 1972, Petenuscci *et al.*, 1970, Bressani *et al.*, 1963, Sherwook *et al.*, 1954).

**Table 4. Effect of soaking and cooking on *in vitro* digestibility of winged bean and soybean.**

| Soaking Time | Cooking Time | Winged Bean | | | | | | | Soybean | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 min | 2 min | 4 min | 6 min | 7 min | 10 min | % Dig | 2 min | 4 min | 6 min | 8 min | 10 min | % Dig |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

Table 5 shows the result of the effect of processing with two types of heat treatment. The protein levels of each of the treatments are given and they show that heat treatment generally increased digestibility. Of the two types of heat treatment, moist heat (autoclaving) tended to give better digestibility than dry heat. Proper processing and proper heat treatment improve the digestibility of both winged bean and soybean, winged bean to a greater extent. During proper heat treatment, the protease inhibitors are destroyed by heat thereby permitting the opening of the protein structure through denaturation. Beyond a certain degree of heat processing, protein digestibility declines due to nonenzymatic browning reaction and thermal cross-linking (Tannenbaum, 1974). Our results support the theory that proper heat treatment increases protein digestibility in legumes.

**Table 5. Effect of processing on *in vitro* digestibility.**

| Sample | Protein Content (%) | | | Digestibility | | |
|---|---|---|---|---|---|---|
| | | | | raw | dry heat[d] | moist heat[e] |
| Winged bean | 33.8[a] | 35.0[b] | 35.0[c] | 70.7 | 71.6 | 84.3 |
| Soybean | 43.8 | 41.3 | 40.6 | 71.6 | 74.9 | 82.3 |
| Great Northern | 22.1 | 23.1 | 22.6 | 77.6 | 73.4 | 79.8 |
| Pinto | 20.9 | 22.3 | 20.0 | 74.9 | 71.8 | 79.6 |
| Casein | 90.6 | | | 93.2 | | |

[a, b, c]raw, dry heat and moist heat protein levels, respectively.
[d]heated in oven at 130° — for 10 min.
[e]autoclaving at 110° — for 10 min.

Table 6 presents the effect of fat content on protein digestibility. Our results indicate that the ether extracted samples had a slightly increased *in vitro* digestibility in the case of winged bean and soybean but slightly lower values for Great Northern and Pinto. It is our suggestion from these results that ether extraction prior to evaluation of *in vitro* digestion was not beneficial.

**Table 6. Effect of fat content on the *in vitro* digestibility of some legumes.**

| Sample | Fat Content % | Digestibility | | |
|---|---|---|---|---|
| | | Raw | Ether Extracted[a] | Autoclaved |
| Winged bean | 15.8 | 70.7 | [illegible] | 84.3 |
| Soybean | 16.1 | 71.6 | 72.7 | 82.3 |
| Great Northern | 2.4 | 77.6 | 75.8 | 79.8 |
| Pinto | 1.9 | 74.9 | 73.4 | 79.6 |

[a]Extracted with petroleum ether for 4 hours.

## Amino Acid Composition

The amino acid composition of the seeds of the winged bean and soybean as compared to casein is presented in Table 7. Soybean is generally accepted as the legume with the best quality protein, being not too deficient in sulphur amino acids when compared with egg protein. We found winged bean to contain approximately twice as much lysine as soybean and higher in lysine than casein. The winged bean also had higher contents in alanine, leucine, tyrosine and arginine but lower values of phenylalanine, methionine and aspartic acid. Like other legumes it is deficient in methionine when compared to casein. Claydon (1975) reports that both Pospisil *et al* (1977) and Cerny *et al* (1971) found the winged bean to contain a slightly higher percentage of total sulphur amino acids than the soybean. Our results however do not support this view. Even during the process of heat treatment, the soybean still contained slightly higher levels of the sulphur amino acids. The tryptophan, threonine, serine, proline, isoleucine contents of both legumes were somewhat identical. In terms of the essential amino acids the winged bean seems to have a better profile than soybean and a greater amount of total aromatic amino acids.

**Table 7. Amino acid pattern of winged bean, soybean and casein.**

| Amino Acid | (g 100 g of protein) | | |
|---|---|---|---|
| | Winged Bean | Soybean | Casein |
| Aspartic acid | 6.93 | 10.96 | 6.14 |
| Threonine | 3.91 | 3.79 | 3.84 |
| Serine | 4.56 | 4.47 | 3.19 |
| Glutamic acid | 14.99 | 17.22 | 13.53 |
| Proline | 5.97 | 5.09 | 5.60 |
| Glycine | 4.07 | 5.03 | 1.99 |
| Alanine | 4.11 | 3.92 | 3.20 |
| Cysteic acid | 1.41 | 2.27 | 0.51 |
| Valine | 4.91 | 4.28 | 5.62 |
| Methionine S | 0.86 | 1.93 | 3.49 |
| Isoleucine | 4.60 | 4.38 | 6.59 |
| Leucine | 8.32 | 7.00 | 10.07 |
| Tyrosine | 4.74 | 3.66 | 7.72 |
| Phenylalanine | 4.64 | 5.12 | 6.89 |
| Lysine | 7.91 | 4.09 | 5.72 |
| Histidine | 2.99 | 2.19 | 3.14 |
| Ammonia | 1.58 | 2.25 | 2.05 |
| Arginine | 7.54 | 6.27 | 4.26 |
| Tryptophan | 0.94 | 0.97 | 1.43 |
| Total EAA* | 42.24 | 37.49 | 51.88 |
| Total S aa** | 2.27 | 4.20 | 4.00 |
| Total aromatic | 9.38 | 8.78 | 14.61 |

*Total essential amino acids.
**Total sulfur amino acids.

The results of different times of hydrolysis and types of heat treatment on the yield of amino acids are shown in Table 8. Some anti-nutritional factors inhibit the liberation from protein of the amino acid, methionine, so that the effectiveness of methionine (which is limiting in legumes) in protein synthesis is reduced. Similarly, chemical analysis of available lysine do not in each case relate to the nutritive value (Haekler *et al.* 1967, Boctor and Harper, 1968; Atkinson and Carpenter, 1970). If the sample being analyzed

**Table 8. Amino acid content of the winged bean as affected by time of hydrolysis and heat treatment.**

| Amino Acid | (g 100 g protein) 18 hr hydrolysis | 24 hr hydrolysis | Autoclaving | Casein |
|---|---|---|---|---|
| Aspartic acid | 8.30 | 6.93 | 11.03 | 6.14 |
| Threonine | 3.91 | 3.91 | 4.15 | 3.84 |
| Serine | 4.84 | 4.56 | 5.13 | 3.19 |
| Glutamic acid | 14.53 | 14.99 | 13.65 | 13.53 |
| Proline | 6.01 | 5.97 | 6.00 | 5.60 |
| Glycine | 3.98 | 4.07 | 4.26 | 1.99 |
| Alanine | 3.96 | 4.11 | 4.10 | 3.20 |
| Cysteic acid | 1.32 | 1.41 | 2.27 | 0.51 |
| Valine | 4.76 | 4.91 | 4.95 | 5.62 |
| Methionine | 1.01 | 0.86 | 0.92 | 3.49 |
| Isoleucine | 4.43 | 4.60 | 4.57 | 6.59 |
| Leucine | 8.22 | 8.32 | 7.93 | 10.07 |
| Tyrosine | 4.74 | 4.74 | 5.31 | 7.72 |
| Phenylalanine | 4.52 | 4.64 | 4.98 | 6.98 |
| Lysine | 7.64 | 7.91 | 5.24 | 5.72 |
| Histidine | 2.89 | 2.99 | 2.24 | 3.14 |
| Ammonia | 1.42 | 1.58 | 1.72 | 2.05 |
| Arginine | 7.27 | 7.54 | 5.42 | 4.26 |
| Trytophan | 1.25 | 0.94 | 1.13 | 1.43 |
| Total sulphur containing amino acid | 2.33 | 2.27 | 3.19 | 4.0 |

contains elevated levels of carbohydrates, serious problems associated with Maillard reactions occur (Bodwell, 1976).

It is essential to inactive anti-nutritional factors in legumes in order to use the available lysine as an index for assessing the effect of heat on legume products. The usual acid hydrolysis releases the biologically unavailable lysine. If anti-nutritional factors are inactivated, Carpenter's available lysine procedure can be relied upon (Carpenter, 1960; Carpenter and Booth, 1973). In Table 8, we see that the yield of certain amino acids is affected by the length of hydrolysis as well as type of heat (dry heat or moist heat). Comparing an 18 hr and 24 hr hydrolysis shows that the total sulphur amino acids, lysine or most of the essential amino acids are not significantly affected. However, when the same 24 hr hydrolysis was compared between raw and autoclaved samples, different and significant results were obtained. We observed that the 24 hr hydrolysis of raw beans yields values of 1.41 and 0.86 for cystine and methionine respectively. Autoclaving on the other hand prior to a 24 hr hydrolysis increases these values to 2.27 and 0.92 respectively.

Our result also indicate that although heat processing inactivates anti-nutritional factors, beyond a certain point, the proteins of legumes are denatured. We observed in this case that the sample was subjected to the heat effect of autoclaving and then that of hydrolysis. Our results show therefore that increasing the heating time beyond a certain point produces a decrease in available lysine. This we suggest would result in a biological damage to the protein. Lysine and cystine will be destroyed, and while autoclaving improves the values of some amino acids (cysteic acid, tyrosine and tryptophan), others (lysine, leucine, histidine and arginine) are negatively affected. Although some anti-nutritional factors inhibit the liberation of methionine, once these anti-nutritional factors are inactivated, the total sulphur amino acid values increase, 2.27 in raw as against 3.19 in autoclaved samples.

The complete amino acid composition of the entire portions of the winged bean plant is in Table 9. It is of significance to note the high levels of the essential amino acids in the roots of the winged bean and to consider the fact that these were roots of the winged bean and to consider the fact that these were roots with no nodulation. In fact the root of the winged bean contains higher levels of the essential amino acids lysine, methionine, histidine, cysteine and equal levels of others as autoclaved winged bean. When one considers those countries of the world where their protein sources come from legumes, it is encouraging to note, too, that the different parts of the winged bean contain such high levels of known amino acids.

**Table 9. Amino acid composition of the different parts of the winged bean plants (g/100 g protein).**

| Amino Acid | Raw Meal | Autoclaved Meal | Immature Pods | Mature Pods | Young Leaves | Mature Leaves | Plant No Pods | Entire Plant | Roots Only |
|---|---|---|---|---|---|---|---|---|---|
| Aspartic acid | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Threonine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Serine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Glutamic acid | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Proline | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Glycine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Alanine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Cysteic acid | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Valine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Methionine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Isoleucine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Leucine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Tyrosine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Phenylalanine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Lysine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Histidine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Ammonia | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Arginine | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Tryptophan | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

The effect of autoclaving of the winged bean seeds is reflected in an increase in the release of cysteine, threonine, tyrosine and phenylalanine after autoclaving. A considerable decrease in the release of lysine, histidine, methionine and arginine was also observed after autoclaving the winged bean meals. We confirm a decrease in lysine content with heat treatment. This demonstrates that in heat processed proteins, the amino acid profile obtained after acid hydrolysis may not be a proper indicator of the extent of damage of an essential amino acid like lysine. It appears that chemical nonenzymatic procedures for evaluating protein quality may not show the availability of lysine if the sample contains an inhibitor. No single animal assay provides data to show if the low quality of a protein is due to its poor digestibility or lack of destruction of any of the essential amino acids.

Heat treatment has a significant effect on the availability of some amino acids, especially the essential amino acids. Kakade and Evans (1965) noted the improvement in the nutritive value of navy bean when subjected to heat treatment. They attributed this to be due to the destruction of the trypsin inhibitor and to the denaturation of the protein molecule. Lea and Hannan (1950) attributed this loss to the interaction between the free amino acid groups and the reducing carbohydrates. Our studies confirm these findings. Elias *et al.* (1976) have similarly indicated that the loss in protein quality with precooked legume flours was due mainly to a decrease in available lysine caused by a non-enzymatic browning reaction, favored by the high temperature developed during processing. In the rat experiments of Cerny *et al.*, (1971) the PER value obtained was 2.14 on a 10% winged bean protein diet. This value increased to a maximum of 2.7 when unfermented maize was supplemented with winged bean flour.

Using the model created by Kendrick *et al.* (1976) we obtained the results shown in Table 10. Winged bean has a PER of 2.13 and a C-PER of 1.68 compared to 2.29 and 1.86 respectively for soybean. The value of 2.13 for winged bean agrees with the data of Cerny *et al.* (1971). When the winged bean was autoclaved, the PER and C-PER increased to 2.83 and 2.38 respectively, with the latter being superior to the C-PER of casein (2.66). The PER value of casein is usually taken as 2.5. The PER of soybean based on data compiled from Altschul (1965) and FAO (1965) has been shown to vary between 0.7 to 1.8. The different values of PER we have obtained from winged bean indicates that winged bean, like soybean, may exhibit considerable variation in PER values (corrected and uncorrected) depending on processing conditions and more especially the type of heat applied (dry heat or moist heat) and the duration of the heating process. Compared to casein

and soybean, the roots and the immature pods also have PER values similar to or even better than soybean meal. Surprising though as the result might appear, the entire plant has a negative C PER value (−1.37). Our suspicion therefore is that it is possible that besides the beans, there are other protease inhibitors present in some other parts of the winged bean plant.

**Table 10.** Essential amino acid content, % protein, % digestibility and PER value of the different parts of the winged bean compared to the soybean.

| Essential Amino Acid (g/100 g protein) | 24 hr hydrolysis | Autoclaving | Raw SM | Casein | Immature pods | Mature pods | Young Leaves | Mature Leaves | Above Ground No Pods | Entire Plant | Root Nodules |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lysine | 7.9(102) | 5.24(7) | 4.06(53) | 5.72(95) | 6.66(88) | 4.45(55) | 2.56(34) | 4.67(54) | 4.23(53) | 0.71(9) | 5.62(7) |
| M + C | 2.27(45) | 3.19(72) | 4.26(84) | 4.01(102) | 4.35(86) | 3.23(66) | 2.96(60) | 2.57(45) | 2.13(42) | 5.01(102) | 4.58(8) |
| Threonine | 3.91(68) | 4.15(82) | 3.75(67) | 3.84(85) | 3.70(65) | 2.83(52) | 4.63(85) | 3.96(63) | 4.35(75) | 3.07(6) | 4.13(7) |
| Isoleucine | 4.66(86) | 4.57(96) | 4.35(77) | 6.54(145) | 4.25(76) | 4.04(75) | 5.51(97) | 5.33(85) | 4.81(83) | 4.42(79) | 4.32(7) |
| Leucine | 8.32(83) | 7.93(89) | 7.00(70) | 10.07(122) | 6.88(70) | 7.05(74) | 9.52(95) | 9.41(85) | 8.47(83) | 7.71(79) | 7.37(7) |
| Valine | 4.91(69) | 4.95(79) | 4.35(62) | 5.21(102) | 5.13(74) | 4.93(73) | 6.44(92) | 5.10(78) | 6.36(87) | 5.85(85) | 6.74(9) |
| P + T | 9.38(105) | 10.29(134) | 8.78(102) | 14.51(216) | 8.43(100) | 9.05(110) | 11.39(132) | 9.35(98) | 7.57(86) | 7.25(86) | 7.72(8) |
| Tryptophan | 0.94(69) | 1.13(93) | 0.77(71) | 1.43(134) | 0.95(71) | 0.66(45) | 2.06(154) | 0.93(61) | 4.94(354) | 2.26(169) | 1.13(8) |
| Protein % | 37.62 | 50.00 | 39.06 | 90.06 | 17.06 | 16.63 | 27.00 | 14.62 | 12.44 | 19.25 | 11.56 |
| Digest % | 69.58 | 79.21 | 70.52 | 89.90 | 71.79 | 73.78 | 70.52 | 63.44 | 68.71 | 71.79 | 68.35 |
| Pred. PER[a] | | 2.83 | 2.29 | 3.31 | 2.62 | 2.08 | 1.67 | 2.07 | 2.00 | 0.45 | 2.69 |
| C PER[b] | | 2.38 | 1.86 | 2.66 | 2.20 | 1.62 | 1.03 | 1.60 | 1.52 | −1.37 | 2.27 |

( ) Values in parentheses represent FAO's adjusted % digestibility

[a]Predicted PER (uncorrected).

[b]Corrected PER.

## Protein Extraction

1. **Effect of pH.** Results in Table 11 show that the solubilities of the nitrogenous constituents of winged bean and the other legumes used for comparison as evaluated over a pH range of 2 to 12, are strongly pH-dependent. The amount of protein extracted from the samples at the very high alkaline pH is higher than the amount obtained at either neutral or acidic pH. This is very true in the case of winged bean and Pinto. In all four cases, the proteins of the beans have a common point of minimum dispersion at pH 4.0 and a corresponding point of maximum dispersion at pH 12.0. The pH-solubility curves of these beans are identical to the patterns described for soybeans (Smith and Circle, 1938; Fan and Sosulski, 1974; Thompson, 1977; red kidney beans (Pusztai, 1965; Hang *et al.*, 1970) and solvent-extracted peanut meal (Fontaine and Burnett, 1944). Results indicate that this point of minimum solubility corresponds to the apparent isoelectric point previously found for commercial soybean flours by a cataphoretic method as reported by Managhan-Watts (1937). Our data also suggest that a major portion of the protein extracted can be precipitated at the isoelectric point, at a pH of 4.0.

   Using distilled water as the extractant for winged bean, we obtained a pH of 6.5. When alkali was added to increase the pH to varying levels, the amount of total protein extracted increased considerably. However results with other legumes have suggested that at very high alkaline pH, there is the possibility of protein denaturation, darkening of protein isolates (Fan and Sosulski, 1974) and more chance of starch gelatination (Wu *et al.*, 1976). It is therefore necessary to control the pH for the extraction of winged bean.

   A value of about 90% precipitation of the extracted protein was obtained at pH 4, the apparent isoelectric point. This suggests that a pH value of around 4.0 is adequate to precipitate the winged bean protein from the alkaline extract.

2. **Effect of solvents.** A small number of solvents was used to extract winged bean protein at a solid-to-solvent ratio of 1:15 (Table 12). The most effective solvent was found to be NaOH at 0.1 M and a pH of extraction of 12.4. Increasing the molarity of the NaOH up to 0.5 M did not yield reasonable amounts of extracted protein. The 0.1 M NaOH with a pH of 12.4 confirms our result above. Compared to water, NaOH at 0.1 M and pH 12.4 still did not however disperse as much of the nitrogenous matter from winged bean. Our data also show that Great Northern yielded the highest amount of protein extracted at 0.1 M NaOH and pH of 11.5. We can therefore suggest that NaOH at 0.1 M extracted the same amount of winged bean protein as water at pH 10.0. Considering the risks involved

**Table 11. Effect of pH on protein extraction of winged bean and some other legumes.**

| pH of extraction | % Total Protein Extracted[a] | | | |
|---|---|---|---|---|
| | Winged bean | Soybean | Great Northern | Pinto |
| 2 | 79.4 | 56.4 | 72.5 | 74.7 |
| 4 | 19.5 | 13.7 | 20.1 | 17.4 |
| 6 | 51.9 | 33.0 | 40.2 | 35.6 |
| 8 | 62.0 | 61.8 | 80.4 | 85.9 |
| 10 | 82.2 | 79.9 | 84.3 | 85.9 |
| 12 | 90.6 | 86.1 | 84.7 | 90.3 |

[a]Values represent mean of duplicate extractions.

**Table 12. Effect of different solvents on protein extraction of winged bean.**

| Molarity[a] | Sodium hydroxide | | Sodium chloride | | Hydrocoloric acid | |
|---|---|---|---|---|---|---|
| | pH of attraction[b] | % P[c] | b | c | b | c |
| .1 | 12.4 | 82.2 | 6.6 | 54.0 | 1.4 | 67.2 |
| .2 | 12.7 | 73.5 | 6.6 | 51.9 | 1.2 | 60.8 |
| .3 | 12.8 | 59.2 | 6.5 | 58.5 | 1.0 | 52.4 |
| .4 | 13.0 | 71.8 | 6.3 | 59.2 | 0.8 | 51.3 |
| .5 | 13.1 | 79.8 | 6.3 | 58.9 | 0.5 | 37.1 |
| 1.0 | 13.3 | 81.5 | 5.8 | 60.6 | 0.4 | 39.0 |

[a]molarity of the extractment; same for all three solvents.
[b]pH of protein extract.
[c]percent of total protein extracted.

with only alkaline pH it is safe to suggest a pH of 10 for the extraction of the proteins of winged bean with water.

Pusztai (1965) demonstrated the significance of processing variables — pH, ionic strength — of the dispersing media on nitrogen extractability of kidney beans. Lofquist and Munck (1969) investigated the extraction and precipitation of broad bean proteins using NaOH at pH 11.6. So far the extraction and precipitation of the winged bean has not been fully investigated. Our data are in agreement with that of Hang *et al.* (1970) who showed that the amount of extractable nitrogen is greater at alkaline pH than at neutral or acidic pH. The proteins of different legume varieties have a common point of minimum dispersion at an acidic pH (4.0) and a large amount of nitrogenous constituents can be extracted either by dilute NaOH or dilute HCl at the pH of maximum dispersion.

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# The Winged Bean as a New Source of Protein for Rural Populations in the Ivory Coast, West Africa

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This report outlines a field project presently being undertaken in the forest region of the Ivory Coast by the Nestle Foundation for the Study of the Problems of Nutrition in the World. The project's aim is to increase the protein content of the local diet — which consists mainly of yam and cassava — through the consumption of the winged bean by encouraging its culture in family gardens.

Results obtained in field trials with seeds obtained from Papua New Guinea (PNG) variety UPS 32 and from Ghana (GH). Materials and methods of culture are described. The behavior of the two varieties (PNG and GH) under varying environmental conditions and their morphological characteristics are compared. Pest problems (mainly nematodes, *Meloidogyne* sp. and viral diseases) are discussed. The Ghana variety was found to be more vigorous, more resistant to pest attacks and better adapted to local environmental conditions. Although the region under study can be defined as "hot humid tropics" (latitude 5° to 7° North, pluviometry 2,300 to 1,500 m.m. annual average) both varieties behaved like annual plants in that they did not survive the dry season — November through March — and thus failed to show a perennial behavior. Tuber production was found to be scant in both varieties. Composition tables are given for both varieties.

The project's nutritional aspect is outlined. Two villages, comparable in size and population composition, situated at the northern limit of the Ivorian rainy forest were chosen: an experimental village and a control village. In both villages the preschool-age population receives medical attention and the children's nutritional status is periodically assessed by clinical, anthropometrical and biochemical standards. In the experimental village the winged bean culture (Ghana variety) in family gardens is being promoted by agronomic assistants and the consumption of green pods, leaves seeds and possibly tubers is encouraged by household assistants. Both villages show a sizable prevalence of marginal to frank PCM, with yam and cassava as staple food and with a low protein content of the diet. It is hoped that the additional protein source from the winged bean will result in improved nutritional status and better growth pattern in the children of the experimental village. Acceptability problems and the population's reaction to the culture of this new crop is discussed.

## INTRODUCTION

This report outlines a field project presently being undertaken in the forest region of the Ivory Coast by the Nestle Foundation for the Study of the Problems of Nutrition in the World. The project's aim is to increase the protein content of the local diet — which consists mainly of yam and cassava — through the consumption of the winged bean (*Psophocarpus tetragonolobus*) by encouraging its culture in family gardens.

The first WB field trials were started in 1976 with seeds obtained from the University of Papua New Guinea (PNG) variety UPS 32 and with seeds from Ghana (GH) obtained from the Kade Research Station, University of Ghana. Only a small amount of seeds of each variety was available and thus the first year trials were aimed at seed multiplication. A small amount of seeds of PNG variety UPS 31 was also available and was given to the agronomic research station of ORSTOM (Office de Racherche Scientifique et Technique Outre Mer) in Abidjan for variety genealogical selection. These experiments were carried out on the coastal area, at 5 degrees latitude North where rainfall averages 2,300 mm per year. Except for a few information on viral disease, no report on these ongoing experiments will be given.

The project which is presently under way was started in early 1977 and is scheduled to last over a period of at least three years. Two villages, comparable in size and socio-economic composition were chosen at the

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northern limit of the Ivorian rainy forest: an experimental village in which the WB culture in family gardens is being promoted and a control village. In both villages a medical program mainly aimed at the preschool age population is under way. In the experimental village WB consumption (green pods and dry seeds) is being encouraged and its importance for an improvement of the children's health status is being stressed. Details on the programs medical and nutritional aspects are discussed later.

The villages under study are located at 7 degrees latitude North where the rainy forest progressively gives way to a savanna in which clusters of tall trees and palm trees still abound. To the East and to the West of the villages the rainy forest stretches further north for several tens of miles so that study the region is situated at the southern tip of a wedge of savanna that penetrates into the forest. The mean yearly rainfall is 1,500 mm. The rains are not uniformly distributed over the year: a "long rainy season lasts from April through July, followed by a "short rainy season with insignificant occasional rainfalls in August; this is followed by a "short rainy season" during September and October with small but frequent rainfalls' the "long dry season" lasts from November through March with occasional thunderstorm at the turn of the year. The inhabitants of the region belong to the Beoule tribe, a sub group of the Akan people whose origins go back to present day Ghana from where they migrated West in the eighteenth century. The area produces coffee and cocoa and the inhabitants are virtually all planters. The men are busy on small plantations they own and on which they farm without any mechanical help, a metchet and a hoe being the only tools they use. The women take care of family gardens where they grow mainly yam — the region's staple food — next to cassava, gombo, eggplant, tomatoes, hot peppers and a few other legumes. There is no tradition of cattle rearing. Goats and muttons as well as fowl are left free to remble among the huts. Their contribution to the local diet is insignificant since they are sacrificed only on special occasions such as religious ceremonies or funerals.

The local diet is based on yam (*Dioscorea alata*) as staple food. Consumption of cassava (*Manihot esculenta*), plantain (*Musa paradisiaca*) egg plant, gumbo (*Hibiscus esculentus*) and taro (*Colocasia esculenta*) is frequent. The traditional dish is "foutou" consisting of a dough of pounded yam or cassava or plantain to which are added sauce containing either gumbo or ground nuts, eggplant, hot peppers etc. mostly flavoured with small quantities of smoked fish. The culture of pluvial rice has been introduced to the region over the past years by the agronomic team of the Nestle Foundation. Acceptance was good after initial resistance and rice consumption has become relatively frequent. Meat is rarely eaten and comes mostly from small game such as rodents and small antelopes. During the rainy season large snails represent a non negligible source of protein. Eggs are rarely eaten since local beliefs forbid their consumption by pregnant women and children. The dietary picture can be illustrated by a dietary 24 hour recall survey undertaken in November 1977 in the experimental village and which gave the following results:

One hundred and thirty women were interviewed and asked the following question "What did you cook yesterday for the morning and the evening meal?" and their answers were registered. Furthermore they were asked whether during the previous week they had prepared one or more of the following: chicken, goat or mutton, milk and eggs and whether they had cooked any beef during the past month. The results were the following: 96 women representing 74% of those interviewed had prepared yam, 71 (55%) cassava, 57 (44%) rice 42(32%) plantain 23 (18%) some game and 69 (53%) had cooked some fish. During the previous week, only 10 women (8%) had prepared dishes including chicken, 3 (2%) had prepared mutton and only 2 had used both milk and eggs. Of 47 women who had received winged bean seeds at the start of the rainy season, 14 (30%) had cooked green pods the day before the interview. Dry seeds were not yet produced at the time of the survey and thus no consumption was registered.

## MATERIALS AND METHODS

Trials were conducted for the UPS 32 and Ghana varieties in May 1977 coinciding with the start of the rainy season in a one hectare field piece of land previously grown to pluvial rice. Ridges were built with an approximate height of 20 centimeters and 80 centimeters apart. On these, seeds were sown with a spacing of 50 centimeters between planting points, with 2 seeds per planting point. Stalking consisted of single poles about 3 meters in height connected by iron wire running horizontally at 1.5 meters from the ground.

## RESULTS

### Vegetative Cycle

Table 1 compares the two varieties in terms of length of their vegetative cycles.

**Table 1. Winged bean trial: vegetative cycle.**

| Vegetative Cycle | PNG (UPS 32) | Ghana |
|---|---|---|
| Germination (%) | 90 | 96 |
| 1st flower buds (day) | 27 | 44 |
| Flower opening (day) | 42 | 61 |
| 1st pods (day) | 48 | 66 |
| 1st dry seeds (harvest) (day) | 105 | 130 |

PNG — seeds from Papua New Guinea
UPS — University Accession number of *Psophocarpus*
Ghana — seeds from the Kade Research Station, University of Ghana.

Germination was excellent in both varieties: 90% of seeds germinated for the PNG and 96% for the Ghana variety within 2 weeks. The PNG variety proved to be more precocious, the first flowers appearing after 4 weeks as compared to 6 weeks for the Ghana variety. Correspondingly, flowers were completely open after 42 and 61 days, respectively. In both varieties the first pods appeared 5 to 6 days after flower opening. Harvestable dry seeds first appeared on the PNG variety after 105 days (i.e. three months and a half) while it took 130 days or just over 4 months for the first dry seed to appear on the Ghana variety. During the day, flowers opened between 8 and 10 in the morning, corresponding to what has been reported from trials in Ghana (*Pospisil et al.* 1971). Insects did not appear to play an important role in pollination except possibly for butterflies, contrary to what had been reported from Ghana where bumble bees were found to play an important role in pollination (Karikari, 1972). Our observations however are not based on a systematic study and need further confirmation.

### Morphological Characteristics

In both varieties blue and light blue flowers dominated over light purple and mixed blue-purple flowers. The majority of pods (84%) showed a smooth surface while the remainder (16%) had a rough surface. Pod color in decreasing order of frequency, was either olive-green, green or purple. The wings showed the following colors in decreasing frequency: purple, green and mixed green with purple spots. In the PNG variety the majority of pods showed a rectangular section while the Ghana variety had a predominance of pods flat on the sature. The PNG variety had a thinner stem than the Ghana variety. In both varieties stem color was predominantly purple followed by green and mixed purple-green stems.

Table 2 shows the growth in length over time. After 3 months the PNG variety had reached 4 meters and 10 centimeters height on the average while the Ghana variety attained 3m and 70 cm. and was expected to overgrow the PNG variety. At 3 months the Ghana variety had shorter but nevertheless heavier plants due to their stem and broader leaves.

**Table 2. Winged bean trials: growth pattern.**

| Days after sowing | UPS 32 (N = 40 plants) cm | Ghana (N = 40 plants) cm |
|---|---|---|
| 30 | 49 | 40 |
| 45 | 149 | 110 |
| 60 | 330 | 220 |
| 90* | 410 | 370 |
| (range) | (290-460) | (200-517) |

*Growth ended for PNG but not for Ghana by the 90th day.

Table 3 compares the 2 varieties in terms of pod and seed production. The Ghana variety with a mean pod length of 25 ± 5 cm had longer pods than the PNG variety with pods averaging 17 ± 3 cm. Correspondingly, the mean number of seeds per pod was higher in the Ghana variety with 17 seeds against 11 seeds for the PNG variety. The Ghana variety also had longer and heavier seeds. The average weight of 100 seeds was 42g against 28 g for the PNG variety. The average seed production per plant was 88g for the Ghana variety and 51g for the PNG variety. The shelling percentage seed weight in a dry pod totalling 48 ± 6% and Ghana 47 ± 7% which means that just short of half the weight of a dry pod is edible matter. This compares favourably with the figures reported by Khan (1976), 42% and by Rachie in Ibadan (Undated), 40%.

**Table 3. Winged bean trials: morphological characteristics.**

| | UPS 32[a] | Ghana[a] |
|---|---|---|
| Pod length (cm) | 17 ± 3 | 25 ± 5 |
| Number of pods/plant | | |
| Number of seeds/pod | 11 ± 4 | 42.5 ± 7 |
| Weight of 100 seeds (g) | 28 ± 4 | 42.5 ± 7 |
| Seed weight/plant (g) | 51 ± 22 | 88 ± 31 |
| Shelling percentage[b] (%) | 48 ± 6 | 47 ± 7 |
| Estimated yield (kg/ha.) | 300 | 670 |
| (Range) | (260 — 330) | (550 — 790) |

[a]Mean ± 1 SD
[b]Shelling percentage: seed weight/pod weight × 100.

The estimated yield per hectare was 670 kg for the Ghana variety vs. 300 kg for the PNG variety. These figures are probably well below the optimum production due to parasitic infestation which impaired production. The reported estimation are based on actual measurements of the yield of 25 to 30 are (1 are = 119 square yards). Extrapolations based on the yield measured surfaces of the order of 1 are, gave higher yield ranging between 2 and 3 tons per hectare.

Figure 1 illustrates the number of flowers per cluster and the resulting number of pods. It can be seen that while the PNG variety rarely produced more than 1 pod per cluster the Ghana variety often had 2 pods per cluster.

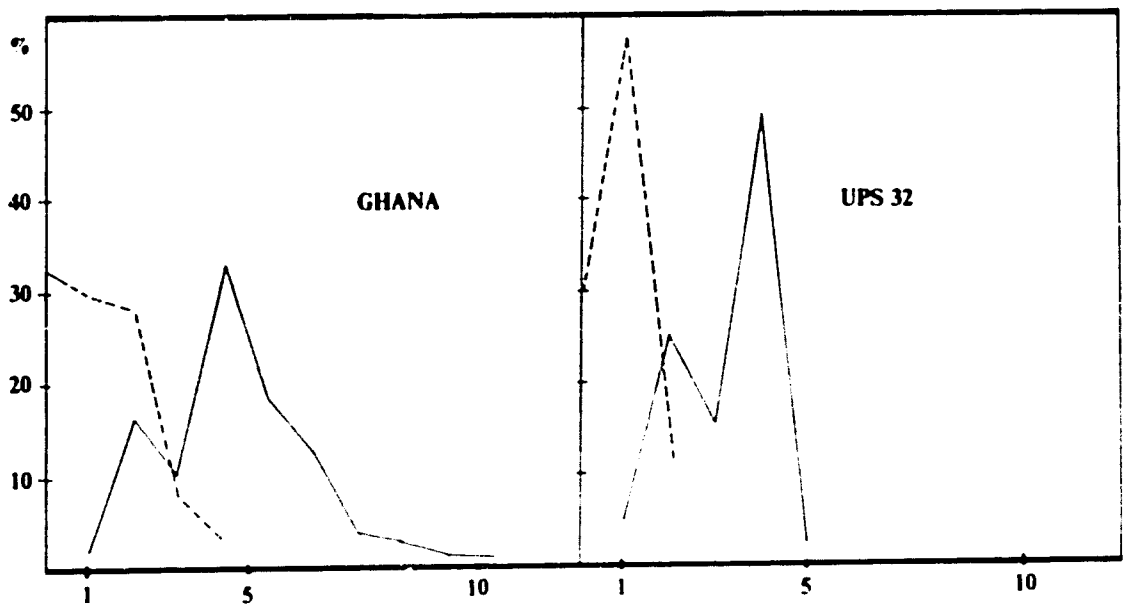


Fig. 1. Number of flowers per cluster (———) and number of resulting pods (— — — —)

**Tuber Production**

On a few areas the plants were left unstalked to enhance tuber production (Masefield, 1973). On these plants rambling on the ground, flowers and young pods were picked, also with the aim of enhancing tuber production (Burkill, 1906, as quoted NAS, 1975).

Table 4 gives the results of these experiments, based on 50 plants for each variety. Contrary to our expectations tuber production was found to be higher in stalked plants than in unstalked plants. Also, the Ghana variety had better yields than the PNG variety. The latter did not survive when left unstalked and the plants died with no apparent cause and without showing signs of viral or other disease. In the Ghana variety 60% of stalked plants produced tubers vs. 26% for unstalked plants, while 55% of stalked PNG plants produced tubers. These figures are higher than those reported by Khan 1976 who found 16% of plants producing tubers in a PNG variety. Mean tuber weight per plant was higher in stalked GH plants (50 g) followed by unstalked Ghana plants (33 g) and by PNG stalked plants (25 g). The largest tuber yield per single plant was 140 g, found in a stalked Ghana plant, a figure almost 3 times higher than that reported by Khan 1976: 50:3 g. The estimated tuber yield per hectare, based on mean tuber yield per plant was 1200 kg for stalked Ghana, 790 kg for unstalked GH, 600 kg for stalked PNG. In both varieties tuber production started during the fourth month. Based on these observations it is our tentative belief that picking of flowers and young pods before the 4th month does not influence the degree of root thickening: the plants appear to continue their growth above ground and root thickening starts only from the 4th month onward. This hypothesis needs to be confirmed by systematic picking of flowers and young pods after the fourth month of growth.

Table 4. Winged bean trials: tuber production.

| | UPS 32 (N — 50 Plants) | | Ghana Variety (N — 50 Plants) | |
|---|---|---|---|---|
| | Stalked | Unstalked | Stalked | Unstalked |
| Tubers Producing Plants (%) | 55 | 0 | 60 | 26 |
| Average Tuber Yield Per Plant (g) | 25 | 0 | 50 | 33 |
| Estimated Tuber Yield (kg/ha) | 600 | 0 | 1200 | 790 |
| Largest Yield in Plant (g) | 55 | 0 | 140 | 70 |

**Pests and Diseases**

Information about winged bean pests and diseases is still scant. In 1973, Masefield in his article reviewing the information available at that time on winged bean stated that "Neither pests nor diseases appear to be a very serious threat to the crop". The 1975 Monograph on the winged bean published by the NAS described the plant as being "unusually free from serious pests and diseases". Unfortunately our observations are not in agreement with this statement. Our cultures were plagued by fungus, insects, nematodes and viral diseases. Fungus: during our first year trials fungal disease was observed on the leaves and identified as *Pythium* and *Anthracnose*. Treatment with Benlate was effective and the vegetative cycle went on undisturbed.

Several types of caterpillars and butterflies attacked the young plants, especially the flowers and young pods. An unidentified insect laid eggs inside the unripe seeds. The heaviest damage was caused by *Mylabris afzelii* (fam. *Meilodae*) which fed on the flowers.

Two types of nematodes were found to attack the roots and cause root rot: Nematodes of the *Meloidogyne* species and to a lesser extent *Pratylenchus brachyurus*. Nematodes of the *Meloidogyne* species are ubiquitous in West African soils and in the Ivory Coast in particular where practically no soil is free from it. They can be found even in soils on which the forest has just been cut. Infestation in the cultures was heavy. No treatments were done in order to be able to observe the natural course of the disease. The parasite produced large galls on the roots, impairing nodule formation and root thickening for the formation of tubers.

Infestation by virus on both varieties was the main phytosanitary problem encountered. Three types of

virus could be distinguished according to their symptoms but final identification is still pending. Two viruses were observed on our forest culture. Ring spot mosaic and above all Crincle virus. Ring spot mosaic was found to be transmitted by aphids and was mechanically transmittable. It resulted in the weakening of the plant which estimatedly reduced production by 10 to 29% approximately. Damage caused by crincle virus was more serious and more widespread. Flowering was greatly impaired with resulting reduced pod and seed production. This virus was not mechanically transmittable.

Spreading of the disease was slow and this led us to suspect a vector living in the soil such as insects of the Macarodes type or possibly through nematodes. There was no support for a seed borne transmission. The third virus was of the necrotic mosaic type and was found only on plants in the coastal areas in trials previously referred to.

Among the Ghana variety, several plants appeared "immune" from viral disease. This line of plants which were revealed after the surrounding plants had died out were different from the others in the following characteristics: they had smaller and narrow leaves, their pods were light green instead of olive green and were shorter than the pods of the Ghana lines, their vegetative cycle was considerably longer and dry seed production intervened after 7 months instead of 4 to 5 months, they also showed a smaller susceptability to nematode infestation and did not seem to suffer from viral disease, their seeds were smaller with an average weight one hundred seeds of 24 grams vs. 42 g. In this, they had lighter seeds than the PNG variety which had an average 100 seed weight of 28 grams, the shelling percentage was the same as that of the other Ghana plants: 47%.

We hesitate to call this line as resistant to pests and diseases and prefer to call it "Ghana long cycle" pending further investigations. The length of the vegetative cycle in this case is a handicap since it exposes the plants to the dry season at the moment they begin to produce harvestable seeds.

Table 5 illustrates the influence of parasitic disease in PNG, Ghana and "Ghana long cycle" plants in terms of seed formation and seed quality by comparing healthy vs. diseased plants for each variety. It can be seen that in PNG and Ghana plants, the percentage of healthy seeds per pod was reduced from approximately 80% to less than 60% while in Ghana long cycle plants 93% of seeds per pod were healthy. On the same table it can be seen that viral disease apparently had no effect on the number of empty seed beds per pod.

**Table 5. Winged bean trials: influence of parasitic diseases (virus) on seed formation and seed quality.**

| | UPS 32 | | Ghana | | |
|---|---|---|---|---|---|
| | Healthy Plants | Diseased Plants | Healthy Plants | Diseased Plants | Ghana Long Cycle |
| Seeds/pods | 11 | 11 | 17 | 17 | 13 |
| Healthy seeds/pods | 9.1 ± 2.8 | 7.2 ± 3.4 | 14.2 ± 2.5 | 9.8 ± 4.1 | 12.3 ± 2.4 |
| | (80.7%) | (59.6%) | (80.1%) | (58.2%) | (93.2%) |
| Non viable seeds/pods | 1.0 ± 0.8 | 3.5 ± 2.6 | 2.0 ± 1.7 | 5.5 ± 3.4 | 0.3 ± 0.8 |
| | (8.7%) | (29.4%) | (12.2%) | (32.8%) | (2.1%) |
| Empty seed beds | 1.2 ± 1.1 | 1.3 ± 1.2 | 1.3 ± 1.1 | 1.5 ± 1.3 | 0.6 ± 0.5 |
| | (10.6%) | (11.0%) | (7.7%) | (9.0%) | (5.7%) |

**Mean ± 1 SD.**

## Composition and Nutritive Value of Winged Bean

Table 6 gives the proximate composition of dried pods, seeds and dried leaves for both varieties. One hundred grams of seeds of the Ghana variety contained 37.5 g of protein. For the PNG variety the protein content of seed was 36.2 g per 100 grams of seeds.

These values as well as the fat and carbohydrate content are similar to those found in the literature (NAS, 1975). Table 7 shows the content in essential amino acids for both varieties, in dried pods, seeds and dried leaves. The essential amino acid content found in our seed samples is very similar to that reported by Cerny and co-workers 1971 for winged bean grown in Ghana, with the exception of tyrosine whose content was found to be higher in our sample (6.9 g/% vs. 3.2 g/%).

**Table 6. Proximate composition of 2 varieties of winged beans grown in the Ivory Coast.**

| | Ghana | | | UPS 32 | | |
|---|---|---|---|---|---|---|
| | Pods (dried) | Seeds | Leaves (dried) | Pods (dried) | Seeds | Leaves (dried) |
| Proteins (N x 6.25) | 28.7 | 27.5 | 35.6 | 28.1 | 36.2 | 33.7 |
| Fat (%) | — | 17.1 | — | — | 16.5 | — |
| Carbohydrates (%) | 43.0 | 26.4 | 36.8 | — | 26.8 | — |
| Fiber (%) | 20.8 | 14.9 | 20.9 | — | 16.1 | — |
| Ash (%) | 7.5 | 4.1 | 6.7 | 8.4 | 4.4 | 6.4 |

Moisture 5% (seeds, vacuum dried), 3% (pods and leaves, lyophilized).
Analyses performed on dried samples expressed as g 100g vacuum dried samples.

**Table 7. Amino acid composition of 2 varieties of winged beans grown in the Ivory Coast.**

| Essential Amino Acid (g 16gN) | Ghana | | | Papua New Guinea | | | Winged bean (Cerny et al 1971) | Soyabean (Kapiostis 1968) |
|---|---|---|---|---|---|---|---|---|
| | Pods | Seeds | Leaves | Pods | Seeds | Leaves | | |
| | | | | | seeds | | | |
| Isoleucine | 2.5 | 5.5 | 3.8 | 2.8 | 5.1 | 5.7 | 4.9 5.1 | 5.8 |
| Leucine | 4.5 | 11.0 | 7.2 | 5.1 | 8.7 | 11.4 | 8.6 9.2 | 7.6 |
| Lysine | 3.5 | 8.5 | 5.2 | 4.0 | 7.0 | 8.0 | 7.4 8.0 | 6.6 |
| Methionine | 0.9 | 1.1 | 1.2 | 1.0 | 1.3 | 2.6 | 1.2 | 1.1 |
| Phenylalanine | 2.9 | 6.7 | 4.7 | 3.4 | 5.0 | 7.4 | 4.8 5.8 | 4.8 |
| Tyrosine | 2.0 | 6.9 | 3.8 | 1.9 | 5.8 | 7.3 | 3.2 | 3.2 |
| Threonine | 2.8 | 4.1 | 4.0 | 3.5 | 3.3 | 4.1 | 4.3 4.5 | 3.9 |
| Valine | 3.0 | 5.5 | 4.8 | 3.5 | 4.3 | 5.9 | 4.9 5.7 | 5.2 |

Table 8 shows the Protein Efficiency Ratio (PER) i.e. the weight gain of growing rats fed on a composite diet containing 10% of protein, all supplied by winged bean seedflour, divided by their protein intake. Compared to a PER of 3.2 for casein and of 2.40 for soybean, the values found with our winged bean diet were PER = 1.81 for Ghana seeds and PER = 1.75 for PNG seeds. These values are less satisfactory than the value of a PER of 2.14 found by Cerny and co-workers (1971) for winged bean grown in Ghana. Tables 9 and 10 give the mineral composition and vitamin contents respectively.

**Table 8. Protein efficiency ratio, PER (weight gain of growing rats divided by their protein intake).**

| PER (casein 3.2) | Ghana | Papua New Guinea | Soya |
|---|---|---|---|
| Autoclaved 10 min at 120°C | 1.43 | 1.57 | 2.13 |
| Heated 10 min at 90°C | 1.81 | 1.75 | 2.40 |

## NUTRITIONAL PROGRAM IN THE EXPERIMENTAL VILLAGE

At the beginning of the rainy season, in April 1977, we started the promotion of the WB culture of the Ghana variety among the villagers. One hundred and fifty women and men were given seeds with instructions on how to plant them. Preschool age children were examined to determine their nutritional status by anthropometrical and biochemical standards. These examinations are scheduled to be performed periodically while the mothers are encouraged to feed winged bean pods and seeds to their children. Preliminary data analysis indicated that, if judged by the anthropometrical standard of mid upper arm circumference over head circumference (*Kanawati and McLaren*, 1970) 49% of the under five are marginally malnourished and 5% suffer from severe malnutrition. It is our hope that the consumption of winged bean in families will become

frequent as this brings a badly needed additional amount of protein. Acceptance of the new culture has been satisfactory, considering the difficulties that are very likely to be encountered when trying to introduce a new food to a rural population. Green pods were easier to promote than the consumption of dry seeds. The seeds have the disadvantage of requiring to be peeled in order to loose the bitter taste and of requiring a long

**Table 9. Mineral composition of 2 varieties of winged beans grown in the Ivory Coast.**

| | Ghana | | | UPS 32 | | |
|---|---|---|---|---|---|---|
| | Pods (dried) | Seeds | Leaves (dried) | Pods (dried) | Seeds | Leaves (dried) |
| Calcium (%) | 0.67 | 0.26 | 0.64 | 0.92 | 0.36 | 0.63 |
| Magnesium (%) | 0.39 | 0.22 | 0.27 | 0.36 | 0.22 | 0.31 |
| Potassium (%) | 2.55 | 1.20 | 2.18 | 2.25 | 1.22 | 1.94 |
| Sodium (ppm) | 225 | 138 | 125 | 175 | 150 | 112 |
| Phosphorus (%) | 0.46 | 0.61 | 0.49 | 0.48 | 0.52 | 0.43 |
| Iron (ppm) | 88 | 67 | 102 | 325 | 91 | 112 |
| Copper (ppm) | 40 | 13 | 25 | 43 | 16 | 37 |
| Manganese (ppm) | 145 | 39 | 75 | 176 | 56 | 159 |
| Zinc (ppm) | 45 | 38 | 34 | 37 | 35 | 35 |

**Table 10. Vitamin content of 2 varieties of winged beans grown in Ivory Coast.**

| | Ghana | | | Papua New Guinea | | |
|---|---|---|---|---|---|---|
| | Pods (dried) | Seeds | Leaves (dried) | Pods (drued) | Seeds | Leaves (dried) |
| $\beta$ — carotene (mg) | 2.5 | traces | 15.8 | — | traces | — |
| Vitamin A (IU) | 300 | 0 | 0 | — | 0 | — |
| Vitamin $B_1$ (mg/100g) | 1.8 | 1.7 | 3.6 | — | 1.5 | — |
| Vitamin $B_2$ (mg/100g) | 1.3 | 0.45 | 2.6 | — | 0.5 | — |
| Vitamin $B_6$ (mg/100g) | 2.0 | 0.25 | 1.0 | — | 0.25 | — |
| Vitamin E (mg/100g) | 0.5 | 0.4 | 3.5 | 1.0 | — | — |
| Niacin (mg/100g) | 9.6 | 4.0 | 15 | — | 4.6 | — |
| Folic acid (ug/100g) | 62 | 63.5 | 67 | — | 51 | — |

**Table 11. Winged bean trials — scoring of PNG and Ghana varieties.**

| Characteristics | SCORE | |
|---|---|---|
| | UPS 32 | Ghana |
| Precocity of plants | 3 | 2 |
| Stalking easiness | 3 | 2 |
| Pod length | 2 | 3 |
| Number of seeds/pods | 2 | 3 |
| Weight of seeds | 2 | 3 |
| Seed yield/hectare | 1 | 3 |
| Tuber production | 1 | 2 |
| Disease resistance | 1 | 2 |
| Peeling easiness of seeds | 1 | 2 |
| Cooking time (seeds) | 1 | 2 |
| Seed tenderness after cooking | 1 | 2 |
| Taste acceptability | 2 | 2 |
| TOTAL | 20 | 28 |

1 — unsatisfactory
2 — acceptable
3 — good

cooking time. We tried several recipes which were demonstrated in courtyards. The seeds were incorporated into local dishes. Peeling of seeds was found to be easier after the seeds had been soaked in water for 48 hours. The peeled seeds were then dried in the sun. Subsequently, they were briefly parched before being pounded in a mortar like what is usually done with groundnuts. The resulting flour was used to prepare a sauce. Another recipe included whose seeds cooked in a soup with smoked fish. The people especially liked the dish in which the ground winged bean seeds were used to prepare the sauce and often could not distinguished it from the traditional groundnut preparation. Seeds from the Ghana variety were found to be easier to peel, quicker to cook (1 1/2 hrs vs. 3hr) and to have softer consistency after cooking.

Table II lists a comparison of the two varieties on several criteria and it can be seen that based on these criteria, the Ghana variety outscores the PNG variety.

In conclusion, the result of this first year of promotion of winged bean culture in the Ivorian rainy forest has been encouraging. It gives hope for a successful second year campaign which will be conducted on a larger scale involving the whole village.

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# Utilization of Winged Bean for Thai Traditional Consumption

*Amara Bhumiratana and Prateap Rachapaetayakom*[1]

## INTRODUCTION

The winged bean (*Psophocarpus tetragonolobus*) is a tropical crop popularly known to the Thai through its young edible pods. Its young pods are used as a green vegetable that can be eaten raw or cooked along with chilli paste, dressed salad, in sour soup, etc. Due to its unique characteristics in fixing nitrogen from the air and in changing it into utilizable nitrogen compounds, agriculturists and nutritionists have started to look in to the possibility of developing winged beans into an economic crop for tropical countries. It has been known for sometime that the winged bean is one of the most useful crops since practically every part of it, with exception of its stem, is edible. In addition, the winged bean is a crop of high nutritive value, especially in protein.

### Botany of the Winged Bean

The winged bean belongs to the family Leguminosae, Genus *Psophocarpus*. Among the crops in this genus, the winged bean (*P. tetragonolobus* (Linn.) DC) is the only cultivated crop. Another cultivated species is *P. palustris* Desv., which is cultivated by natives in Ghana and neighbouring countries as a food crop whenever the problem of food shortage arises. Other species, growing wild in tropical Africa, have not been cultivated at all.

### The Winged Bean Varieties

The winged bean is a crop of great variation. In Papua New Guinea where the inhabitants grow the winged bean as a staple crop, it appears to have a total number of 122 strains. In Burma, Indonesia and the Philippines, it was reported that the characteristics of the winged bean are different from one another. It is believed that Thailand might possess as many strains as those found in Papua New Guinea.

The variations of the winged bean can be summarized as follows

1. The color of the pods can be green, light purple or dark purple. In addition, the color of the edges are also different, some have yellow patches, some may have purple edges, etc.
2. The shape of a pod displays slight variation. On a cross section, it appears that the pod shape is generally rectangle, having the four edges as the extension of the diagonal lines. However, some have very flat pods while others have the flat portion on the crack sides.
3. The color of the seeds vary greatly. They are either pale, light brown, dark brown or black and occasionally also have color patches on seed coats.
4. Pod peels range from smooth to very rough. Besides, there also exist quantitative features which may be regarded as varietal differences such as the growth habit, pod length, the number of seed/pod, the number of the plant, seed weight, the yield of the dry seed per plant and per rai, ratio of the seed weight to the whole pod weight, etc.

The winged bean grown in Thailand is in majority the varieties whose young pods are picked for consumption. In foreign countries, there exist special varieties producing either only tubers or both tubers and pods. All the existing varieties in the world are of the climbing type requiring bean poles in order to produce the highest yield. At present many attempts have been made in order to obtain a bushy type which requires no staking support. As only 60 years ago, the soybean varieties were of the climbing type, but nowadays it is all of bushy type.

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Currently a Thai winged bean research group is studying the characteristics of all the winged bean varieties collected (Table 1) and have selected promising ones for certain purposes, to be grown in the plain region and in the highlands of the northern region. Table 2 is a list of foreign collections.

**Table 1. Collection of Thai winged bean varieties.**

| No. | Variety* | Strain** | Seed Appearance | 20-Seed Weight (g) |
|---|---|---|---|---|
| 1 | Phuket 01 | 01 | Light brown | 4.9 |
| 2. | Phuket 02 | 01 | very light brown | 4.8 |
| | | 02 | light brown | + |
| | | 03 | dark brown | + |
| | | 04 | color patches | + |
| 3. | Chainat 01 | 01 | + | 5.1 |
| | | 02 | + | + |
| | | 03 | + | + |
| | | 04 | + | + |
| | | 05 | + | + |
| | | 06 | + | + |
| 4. | Songkhla 01 | 01 | dark brown | + |
| 5 | Phetchaburi 01 | 01 | dark brown | |
| | | | round, shiny | 8.7 |
| 6. | Phetchaburi 02 | 01 | light brown, round | 7.7 |
| 7. | Phetchaburi 03 | 01 | light and dark brownish patches | 5.3 |
| 8. | Chonburi 01 | 01 | light brown, rough | 5.2 |
| | | 02 | brown | 5.6 |
| | | 03 | dark brown | 7.2 |
| 9. | Chumphon 01 | 01 | red brown, rough, big | 8.2 |
| 10. | Yala 01 | 01 | very dark brown, round | 4.7 |
| | | 02 | red brown, round | 5.2 |
| | | 03 | dark brown, round | 4.5 |
| | | 04 | light brown, rought coat | 4.8 |
| | | 05 | Pale, round | 5.4 |
| 11. | Yala 02 | 01 | dark brown, round | 5.5 |
| | | 02 | redish brown, round | 5.0 |
| | | 03 | light brown, rough | 4.4. |
| | | 04 | pale, round | 5.8 |
| 12. | Nakhon Sawan 01 | 01 | dark green, round | 8.0 |
| | | 02 | light brown, round | 7.3 |
| | | 03 | dark brown, round | 8.2 |
| | | 04 | very light brown, round | 7.2 |
| 13. | Nakhon Sawan 02 | 01 | dark green, round and oblong | 6.4 |
| | | 02 | very dark brown | 5.6 |
| | | 03 | dark brown | 6.4 |
| | | 04 | brown | 6.1 |
| | | 05 | light brown | 5.6 |
| 14. | Nakhon Sawan 03 | 01 | dark green, round and oblong | 6.4 |
| | | 02 | very dark brown, round, angle | 6.2 |
| | | 03 | dark brown | 6.1 |
| | | 04 | brown, round, flat | 6.3 |
| | | 05 | light brown, round flat | 6.3 |
| 15. | Nakhon Sawan 04 | 01 | dark green, round | 6.1 |
| | | 02 | brown and dark green | 8.0 |
| | | 03 | brown | 6.7 |
| 16. | Nakhon Sawan 05 | 01 | dark green, round, big | 8.2 |
| | | 02 | brown | 5.5 |
| | | 03 | light brown | 6.0 |
| 17. | Nakhon Sawan 06 | 01 | very dark brown, round | 5.8 |

**Table 1.** *continued...*

| No. | Variety* | Strain** | Seed Appearance | 20-Seed Weight (g) |
|---|---|---|---|---|
| | | 02 | brown, round | 5.8 |
| | | 03 | light brown, round and angle | 5.4 |
| 18. | Nakhon Sawan | 01 | very dark brown | 5.6 |
| | | 02 | brown | 5.1 |
| | | 03 | light brown | 7.8 |
| 19. | Nakhon Sawan | 01 | dark green and dark brown, round | 6.9 |
| | | 02 | dark green and brown | 7.2 |
| | | 03 | dark brown | 7.2 |
| | | 04 | brown | 6.4 |
| | | 05 | light brown | 7.6 |
| 20. | Nakhon Sawan 09 | 01 | dark green, round and rough | 6.0 |
| | | 02 | dark brown, round and oblong | 6.3 |
| | | 03 | brown, rough | 5.9 |
| 21. | Nakhon Sawan 10 | 01 | dark green, round, big | 9.8 |
| | | 02 | dark brown and dark, round, big | 8.2 |
| | | 03 | redish brown | 8.5 |
| | | 04 | light brown | 8.9 |
| | | 05 | very light brown | 8.5 |
| 22. | Nakhon Sawan 11 | 01 | dark green, round, oblong, small | 4.1 |
| | | 02 | brown and dark, small | 5.2 |
| | | 03 | red brown, small | 4.8 |
| | | 04 | brown, small | 4.9 |
| 23. | Nakhon Sawan 12 | 01 | dark brown and black | 6.0 |
| | | 02 | brown | 6.2 |
| 24. | Nakhon Sawan 13 | 01 | light brown | 7.0 |
| 25. | Nakhon Sawan 14 | 01 | dark green | 7.2 |
| | | 02 | dark brown and black | 7.5 |
| | | 03 | brown | 7.1 |
| 26. | Nakhon Sawan 15 | 01 | dark brown | 7.3 |
| | | 02 | brown | 7.0 |
| | | 03 | light brown | 7.4 |
| 27. | Nakhon Sawan 16 | 01 | dark | 5.2 |
| | | 02 | dark green | 6.3 |
| | | 03 | dark brown | 6.3 |
| | | 04 | light brown | 6.2 |
| 28. | Nakhon Sawan 17 | 01 | dark green | 6.5 |
| | | 02 | brown and black | 5.2 |
| | | 03 | dark brown | 5.7 |
| | | 04 | light brown | 6.0 |
| 29. | Nakhon Sawan 18 | 01 | dark brown, flat | 5.3 |
| 30. | Saraburi 01 | 01 | brown and black | 6.7 |
| 31. | Sakon Nakhon 01 | 01 | dark green and black, small | 5.4 |
| 32. | Sakon Nakhon 02 | 01 | dark brown and black | 7.0 |
| 33. | Sakon Nakhon 03 | 01 | dark green, small | 4.6 |
| | | 02 | dark brown | 4.8 |
| | | 03 | light brown, small | 3.6 |
| 34. | Sakhon Nakhon 04 | 01 | dark green | 5.8 |
| | | 02 | dark brown | 5.2 |
| | | 03 | brown | 6.0 |
| | | 04 | light brown, small | 4.8 |
| 35. | Pathum Thani 01 | 01 | dark brown and black | 6.7 |
| | | 02 | dark brown | 7.0 |
| | | 03 | brown | 6.0 |
| 36. | Chiang Mai 01 | 01 | dark green, round, big | 8.7 |
| | | 02 | brown, round, big | 6.8 |

**Table 1.** *continued*. . .

| No. | Variety* | Strain** | Seed Appearance | 20-Seed Weight (g) |
|---|---|---|---|---|
| | | 03 | dark brown, round, big | 6.3 |
| | | 04 | pale, round, big | 9.2 |
| 37. | Chiang Mai 02 | 01 | dark green and dark brown | 6.1 |
| | | 02 | dark green and brown | 6.2 |
| | | 03 | light brown | 5.3 |
| 38. | Chiang Mai 03 | 01 | dark green and brown | 6.7 |
| 39. | Chiang Mai 04 | 01 | pale, round, big | 7.6 |
| 40. | Chiang Mai 05 | 01 | pale, round | 6.2 |
| 41. | Chiang Mai 06 | 01 | pale, round | 7.6 |
| 42. | Chiang Mai 07 | 01 | dark green and dark brown | 7.1 |
| 43. | Rachaburi 01 | 01 | dark, round | 6.2 |
| | | 02 | very dark brown, round | 7.0 |
| | | 04 | brown, round | 7.4 |
| | | 05 | light brown, round | 6.1 |
| | | 06 | pale, round | 5.5 |
| 44. | Phrae 01 | 01 | dark brown, round | 5.8 |
| 45. | Phrae 02 | 01 | dark brown, round | 6.5 |
| 46. | Phrae 03 | 01 | dark, round, shiny | 7.4 |
| | | 02 | dark brown and black, round, big, shiny | 8.2 |
| | | 03 | dark brown, round, big, shiny | 8.6 |
| 47. | Phrae 04 | 01 | brown, round, big | 7.9 |
| 48. | Phrae 05 | 01 | pale, round | 4.1 |
| 49. | Phrae 06 | 01 | brown and black | 5.2 |
| 50. | Phrae 07 | 01 | brown, round | 5.8 |

*Named after provinces from which the seed was collected.
**Classified by use of seed color and appearance.
+ Not recorded.

**Table 2.** Collection of foreign varieties.

| No. | Variety | Source | 20-Seed Weight (g) |
|---|---|---|---|
| 1. | (BOR) 1086 | Dr. S. Sastrapradja Bogor, Indonesia | — |
| 2. | (BOR) 902 | Bogor, Indonesia | — |
| 3. | (HAW) — | Dr. R. A. Hamilton, Honolulu, Hawaii | — |
| 4. | USP 2 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | — |
| 5. | USP 31 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 3.6 |
| 6. | USP 33 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 5.1 |
| 7. | USP 38 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 5.8 |
| 8. | USP 45 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 5.4 |
| 9. | USP 46 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 5.5 |
| 10. | USP 47 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 4.9 |
| 11. | USP 51 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 3.4 |
| 12. | USP 53 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 5.3 |
| 13. | USP 59 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 6.2 |
| 14. | USP 60 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 6.9 |
| 15. | USP 61 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 5.5 |
| 16. | USP 62 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 5.5 |
| 17. | USP 66 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 5.6 |
| 18. | USP 67 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 6.4 |
| 19. | USP 71 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 3.7 |
| 20. | USP 78 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | — |
| 21. | USP 80 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 6.0 |

**Table 2.** *continued...*

| No. | Variety | Source | 20-Seed Weight (g) |
|---|---|---|---|
| 22. | USP 89 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 5.3 |
| 23. | USP 99 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 6.8 |
| 24. | USP 102 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 3.5 |
| 25. | USP 103 | Dr T.N. Khan, Port Moresby, Papua, New Guinea | 4.7 |
| 26. | USP 111 | Dr T.N. Khan, Port Moresby, Papua, New Guinea | 5.2 |
| 27. | USP 112 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 7.2 |
| 28. | USP 113 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 7.5 |
| 29. | USP 115 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 6.0 |
| 30. | USP 121 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 6.5 |
| 31. | USP 122 | Dr. T.N. Khan, Port Moresby, Papua, New Guinea | 6.1 |
| 32. | K 11 | Dr. H.H. Bryan, Homested, Florida | 5.4 |
| 33. | K 12 | Dr. H.H. Bryan, Homested, Florida | 4.9 |

## CULTIVATION

The winged bean can be cultivated and flowers everywhere in Thailand. Although the winged bean is fond of moisture, it is able to tolerate drought considerably and can be planted throughout the year if good irrigation system is provided during the dry season. It can be grown in soils with less organic matter which is generally found in the north-eastern region and in the slope lands and highlands in northern Thailand.

## PLANTING

Planting should be made during the earlier part of the wet season. As soon as the soil is already prepared, 3 seeds are dropped into a hole (about 2 to 3 cm. deep). If grown for young pods, the spacing of 120 cm. between rows and 60 cm. between plants is recommended. There are some who suggest 60 to 75 cm. distance between rows and 55 to 60 cm. between plants. For ripe seed production, the planting distance is 60 × 60 cm. or 100 × 100 cm. When grown for tubers, the spacing should be closer, e.g. 7.5 to 15 cm. between holes.

Using the method of Dr. Narong Chomchalow (ASRCT), high survival rate is ensured. Seeds, are soaked in water for 4 to 5 hours and covered with tissue paper. As soon as the seeds start to germinate, they are directly transplanted to the prepared soil.

The winged bean can be grown and used in various applications. The pattern of cultivation must be in accordance with its utilization. The most practical methods as adapted both in Thailand and abroad are as follows:

### Growing in the Backyard Garden

This method is popularly practiced in Thailand and throughout Southeast Asia. The traditional practice has allowed the winged bean varieties to survive to this date and is considered a method that should be promoted in order to produce young leaves, tops, flowers and young pods for family consumption. These young pods can be ready for picking at about 10 weeks after planting. Before this period young leaves, tops and flowers should not be harvested because it will retard plant growth. A special feature of the winged bean is that when it is fully grown, flowers and pods are always available. Grown up plants yield a lot of young pods. It can thus serve as a source of additional income. When young pods are not picked, the plant produces fewer pods. Very old plants should be removed and replanted. The time for replanting depends on the plant's condition, but generally this should occur 8 months after planting. When the plants are removed, tubers should be dug for consumption. If not dug, a new crop will start growing upon the onset of the rainy season.

If the winged bean is to be planted in a backyard garden, it should be prevented from flooding and the plot should be fully exposed to sunlight. While the winged bean thrives in less fertile soil, it grows much better in good soil and gives better yield. Fertilizer application is advisable and good seedbed preparation or even ridge planting may be required to avoid occasional flooding.

### Commercial Planting

Although commercial cultivation of the winged bean is not existing in Thailand, in foreign countries

such as Papua New Guinea and Burma, commercial cultivation brings good income to the growers. This commercial cultivation can be divided into the following types:

1. **Cultivated for young pods.** The planting area should be close to the main market. Ridge planting may be required.
2. **Cultivated for ripe seeds.** At present, no winged bean has been supplied to oil factory, animal feeds and human foods factories. Analytical results on the nutritive value of the winged bean indicates that in the future, the seeds may be in demand for these uses. The important problems to be considered are the yield, the cost of production and price.
3. **Cultivated for tubers.** If the Thai people favourably accept the winged bean tubers like the people of Papua New Guinea and Burma do, growing winged bean for tubers will become vital like jam bean *Pachyrrhizus erosus*, L. or sweet potato *Ipomea batatas*, Lamk. This will be a new cash crop for the Thai farmers.

**Cultivated as Cover, Folder, and Manuring Crop**

These three methods of cultivations are generally similar, but different in purpose, however, all of them need no beanpoles. Soil preparation is much easier since seedbed or ridge preparation is discarded. The soil is prepared in the same manner as for other field crops prior to drilling winged bean seeds at a given spacing which is for instance 1 × 1 meter. The winged bean is also good for covering soil, animal feeds and concurrently for enriching the soil. Replanting is not necessary because shoots will naturally develop from the tubers in the coming wet season. If the winged bean is cultivated as manuring crop, it is ploughed under when it flowers prior to cultivation of main crops.

## GROWING PRACTICE

The winged bean (*Psophocarpus tetragonolobus*), should be cultivated only in wet season except where the irrigation system is adequately developed. The growth and development of the winged bean is slow at the first stage. Thus, well prepared soil is necessary to control weeds. Generally the winged bean can be cultivated in every poor soil. As they can fix nitrogen from air, the application of nitrogen fertilizer is not necessary. However, for commercial cultivation the application of chemical fertilizer substantially increases the yield. In growing the winged bean for young pods and pipe seeds, it is necessary to make bean holes to support its climbing habit. The material recommended for making bean holes is "mai-ruak," a thornless type of bamboo of 2 meters long, about 3 to 4 cm. diameters.

It was reported that staking the winged bean increases pod and seed yield. The quality of the pod is also better as compared with these from creeping winged bean.

The winged bean is less damaged by diseases and insects. However, various reports indicated some evidences of infestation. The disease is generally caused by fungi such as crown rot, false rust (*Synchytrium psophocarpi* (Rac.) Groumann) and leaf spot. In West Africa, it was found that *Synchytrium psophocarpi* damaged young tops, inflorescences and young pods, but was easily controlled by spraying with fungicides. Mostly these diseases broke out when the weather was warm and humid.

## HARVESTING

**Young Pods and Seeds**

The plants will flower at about 10 weeks after planting. Pods are developed after pollination of flowers and the pods are just good in quality for consumption at about 2 weeks old. But at 3 weeks old, the pods are fibrous and unsuitable for consumption. The seed will become ripe within 6 weeks (after pollination). The plants carry on producing pods consecutively so far as the soil moisture is prevailing. The yield will greatly decrease when the plants are so old that it does not pay to keep them.

**Tubers**

The tuber type starts to produce tubers at the age of two months. The tubers can be harvested at the age of 4 to 8 months old after the pods have been harvested and when the tubers are 2 to 4 cm. in diameter and 8 to 12 cm. in length. If the plants are pod seed types, the tubers will not be big unless they are so old, perhaps 10 months old. Heavy decapitation of the flowers and top induce tuber formation.

**Yields**

As the winged bean has not been cultivated in commercial scale, data on the yield found in reports are mostly collected from experimental plots and are not necessarily in agreement with that of the commercial cultivation. Moreover, the yields of the young pods throughout the plant life have not been reported previously.

## VALUE OF WINGED BEAN

The winged bean is a crop of high nutritive value, especially in protein, which is often short in moist tropical regions where winged bean is best grown. Among the crops grown for food only a few of them have all their parts edible. The winged bean is one of those few crops

The winged bean is not only relished by humans. It is also good as animal feed because of its higher protein content than other crops (the above ground parts have 25.5% protein on dry weight basis). In the case the winged bean is grown for dry seed, dry stems can be prepared as mixed animal feed when sun dried and ground or made as silage for feeding the animal in time of feed shortage

The winged bean is a typical leguminous plant which is able to fix nitrogen from the air to a form which can be easily utilized by plants. Thus, it helps to increase soil fertility.

**Chemical Composition of Winged Bean**

The dried winged bean seed contains approximately 17% fat. Oil extract from dried winged bean seeds is an excellent cooking oil, because it contains a high quantity of unsaturated fatty acid (about 70%) and linoleic acid (27.2 to 27.8%). The most unsaturated fatty acid in winged bean oil is oleic acid (32.3 to 39.0%). Other important substances beside fatty acid are $\alpha$ and $\beta$ — tocopherol in high quantity, 125.9 mg which is higher than soy bean oil or corn oil. They also act as anti-oxidants.

Dried winged bean seed, tubers and above ground parts contain 34, 25 and 26% protein, respectively. Protein extracted from dried, mature winged bean seed has amino acid composition similar to soy bean seed. It is one of the best vegetable proteins although the amount of sulphur containing amino acid is low. Lysine content in winged bean protein is very high and can be used for supplementation in cereal food where lysine is a limiting amino acid.

**Nutritive Value of Winged Bean Protein**

The dried winged bean seed has similar chemical composition to the soy bean. It has been shown that PER and NPU are 2.14 and 55.0 respectively when rats are fed with food containing 10% winged bean protein. These values can be increased up to 2.70 and 65.7 respectively by the addition of corn in the ratio of 1.0 to 2.7. The food which used winged bean protein was higher protein than ground nut. The results indicated very striking similarity in nutritive value between winged bean and soy bean. Thus, the use of food supplement with winged bean protein to produce high protein foods for combatting protein malnutrition in humans has a great potential.

**Toxicity of Bean**

It is commonly known that different kinds of raw bean contain toxic substance(s) (*haemagglutinin, trypsin, cyanide*) which may give the toxic effect when consumed. Experiments on feeding rats with food containing raw dried matured winged bean seed showed that 50% of the rats die after feeding for 28 days. Further experimentation indicated that a substance extracted from winged bean can react with the red blood cell of humans in every blood group, except the blood group "Bombay" which lacks the H-antigen in red blood cells.

The trypsin inhibitor which is extracted from raw, dried mature winged bean seed reduces the efficiency of protein food. It stops the activity of trypsin in digestion of protein. However, this substance can be destroyed by using moist heat treatment at 130°C for 10 minutes or by boiling for 30 minutes after soaking in water for 10 hours. Dry heat treatment cannot completely destroy this inhibitor.

Winged bean stem and seeds also contain about 5% Hydrogen cyanide which is twice as much as in pea and approximately a third of the amount contained in safe varieties of lima bean.

**Utilization of Winged Bean**

Shortage in protein food still exists in both developing countries, majority of which are located in the humid tropical zone. The winged bean is one of the crops that grow well in these countries, although it has been cultivated only in backyard gardens. The reason for this is that not too many people realize its value. Moreover, the requirement of staking for production of young pods and seed limits winged bean cultivation

due to labour cost and other expenses. At present, many attempts have been made to develop a bushy winged bean variety so that staking can be eliminated. In commercial cultivation, the problems in addition to staking, include marketing of young pods, seeds and tubers. The market for young pods and tubers is limited for fresh products but the cultivation for ripe seeds is potentially possible. Target markets will be the vegetable oil, animal feed, and human food industries.

Winged bean has been used as food for a long time by the Thai and the people from the Southeast Asian region. Its young pods are used as green vegetable which can be eaten raw or cooked along with chilli paste, dressed salad, sour soup and other Thai traditional food. Young seed has not been used for food by the Thai although it can be eaten similar to pea. Mature seeds possess thick seed coat and thus require soaking over night or boiling for 2-3 hours before eating. The mature seeds can also be roasted, just like ground nuts.

In Indonesia, roasted matured seed is used as snack foods. Inspite of the fact that winged bean has never been the traditional food for people in Ghana, the matured winged bean seed after soaking and boiling will give delicious taste and is well accepted as food by the people. Winged bean tubers have been used as delicious food for the people in Burma and the natives of Papua, New Guinea. Flowers and tops have also found their way into various dishes. The tubers can be consumed in fresh form, boiled or roasted or the skin may be peeled and salt is added to enhance the taste and flavour.

In Thailand, the development as well as the utilization of the winged bean are certain to receive excellent support in view of the following reasons.

1 **As a source of daily food.** In the nutritional sense the winged bean is one of the best plant proteins. Ease of cultivation under Thailand conditions and longer yielding period make it superior to other crops.

2 **As a source of animal feed.** Every part of the wingeu bean, including stem and leaves either fresh or dried, can be processed into animal feed in view of their high protein content.

3 **As a source of income.** Though young pods are available in the local market, the planting for young pods for conventional commercial purposes has not be expanded, owing to the limitation of market. However, the cultivation of winged bean for ripe seeds can be promptly encouraged to supply the vegetable oil, food, protein food, and animal feed industries. Its excellent nutritive value and high yielding ability makes the winged bean one of the most potentially important economic crops of the Thai farmers in the very near future.

At the moment, many Thai researchers are engaged in developing new products using dried mature winged bean seeds and young bean seeds. Attempts are also being made in the production of milk and protein food from matured winged bean seeds and in the utilization of young bean seed for canning. Two major obstacles which need immediate attention to promote the winged bean are pureline seed production and improvement of strains. It appears at present, not only in Thailand but also in other countries, that attention has to be focused on increasing production of seeds. The development of bushy types will likewise be of great help in promoting the production of winged bean.

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# Fermentation of the Winged Bean Seeds

*Indrawati Gandjar*[1]

**In Indonesia, the winged bean or *Psophocarpus tetragonolobus* 617 DC is popularly known as "kecipir" or Jaat or "botor". Various parts of the plant are utilized by the people. The young pods and leaves are used as vegetables, while the ripe mature seeds are roasted or boiled and consumed as snack. As many other leguminous seeds can be fermented into tempe, a study was initiated on the fermentation of the dry mature seeds of the winged bean to examine the possibility of obtaining a product similar to tempe from soybean which is well known in Indonesia.**

**Several *Rhizopus* strains that were examined proved to be able to ferment the seeds into a tempe—"tempe kecipir". *R. oryzae* R 128 in particular was selected in the study of the fermentation process. During fermentation an increase in the content of the amino nitrogen, total acids and soluble carbohydrates and a decrease in the total solids was observed.**

**Analysis of the nutrients and amino acid composition of the raw seeds and of the "tempe kecipir" revealed that this can be recommended as an alternative cheap protein source beside tempe from soybeans, especially for people living in the areas where the production of the winged bean seeds is abundant.**

**Twenty three out of the 25 recipes made from "tempe kecipir", which were examined by a panel, proved to be acceptable as a side dish with rice.**

## INTRODUCTION

The winged bean has several nutritional advantages over the soybean, because all parts of it can be eaten. The seeds has a protein content of 29.8-37.4%; fat 15.0-20.4%; carbohydrate 31.6-28.0% (fresh weight). Since its rediscovery in 1975 by the U.S. National Academy of Sciences, research on the winged bean has been actively pursued in many countries (Levy, 1977). Lubis (1977) recommended that besides the common legumes in Indonesia more attention should now be paid to this otherwise less known legume.

In Indonesia, the winged bean is popularly known as "kecipir". Other local names are "keceper", "jaat" and "botor" (Heyne, 1950). The young pods and leaves are utilized as vegetables and the ripe seeds are roasted or cooked and consumed as snack. Only in a very few cases are mature seeds fermented into a kind of "tempe".

Leguminous seeds can be fermented into a tempe which can be served as a side with the staple food. For instance, soybeans are fermented into "tempe kedele", *Mucuna pruriens* seeds into "tempe benguk" (Gandjar, 1977); *Leucaena glauca* seeds into "tempe lamtoro"; and *Dolichos lablab* seeds into "tempe koro wedus" (Yutono, personal communication, 1974).

This study dealt with the fermentation of the dry mature seeds of winged bean into "tempe kecipir" by the *Rhizopus* molds. The results are important in determining whether this kind of tempe could be recommended as an alternative protein source beside tempe from soybeans, especially in regions where the production of the winged bean seeds is abundant.

## MATERIALS AND METHODS

Dry mature seeds of the winged bean with a brown seedcoat harvested in August 1975 were obtained from a market in Sumenep (Madura island, Eastern Java).

*Rhizopus* strains were obtained from the collection of the Nutrition Research and Development Center in Bogor. The strains were maintained on PDA slants at 5°C.

### The Fermentation Process

The seeds were washed, boiled for 60 minutes and removed from the seedcoat. The cotyledons were

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soaked for 24 hours in water, cut into small parts and sterilized for 30 minutes at 121°C.

The *Rhizopus* strains were transferred to fresh PDA slants and incubated for 7 days at 30°C before they were used. Five ml of distilled water was added to each slant to make a spore suspension. One ml of this suspension was used to inoculate 100 g of sterilized substrate. Experiments were also carried out with a commercial *ragi tempe* as inoculum. The *ragi tempe* was obtained from the Bandung Institute of Technology and is widely used for the manufacture of soybean tempe (0.1, 1% w/w).

The inoculated substrate was placed in petri dishes and incubated at 30°C. The fermentation process was stopped when the substrate was bound together by mycelium of the mold forming a compact cake which can easily be removed from the petri dish.

The nutrient composition of the seeds and tempe, including their HCN and the amino nitrogen contents were analyzed according to the methods described in AOAC (1970). The soluble carbohydrates was determined by the anthron method. The amino acid composition of the seeds and of the tempe were analyzed with A high speed Amino Acid Analyzer (Yanagimoto LS 5) after hydrolyzing with 6 N HCL (Yanagimoto, 1974; Spackman *et al.* 1958). Only trytophan was analyzed using the method of Spies and Chambers (1949).

The Net Protein Utilization (NPU) of "tempe kecipir" was determined with the procedure of Miller and Bender (1955) and Bender (1963) using white albino weaning rats (Wister strain) as experimental animals.

Twenty five recipes made from "tempe kecipir" were examined by a special panel of the Division of Food Preparation and Evaluation of the Institute. The ingredients used were the same as used for the preparation of soybean tempe recipes.

## RESULTS AND DISCUSSION

In general *Rhizopus* species were able to cake the cotyledons of the winged bean into a tempe within 24 to 30 hours (30°C). A good product was obtained within 30 hours (Table 1). The beany smell could still be detected in the product after 24 to 30 hours, but disappeared after 48 hours. The same results were obtained if *ragi tempe* was used as inoculum.

*Rhizopus oryzae* Went and Geerlings R 128 was selected for the fermentation study. The first mycelial growth was visible after 16 hours and then faster growth was observed. Within 24 hours most parts of the

**Table 1. The fermentation of *Psophocarpus tetragonolobus* seeds by *Rhizopus* strains.**

| Code | *Rhizopus* strain | Production of "tempe kecipir" 24 | 30 (hours) | 48 |
|---|---|---|---|---|
| 25 | *R. oligosporus* | + + + | + + + | + + + + |
| 31 | *R. oryzae* | + + | + + + | + + + |
| 32 | *R. oligosporus* | + + | + + + | + + + + |
| 36 | *R. oryzae* | + + + | + + + | + + + + |
| 45 | *R. arrhizus* | + + | + + | + + + |
| 104a | *R. oligosporus* | + + | + + | + + + |
| 116 | *R. oligosporus* | + + + | + + + | + + + + |
| 128 | *R. oryzae* | + + + | + + + + | + + + + |
| 112.07 | *R. oryzae* | + + + | + + + + | + + + + |
| 264.60 | *R. cohnii* | + + + | + + + | + + + |
| 110.17 | *R. arrhizus* | + + + | + + + + | + + + + |
| 127.08 | *R. oryzae* | + + + | + + + + | + + + + |
| 348.49 | *R. oryzae* | + + + | + + + + | + + + + |
| 385.34 | *R. achlamydosporus* | + + + | + + + + | + + + + |
| 324.35 | *R. oligosporus* | + + + | + + + | + + + + |
| 256.28 | *R. chinensis* | + + | + + | + + + |

**+ — a few mycelium, no caking of substrate**
**+ + — more mycellium, no caking of substrate**
**+ + + — good growth of the mold, compact cake, sporangia present**
**+ + + + — very good growth of the mold, compact cake, black sporangia present.**

substrate was covered by mycelium of the mold. A few hyaline sporangia were observed together with beany smell. After 30 hours, the mycelial mat became denser. While the amount of sporangial heads, mostly black, increased enormously.

Some biochemical changes that occurred in the substrate during the fermentation process are presented in Table 2. The total solids decreased, indicating the decomposition of the substrate into soluble compounds. A good product was obtained after 30 hours of fermentation. At that phase, the amino nitrogen increased about 15 times the content in the substrate before fermentation. The total acids and soluble carbohydrates showed a threefold and twofold increase respectively. After 48 hours, the beany small could hardly be detected. Prolonging the fermentation time resulted in the formation of $NH_3$ due to the deamination of amino acids. This tempe did not produce a specific aroma like "tempe benguk" (Gandjar, 1977)

Table 2. The amino N and soluble carbohydrate content during the fermentation of "tempe kecipir" with *R. oryzae R128*.

| Fermentation period (hours) | pH | 100 gram dry substrate | | | |
|---|---|---|---|---|---|
| | | Total solids (g) | Amino nitrogen (mg) | Total acids as lactic acid (mg) | Soluble carbohydrate as glucose (g) |
| 0 | 6.51 | 43.5 | 29.9 | 785.8 | 0.11 |
| 24 | 6.89 | 42.2 | 330.5 | 2166.1 | 0.21 |
| 30 | 7.03 | 41.0 | 461.3 | 2770.2 | 0.22 |
| 44-48 | 7.40 | 40.5 | 582.6 | 3580.6 | 0.29 |

Analysis of the nutrients of the raw seeds of the winged bean and of the "tempe kecipir" are presented in Table 3. The absence of vitamin C in the tempe is probably due to the heat treatment during the preparation of the substrate.

Table 3. The nutrient content of tempe kecipir.

| Nutrients in 100 gram | Raw seeds of *P. tetragonolobus* | "Tempe kecipir" |
|---|---|---|
| Water (g) | 9.5-10.4 | 58.2 |
| Ash (g) | 4.2 | 1.4 |
| Fat (g) | 16.9 | 8.0-10.0 |
| Protein (g) | 34.4 | 14.5-17.5 |
| Carbohydrate (by difference) | 34.1 | 12.9-17.9 |
| Fiber (g) | 10.7 | 1.9 |
| Ca (mg) | 468 | 186 |
| P (mg) | 181.8 | 177.2 |
| Fe (mg) | 6.8 | 2.2 |
| Vitamin C (mg) | 3.5 | 0 |
| Thiamin (mg) | 0.3 | 0.2 |
| Calorie | 426.1 | 211.6 |
| HCN (mg) | negative | — |

The amino acid composition of the seeds and the tempe can be seen in Table 4. After fermentation, the composition of some amino acid, increased while others decreased. The total amino acids and total essential amino acids in the seeds were 6243 mg/g N and 2580 mg/g N respectively, while that in the tempe was 5940 mg/g N and 2384 mg/g N respectively. The decrease is probably due to the formation of non-protein compounds among other vitamins. No cystine could be detected during this study. It might have been destroyed during the hydrolyzing process. The National Academy of Sciences (1975) reported that the cystine content of the winged bean is 1.6 to 2.6 g/100 g protein. The composition of the amino acids in the soybeans and raw

mature winged bean seeds did not differ significantly. However, a slight difference occurred in the fermented products. This is probably due to the different treatments (soaking, boiling, dehulling) of the seeds before inoculation.

**Table 4.** The amino acids (mg g N, dry weight) *of Psophocarpus tetragonolobus* seeds and of "tempe kecipir".

| Amino acid | *P. tetragonolobus* seeds | Tempe kecipir | Soybean | Soybean tempe |
|---|---|---|---|---|
| Isoleucine | 263 | 255 | 296 | 182 |
| Leucine | 506 | 510 | 484 | 356 |
| Lysine | 488 | 294 | 356 | 269 |
| Methionine | 58 | 60 | 69 | 52 |
| Cystine | 54 | 46 | 54 | 46 |
| Phenylalanin | 321 | 340 | 309 | 267 |
| Tyrosine | 281 | 262 | 202 | 160 |
| Threonine | 294 | 300 | 258 | 195 |
| Tryptophan | 104 | 100 | 72 | 59 |
| Valine | 265 | 263 | 298 | 183 |
| Arginine | 283 | 215 | 442 | 320 |
| Histidine | 176 | 150 | 144 | 118 |
| Alanine | 296 | 330 | 273 | 245 |
| Aspartic acid | 751 | 756 | 789 | 588 |
| Glutamic acid | 1080 | 1034 | 1444 | 990 |
| Glycine | 268 | 260 | 265 | 209 |
| Proline | 449 | 425 | 276 | 247 |
| Serine | 360 | 386 | 332 | 258 |
| Total essential amino acids | 2580 | 2384 | 2398 | 1769 |
| Total amino acids | 6243 | 5940 | 6363 | 4744 |

The net protein utilization of "tempe kecipir" was carried out with young weanling albino rats (wistar strain) under standardized conditions. The NPU standard ($NPU_{st}$) values can be seen in Table 5. In general the $NPU_{st}$ for grain legumes are within the range of 40 to 55%, with the highest value, i.e., 55 for soybean protein (Lie et al. 1976). Lie and Oey (unpublished data) found various soybean tempe values within the range

**Table 5.** The $NPU_{st}$ of tempe kecipir and other tempes.

| Sample | NPU | | |
|---|---|---|---|
| | Individual values | X | Reference |
| "Tempe kecipir" | 48, 51, 55, 51 | 51 | |
| "Tempe benguk" (1) | 51, 50, 48, 55 | 51 | 1) |
| "Tempe benguk" (2) | 50, 51, 48 | 50 | 2) |
| Soybean tempe | | 50-60 | 3) |
| Soybean | | 55 | 4) |
| Peanut | | 52 | 4) |
| Cowpea | | 47 | 4) |
| Green gram | | 42 | 4) |
| Kidney bean | | 40 | 4) |

[1]Gandjar, 1977.
[2]Gandjar, unpublished data.
[3]Lie and Oey, unpublished data.
[4]Lie *et al.* 1976.

of 50 to 60%. Gandjar (1977) found for "tempe benguk," the tempe from *Mucuna pruriens* seeds, $NPU_{st}$ values of 48 to 55%. From this biological values of "tempe kecipir" which are in the range of the biological values of soybean tempe and of "tempe benguk", it is possible to use this tempe as an alternative protein source beside soybean tempe.

Twenty five recipes were prepared from "tempe kecipir" and the acceptability was tested by a special panel of the Institute. The ingredients used were mostly onion, garlic, chili, pepper, ginger, coconut milk, and coriandum. Twenty-three out of the 25 recipes were found to be accepted as a side dish with the staple food.

Until, today, the production of soybean, peanut and mungbean has not reached the expected target of production considering their importance in the Indonesian diet. It is for this reason that the utilization of the winged bean seeds should be further explored. Further studies should be carried out on the harmful substance that may be present in the seeds and on the vitamins present in "tempe kecipir".

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# Household Preparation of Winged Bean Tempeh, Tofu, Milk, Miso, and Sprouts

*William R. Shurtleff*[1]

Winged bean seeds have traditionally been eaten in their immature, fresh form as a green vegetable; only rarely have the dry seeds been consumed or used to make other foods. Yet dry seeds have the advantage of being much easier to store and transport. Dry winged beans closely resemble soybeans in the high quantity and quality of their protein, yet they provide much higher per hectare yields in tropical countries than soybeans. For over two thousand years, dry soybeans have been used throughout East Asia to prepare a number of tasty, low-cost foods, both fermented and non-fermented, using low-level village technology. Among these are: tempe (Indonesian fermented cakes), tofu (soybean curd), soymilk, miso (a fermented soy and grain seasoning paste), and soy sprouts.

In spite of their nutritional similarities, dry winged beans and soybeans have a number of important physical differences which strongly influence the processing methods and flavor of the foods into which they are made. Winged beans have an extremely hard seedcoat, which is difficult to remove; yet if not removed it prevents proper mycelium penetration in fermented foods such as tempeh and miso, adds a bitter, beany flavor and, in the case of beans with dark-colored seedcoats, imparts an unattractive purple color to foods like tofu and soymilk. Even when dehulled, however, the beans have a slightly bitter, harsh, and beany flavor, which is especially noticeable in winged bean milk. Dry winged bean seeds are much harder and larger than soybeans; even after 1 to 2 days of soaking, roughly 10 percent generally remain unhydrated. And the hydrated beans require considerably longer cooking than soybeans to achieve the same level of tenderness. While boiling in a 1 percent solution of baking soda allows quick tenderizing, baking soda is not readily available in most rural villages; firewood is likewise growing increasingly scarce or expensive. Finally, even when the dry beans are well processed, the resulting foods, while fairly tasty (especially winged bean tempeh), are not generally as delicious as their counterparts made from soybeans.

## HOMEMADE WINGED BEAN TEMPEH

Tempeh starter is now available from The Farm, 156 Drakes Ln., Summertown, TN 38483 or from Dr. H. L. Wang, USDA/NRRC, 1815 University St., Peoria, IL 61604 USA. Instructions for preparing tempeh starter at home or in tropical countries plus 150 tempeh recipes are given in *The Book of Tempeh*, available from the New-age Foods Study Center

590 cc (2½ cups) dry winged beans, washed and drained
3.6 liters water
15 cc baking soda (sodium bicarbonate)
15 cc vinegar or 85% lactic acid
Tempeh Starter (*Rhizopus oligosporus* mold spores): Choose one.
5 cc extended spore-powder or meal texture starter
1 cc spore powder starter
2.5 cc meal texture starter
56 grams minced fresh tempeh **Makes About 800 grams.**

1. Combine winged beans, baking soda, and 1416 cc (6 cups) water in an 8 to 10 liter cooking pot, bring to a boil, and simmer covered for 20 minutes, then remove from heat and allow to stand at room temperature for 16 hours.

2. Pour off excess water in pot, then rub beans in pot vigorously between the palms of both hands for 3 minutes in order to remove hulls (seedcoats). Add water to pot until it is almost full, gently stir in a circle causing hulls to rise to surface, then pour off water and hulls into a colander or strainer. Refill pot with water, stir

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and again pour off water and hulls. Now repeat process of rubbing beans for 1 minute, filling pot and pouring off hulls three to five times, or until all beans have been dehulled and at least 95 percent of the hulls poured off. Transfer any beans from colander back into pot, discard hulls, using them as compost or livestock fodder.

3. Add 1770 cc (7½ cups) hot water and the vinegar or lactic acid to drained beans in cooking pot. Bring to a boil and cooked, uncovered, at an active boil for 25 minutes.

4. Pour beans into a large colander set in sink, allow to drain dry for several minutes, then shake well to expel as much water as possible. Now transfer beans into a larger diameter, shallow colander or woven bamboo tray (or onto a baking tin or tray lined with toweling), spread beans in an even layer and allow to stand for 20 to 30 minutes, stirring occasionally, until they have cooled to body temperature and their surface is almost dry. Now pat surface of bean layer with toweling (or fan it) to remove excess moisture, then transfer beans to another well washed baking tin or large mixing bowl (or leave in shallow colander). For a finer textured tempeh, mince beans with a sterile knife. Sprinkle tempeh starter evenly over beans and mix for about 2 minutes with a large spoon to distribute starter evenly. Wash hands well. Choose one of the following containers.

**Polyethylene (plastic) Bags.** Place two 7 by 8 inch plastic (Ziploc) bags one atop the other on a clean 3 or 4 thicknesses of clean soft cloth. Using a sharp ice pick, slender clean nail, or fat sewing needle (0.6 diameter), poke holes through both the bags in a grid pattern at intervals of 1 cm. Spoon one half the inoculated beans into each bag, seal mouth with Ziploc or candle flame, then place bag on a flat surface and pat upper surface of bag with palm of hand to distribute beans in a uniform layer about 2 cm thick.

**Baking Pans or Pie Tins.** If using aluminum foil pans or tins, perforate bottom of each at 1 cm intervals as described above. Spoon inoculated beans to a depth of about 2 cm into 1 or 2 well washed pans or tins; level surface of beans and pack firmly, then cover each container with a sheet of aluminum foil (to prevent drying and contamination), perforated at 1 cm intervals.

5. Place tempeh containers on a rack in an incubator or other warm place and incubate at 30° to 31°C for 27 to 30 hours (or in tropical climates, at air temperature for 36 to 48 hours). Check temperature occasionally, especially toward end of incubation when it may rise suddenly. Toward end of incubation, examine tempeh quality.

**Good Tempeh.** Beans are bound into a firm, compact cake by a dense, uniform, white mycelium which should permeate the entire cake. In bread pans or aluminum foil containers, beans are barely visible under a cottony cover. Tempeh has a pleasant, clean, subtly sweet or mushroomy aroma. The entire cake can be lifted up as a single cohesive cake and thinly sliced pieces should hold together well without crumbling. Tempeh with gray mycelium or black sporulation near pin holes or edges has been incubated a little too long but is fine if the aroma is fresh without a strong ammonia odor. Cook good tempeh as described below (do not scrape or cut off the mold). If not used immediately, it should be refrigerated, frozen, or stored in a cool place. Crumbly tempeh having a weak mycelium may be steamed for 20 minutes then pureed to make dressings or fried for condiments.

**Immature Tempeh.** Beans are bound together only loosely by a sparse white mycelium. Thinly sliced pieces crumble easily. Incubate longer, unless it has gone more than 8 hours past the recommended time, in which case, discard.

**Inedible Tempeh.** Beans are foul or rotten smelling like strong ammonia or alcohol, indicating the development of undesirable bacteria due to excess moisture or overheating. Tempeh cake is wet, slimy, mushy, or sticky with a collapsed structure that is limp when bent. Color is tan to brown. Mold grows in sparse patches or there may be small colonies of alien microorganisms different in color or form from the predominant white mold. Discard bad portions and try again.

6. To serve tempeh: cut cake into thin (5 mm thick) slices, dip into a solution of salt water (118 cc water and 10 cc salt), and deep-fry until crisp and golden brown. Delicious as is or topped with ketchup, soy sauce, Worcestershire sauce, etc. If desired, add 1 clove of crushed garlic and 2.5 cc coriander to the salt water above.

**Troubleshooting.** If your tempeh did not turn out properly, find the problem and correct it next time:

***Tempeh is too wet.** Cakes may have been too near heat source in incubator, incubator temperature may have been too high, environmental humidity may have been too high, beans may not have been drained and dried sufficiently before packaging, perforations may have been too small or too far apart, or the culture may have been mixed with unclean utensils.

***Mold is sparse and does not bind beans tightly.** Your starter may have lost its potency; increase amount of old starter by 50 percent, incubate longer, or order new starter and keep it well sealed with a dessicant in a refrigerator.

***Tempeh contains black spots or patches.** This sporulation occurs when the tempeh mold receives too much oxygen or is incubated for too long or at too high a temperature.

***Tempeh smells strongly of ammonia.** The tempeh got too hot or was incubated too long. See also reasons for tempeh becoming too wet.

***Mold grew abundantly in some places but sparsely in others.** The sparse places may have been too near the heat source or lacked proper aeration. Or the starter may not have been mixed uniformly with the beans.

## HOMEMADE WINGED BEAN TOFU

This low cost, versatile pressed curd should be ready to serve 40 to 50 minutes after you start work. In tropical climates it will keep for 1 to 2 days. Refrigerated in water that is changed daily, it will stay fresh for 5 to 7 days. The tofu yield from winged beans is only about 50 to 60 percent that from soybeans. The resulting tofu has relatively little cohesiveness and a rather beany, bitter flavor, which can be partially masked by deep-frying. Illustrated details of the process for making tofu and soymilk plus 500 recipes are given in *The Book of Tofu* ($7.95). Nigari is made from clean seawater from which most of the table salt (NaCl) and water have been removed. Both are available from the New-age Foods Study Center.

Makes 450-550 gms

350 cc (1½ cups) dry winged beans, washed, soaked in excess warm water for 2 days, rinsed, and drained (or crack beans lightly in a blender or mill to enhance hydration, then soak for 12 to 16 hours)

3775 cc water (approximately)

Coagulant: 2.5 cc natural nigari, magnesium chloride (refined nigari), chloride, Epsom salts (magnesium sulfate) or calcium sulfate; or 15 cc lemon juice or vinegar; or 350 cc seawater.

1. Run 1770 cc (7½ cups) hot water into a 6 to 8 liter cooking pot and 1416 cc (6 cups) hot water into a saucepan or teapot; cover both and bring to a boil over high heat. Meanwhile place a deep, 6 to 10 liter "pressing pot" in sink and set a large colander into mouth of pot. Line colander with a moistened coarse weave sack or dishcloth. Line a 1900 cc-strainer or perforated settling box with moistened cheesecloth or a thin dishtowel.

2. Divide drained beans into 2 equal portions. Combined 1 portion in a blender with 235 cc tap water then 235 cc boiling water from the saucepan (or 470 cc hottest tap water, about 75°C); cover and puree at high speed for 2 minutes, or until very smooth. Add puree to water boiling in pot. Puree remaining beans with 470 cc water in the same way and add to pot. Rinse out blender with 60 cc hot water to retrieve any puree and add to pot; fill blender with cold water to soak. (If using a food mill or meat grinder, grind beans without adding water, but increase water in cooking pot to 2714 cc (11½ cups).

3. Stirring constantly, bring contents of pot just to a boil, then pour into cloth-lined colander or sack. Gather corners of cloth or sack and twist closed. Using a glass jar or potato masher, press sack repeatedly against bottom of colander to extract as much milk as possible. Open mouth of sack wide in colander, stir solids (okara) briefly, then measure out 700 cc (3 cups) boiling water from the saucepan and over okara. Stir again, twist closed sack, and again press repeatedly with jar to extract any remaining milk. Pour milk into cooking pot; reserve okara for use in cooking, or as a livestock fodder or compost.

4. Bring milk to a boil over high heat, stirring bottom of pot frequently, then reduce heat to medium and simmer for 5 to 7 minutes. During simmering, measure coagulant into a dry 236 cc (1-cup) measuring cup and set aside.

5. Remove pot from burner. Add water to coagulant in measuring cup (unless using sea water) until total volume equals 236 cc; stir until coagulant dissolves. Using a wooden spoon or spatula, stir milk back and forth vigorously 5 or 6 times and, while stirring, pour in one-third of coagulant solution. Stir 5 to 6 times more, making sure to reach bottom and sides of pot. Now stop spoon upright in milk and wait until liquid movement ceases; lift out spoon. Sprinkle another one-third of the coagulant solution over surface of milk, cover pot, and wait 2 to 3 minutes while curds form slowly — from the bottom up. Use this time to wash utensils, first in cold water.

6. Stir remaining one-third of coagulant solution. Uncover pot and, while very slowly stirring upper 1-cm-thick layer of curdling milk, sprinkle coagulant solution a little at a time over milky areas. (If milk has completely curdled, do not add more coagulant; proceed to step 7.) Cover pot and wait 3 minutes. (Wait 6 minutes if using Epsom salts or calcium sulfate.) Uncover and stir surface layer again for 20 to 30 seconds, then gently push spatula down edge of pot to the bottom in several places to free any milk that may be trapped below curds; stir again until milky liquid curdles. Large delicate curds should now be floating like white clouds in the pale yellow whey.

(If any uncurdled milk persists, dissolve one fourth of the original amount of coagulant in 80 cc water and sprinkle over the uncurdled portions; stir gently until curdled.)

7. Place cooking pot in sink next to settling container. Gently press a fine mesh strainer partially into curds and whey so that whey collects in strainer and curds are held out. Ladle all whey out of strainer and over cheesecloth in settling container so cloth clings smoothly to sides of container. Repeat until most whey is removed from curds, then set strainer aside.

8. Now gently ladle fragile curds and any remaining whey into settling container one layer at a time. Fold edges of cloth neatly over curds, place lid atop cloth, and set a 600 to 1200 gram weight on lid to press tofu for 15 minutes. (For firm tofu, use a 2200 gram weight for 20 minutes.)

9. Fill a large basin or sink with cold water. Remove weight and lid, and submerge tofu-filled container in water. Slowly invert then lift out container, leaving cloth-wrapped tofu in water. Gently unwrap tofu underwater then cut cake crosswise into halves. Leave tofu in water for 3 to 5 minutes, until firm. Then, using a small plate for support, lift out tofu cakes and drain briefly.

10. To serve, cut into cubes or thin slices and deep fry in 175°C oil for 3 minutes, or until golden brown. Serve topped with a sprinkling of soy sauce or use like meat in your favorite recipes. Keep unused portions refrigerated.

**Troubleshooting.** If your tofu did not turn out properly, find the problem and correct it next time.

***Low yield.** Beans are too old or not thoroughly soaked; puree was ground too coarsely; pressing sack weave is too tight; coagulant was added improperly, probably too much or too quickly.

***Small curds or crumbly tofu texture.** Too much coagulant was added too fast causing curds to form quickly; curds were stirred or ladled too roughly.

***Coagulant was insufficient:** Milk was allowed to cool too much before coagulant was added.

## HOMEMADE WINGED BEAN MILK

Even after the time consuming operations of dehulling the soybeans, we find this milk to be palatable only if it is heavily flavored to mask the bean's bitter, beany flavor.

354 cc (1½ cups) dry winged beans
2832 cc (12 cups) water, approximately **Makes 1770 cc**

In advance: Lightly crack the seedcoat of each bean by using a blender (push the button briefly about 20 times) or between loosely set millstones. Soak for 16 hours in plenty of water, changing the water several times during the process. Then rubbing the beans between the palms of both hands, dehull and float off the hulls (see tempeh, step 2).

Proceed as for homemade tofu except (1) heat only 590 cc (2½ cups) water in the cooking pot initially; (2) rinse okara with only 472 cc (2 cups) boiling water. Stop near the end of step 4 after milk has been simmered for 7 minutes. If desired, add to the 1770 cc (7½ cups) milk, one of the following flavoring combinations:

***Honey-Vanilla.** Add 37 to 60 cc honey or natural sugar, 1/2 cc vanilla extract, and a pinch of salt, mix or puree well.

***Rich and Creamy.** To any of the flavoring combinations above or below, add 30 to 45 cc vegetable oil; puree at high speed until well dispersed. For extra thickness, add 1/2 cc granular lecithin.

***Carob-Honey.** Add 60 cc honey or natural sugar, a pinch of salt and, if desired, 1/2 cc vanilla extract. After milk has cooled, whip in 12 to 16 cc carob (or cocoa) powder, which has first been creamed in a little of the cold milk.

***Malt, Mocha, or Coffee.** Add 30 to 45 cc granular malt, mocha, or coffee to the Honey-Vanilla above.

## HOMEMADE RED WINGED BEAN MISO

475 cc (2 cups) dry winged beans
945 cc (4 cups) water
135 cc salt
15 cc mature miso, unpasteurized and preservative-free (optional)
475 cc firm granular rice koji (molded rice) **Makes 1650 grams.**

Precrack, soak, and dehull winged beans as described at Winged Bean Milk, above. Combine beans with 945 cc water in a pressure cooker, bring to full pressure (15 pounds), reduce heat to low, and simmer for 30 minutes. Remove from heat and allow to stand for 15 Minutes, while pressure returns to normal. Open cooker, pour beans into a colander set over a pot, and allow to drain for 3 to 5 minutes. Return beans to cooker and, using a pestle or potato masher, mash beans until only about one fourth remain whole. Allow to cool to slightly above body temperature (43½°C).

In a 6 to 8 liter pot, combine 128 cc salt and, if desired, the mature miso; mix well. Then slowly stir in 355 cc of the soybean cooking liquid. Finally add koji and mashed soybeans, mixing to even consistency.

Wash and dry a 2 to 4 liter wide-mouthed earthenware, glass, or plastic crock. Sprinkle 2.5 cc salt over its bottom, then spoon in miso mixture and pack firmly; smooth surface and sprinkle on 5 cc salt. Cover surface with a double layer of undyed cloth, butcher paper or plastic wrap, top with a pressing lid (a flat plate or wooden disc), and then with a 2.5-kg weight. Cover entire mouth of container with paper and tie closed to keep out dust. Place in a cool location and allow to age for at least 6 months.

When miso is ready, scrape off and discard any (harmless) mold on surface. Remove several weeks supply and store in kitchen (or refrigerate). Re-cover crock and store in a cool place. For 400 miso recipes, see The Book of Miso, available from the new-age Foods Study Center ($6.95).

## HOMEMADE WINGED BEAN SPROUTS

1 to 1½ cups dry winged beans **(Makes 3 TO 6 cups)**

Prepare a sprouter by making small holes in the bottom of a 10 to 12 inch-deep plastic container, milk carton, or coffee can. Pour in beans to a depth of at least 2 inches, then place sprouter in a slightly larger pot and fill with water to more than cover the beans. Cover pot and allow beans to soak for 12 hours. Lift out sprouter and drain beans being careful not to mix or agitate them. Cover sprouter and place in a dark place at about 22°C. Rinse beans 3 to 4 times daily by sprinkling with water, again taking care not to mix them. Repeat for 5 days, or until sprouts are 2 to 4 cm long. Transfer sprouts to a large pot and rinse with plenty of water; pour off loose hulls and remove unsprouted beans. Parboil for 6 minutes then serve in salads or sautéed vegetable preparations.

# The Winged Bean in Livestock Feeds with Particular Reference to the U.K. and E.E.C.

*L. G. Chubb*[1]

**The most important sources of protein in compound animal feeding stuffs are the oilseed residues, of which soyabean meal is the most important and the one dominating the world market. As the world population grows, so does the demand for high quality protein for human consumption. This in turn will require increased amounts of existing and new sources of protein.**

Compound feed production in the E.E.C. in 1976 was approximately 64 million tonnes, of which 14 million tonnes (22%) was made up of oilcakes/meals. Seventy percent of the latter (10 million tonnes) was soya. In addition, eighty percent of the E.E.C.'s requirements must be imported from Third World Countries and demand is expected to increase over the next 10 years.

The winged bean, a high yielding edible legume of good protein quality, almost equal to that of soya protein, appears to be potentially attractive as an additional and valuable source for farm livestock feeds, especially pigs and poultry. The oil, like other vegetable oils, has a high content of the polyunsaturated essential fatty acids which are also valuable in animal nutrition. On the other hand, two important groups of endogenous toxic factors namely trypsin inhibitors and haemagglutinins are present, but as in the case of other legumes they are destroyed by heating.

The large-scale use of winged bean protein in the E.E.C. will depend on its price relative to other available protein sources, and in particular on the levels of lysine and sulphur amino acids. Chemical and biological data indicate that it could be a serious competitor of soyabean meal. The dried tubers, pods and haulm also appear as potentially useful ingredients for ruminant feeds, providing both protein and essential fiber.

With increasing restrictive legislation in the E.E.C., especially from the point of view of undesirable non-nutrient factors, the winged bean is at no disadvantage compared to other vegetable protein sources.

## INTRODUCTION

There are available worldwide many sources of protein supplements suitable for the feeding of farm livestock, and the main purpose of this paper is to examine critically the suitability of a tropical legume, the winged bean (*Psophocarpus tetragonolobus* (L) DC) as an additional protein source for animal feeding.

During the last twenty years, the standard of living has increased in many parts of the world, especially in the U.S.A., Europe and Japan. On the other hand, there are still many countries in Africa and Asia where food shortages and widespread malnutrition still exist, and in the long term, these will only be alleviated by increasing livestock production in these regions. Standard of living considered in this context thus implies an increased supply of meat, milk and eggs. To produce these high quality nutritional products requires more intensive animal production systems, but these will only succeed if there is a well organized animal feed industry. However, the latter is critically dependent on the availability, at the right price, of protein supplements which can be balanced with various energy sources such as cereals, cereal by-products, fats, together with other miscellaneous feeding stuffs, vitamins and minerals to provide balanced nutritional diets for livestock.

Many attempts have been made to introduce new protein sources, and recent studies on the composition and nutritional value of the winged bean (Nat. Acad. Sci. 1975) suggest that the time is now appropriate for its commercial exploitation. Scientific evidence would indicate it could be a serious competitor of sources of vegetable protein such as soyabean, groundnut, rapeseed, cotton seed meals, and many others.

## WORLD LIVESTOCK PRODUCTION AND FEED PRODUCTION

The potential for growth in farm animal production is well illustrated by the fact that the per capita intake of animal protein is only 5 to 10 grams per day in the poorest countries, compared to 75 grams per head

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in the populations of developed countries. These figures correlate very closely in terms of productivity per head of stock (Table 1). Nestel (1975) has also pointed out that in less developed countries, population growth between 1961/63, 1969/71 has outstripped the growth of animal production in terms of beef/veal/mutton and lamb and milk, and only in the case of pork and poultry has production kept pace with the growth rate of the human population.

Table 1. Regional production of some livestock products per head of animal population.

| | Kg/product/head of livestock production | | |
|---|---|---|---|
| | Beef/Veal | Mutton/Lamb | Pork |
| U.S.A./Canada | 93 | 11 | 98 |
| Latin America | 36 | 3 | 16 |
| Africa | 15 | 3 | 29 |
| Near East | 17 | 4 | 12 |
| Far East | 4 | 4 | 24 |

Source: F.A.O. Production Yearbook.

Turning now to the world production of proteins suitable for animal feeding, Table 2 shows the recent trend and it can clearly be seen how soyabean has steadily increased compared with other sources. Table 3 shows in more detail a comparison of soyabean meal with other individual oilseed meals and fish meal.

Table 2. World production of oilseed meals (000 M.T.)

| Production | U.S.A. | Foreign | World | Soyabean | Other |
|---|---|---|---|---|---|
| 1973 | 28.50 | 29.02 | 57.52 | 33.30 | 24.22 |
| 1974 | 34.05 | 34.47 | 68.52 | 42.14 | 26.36 |
| 1975 | 27.11 | 36.20 | 63.31 | 37.36 | 25.95 |
| 1976 | 33.60 | 38.59 | 72.19 | 45.65 | 26.54 |
| 1977 (forecast) | 28.03 | 38.17 | 66.20 | 40.57 | 25.63 |
| 1978 (forecast) | 34.81 | 40.78 | 75.59 | 48.64 | 29.95 |

Source: Foreign Agriculture U.S.D.A. August 1977

Table 3. World production of oilseed meals and fish meal (000 M.T.)

| | 1975 | 1976 | Forecast 1977 |
|---|---|---|---|
| Soyabean | 38000 | 46190 | 41275 |
| Groundnut | 4170 | 4880 | 4695 |
| Cottonseed | 9620 | 7950 | 8825 |
| Rapeseed | 4180 | 4505 | 4070 |
| Linseed | 1285 | 1395 | 1235 |
| Sunflower | 3855 | 3475 | 3625 |
| Sesame | 1550 | 1625 | 1505 |
| Palm Kernel | 675 | 680 | 705 |
| Fish Meal | 4045 | 4450 | 4375 |
| Total | 67380 | 75150 | 71310 |

Source: FAO — Intergovernmental groups on oilseeds.

Examination of the statistics of the compound feed industry in the E.E.C. (Community of Nine), shows that total production between 1970 and 1976 has steadily increased almost every year as follows: 47.8 (1970), 49 (1971), 52.8 (1972), 58.5 (1973), 57.8 (1974), 58.1 (1975) and 64 million metric tons (1976). In the case of the 1976 figures, the total was made up of approximately 32 million tonnes cereals, 16 million tonnes oil cakes and meal, fish meat meal, 8 million tonnes of cereal derivatives, 2 million tonnes of minerals vitamins and 6 million tonnes of minor raw materials. However, the production of meal/cakes from Community grown seed meets only a relatively small percentage of the total requirement. In terms of individual product groups, the total for 1975 were 17.2 million tonnes of poultry feed, 21.2 million tonnes of pig feed and 17.5 million tonnes of cattle feed.

Thus the Community is very dependent on the international market with 80 percent of its supplies coming from Third World countries. Consequently, the community applies minimal duty for all oilseeds and nuts, the value of which is currently worth approximately $3000M and for oilseed meals/cakes $1500M. On a world and E.E.C. basis oilmeal protein demand is still expected to increase in 1978. As far as the E.E.C. is concerned, the main reason for this trend is the Common Agricultural Policy (C.A.P.) which maintains relatively high prices for domestically produced grains compared to world market price levels. Consequently, oil cakes/meals also make a significant contribution to the total energy content of the mixed feeds, as well as vital protein.

Table 4 shows raw material usage in six of the Community's major producers. It is interesting to note that much higher levels of so called "cereal substitutes" such as cassava, molasses, fats and oils and oil cakes/meals in Germany, France and the Netherlands compared to the U.K. As pointed out above, although oil cakes and seed for crushing are mainly imported to cover protein requirements, they are a valuable source of dietary energy, and as long as internal cereal prices are maintained at high levels, imports of "grain substitutes" and protein sources will represent a valuable source of foreign exchange to developing and other Third World Countries producing these materials.

**Table 4. Raw materials used in animal feeds in Europe during 1974/75 (000 M.T.)**

| | Germany | France | Italy | Netherland | Belgium | U.K. |
|---|---|---|---|---|---|---|
| Cereals | 4238 | 5440 | 3500 | 3349 | 2142 | 5136 |
| Milling by products | 1320 | 1126 | 508 | 834 | 688 | 975 |
| Cassava | 390 | 150 | – | 858 | 448 | — |
| Molasses | 270 | 305 | 85 | 489 | – | — |
| Oil & Fats | 120 | 230 | 76 | 178 | – | — |
| Oil cakes/meals | 3050 | 2173 | 1118 | 2556 | 1056 | 949 |
| Fish & meat meals | 320 | 215 | 127 | 141 | 99 | 525 |
| Dried forage | 260 | 370 | 95 | 280 | 82 | — |
| Dairy products | 220 | 402 | 195 | 346 | 58 | 17 |
| Miscellaneous | 475 | 267 | 649 | 1469 | 257 | 1394 |
| TOTAL | 10663 | 10678 | 6353 | 10500 | 5025 | 9585 |

## NEW FEED INGREDIENTS: AN ECONOMIC EVALUATION

The production of compound feedings stuffs is today governed by a single objective: to provide as economically as possible a diet meeting the nutritional requirements of particular farm animals. Because of the big advances in nutritional knowledge which have been made over the last thirty years, it is now suitable for the different classes of livestock, from a wide range of materials to meet specified requirements of amino acids, energy, minerals and vitamins, rather than stipulating specific amounts of a limited number of materials. It is this ability to interchange a wide range of raw materials which has given the compound feed manufacturer much more flexibility for using materials according to their market price and determining the cheapest combination. In addition to price, two other important factors have to be taken into consideration, namely, the nutritional composition of individual ingredients and the presence of so called "non-nutritive" substances. The cheapest combination is then determined by a "linear programming technique" using the computer.

The degree of flexibility, however, in meeting the nutritional requirements of cattle, pigs and poultry is different. This is well illustrated in the case of dairy and beef cattle, where because of their ability to cope with relatively fibrous materials, and the fact that their dietary requirements have not been defined with the same degree of precision as those for pigs and poultry, a wider range of ingredients can be used. In contrast, feeds for pigs and poultry may be much more closely defined in terms of both nutritional and other requirements of the environment. This tends to reduce the flexibility in formulation and rely to a much greater extent on fewer ingredients of high nutritional value. This trend is likely to continue because of increasing intensification and the need for high performance in terms of growth rate and feed conversion efficiency.

The feed manufacturer is thus faced with a complex of different frequently changing situations, the most important of which are individual ingredient cost, product specifications, patterns of product demand, profit margins, purchasing strategies and inventory levels. A recent paper by Harris (1976) discusses in detail some of the problems of formulating diets for animals, using the computer.

The reliability of any diet formula depends primarily on accurate information on the composition of different ingredients. Today the International Network of Feed Information Centers (I.N.F.I.C.) organizes the description, collection and summarizing of data on feed composition and related topics and F.A.O. acts as the secretariat (Fig. 1). Information is also needed on certain digestibility coefficients such as protein (amino acid) and energy. Recent research has also shown quite clearly that apparent digestibility coefficients of various dietary nutrients change with changes in diet composition. Thus, any new ingredient must not only be subjected to repeated analyses of different samples, but also feeding digestibility trials, before it is accepted as a suitable ingredient for inclusion in compound feeds. Having undergone all these tests, and despite evidence that a particular ingredient is nutritionally satisfactory, the presence of certain non-nutritive substances can still be a problem.

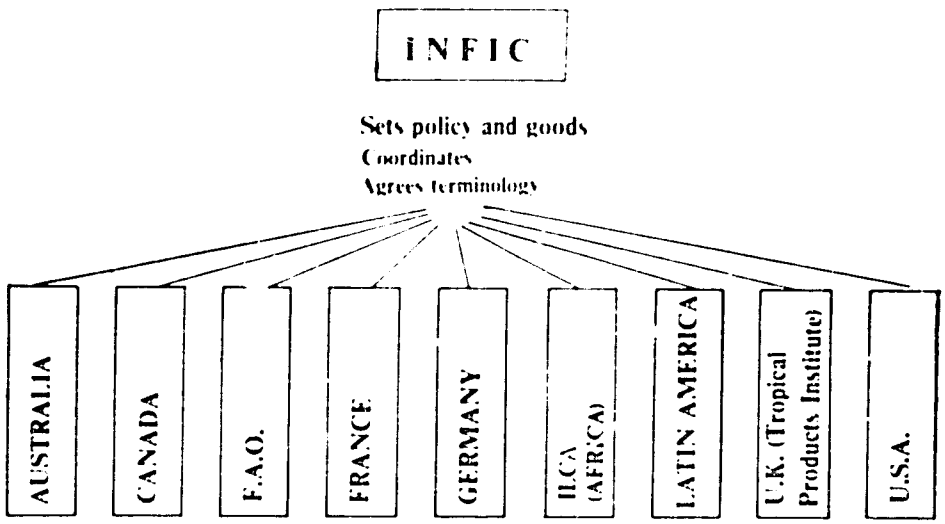


**Fig. 1 The International Network of Feed Information Centers (I.N.F.I.C.)**

Liener (1975) has discussed in detail the wide variety of substances which can adversely affect the nutritive properties of the protein. Some of these substances are, in fact, protein in nature, e.g. trypsin inhibitors and haemagglutinins. These are found mainly in the soyabean and other leguminous seeds. The trypsin inhibitors, in particular, are widely distributed among the legumes causing growth inhibition in a number of animal species. The prime physiological effect produced by this type of inhibitor is on the pancreas which becomes hypertrophic, causing the secretion of large amounts of the enzymes, trypsin and chymotrypsin. This can lead to a loss of the sulphur amino acids which are present in both enzymes.

Trypsin inhibitors are destroyed by heat, the treatment conditions being critical, especially duration of heating, particle size and moisture in order to obtain maximum destruction. The other group of substance, the haemagglutinins, are present in most legumes and cause agglutination of red blood cells. They too can be extremely toxic but are destroyed by heat treatment. The winged bean contains both factors, but there is no reason to doubt they can be destroyed by heat rendering it nutritionally safe.

A second group of factors are the glycosides which can be divided into a number of sub groups. The most important are the goitrogens which are found predominantly in the *Cruciferae* family, e.g. rapeseed (*Brassica napus* L). They contain thioglycosides or glucosinolates, which on hydrolysis release substances which are goitrogenic and growth inhibitory. Detoxification is not easy, the best being to inactivate the enzyme responsible for the hydrolysis by moist heat treatment. Another glycoside which is potentially toxic are those which release hydrocyanic acid upon hydrolysis, e.g. linen flax contains a glycoside, linamarin, which is hydrolyzed by the enzyme linamarase. This enzyme is also rapidly inactivated by heat treatment. Saponins, the so called foam producing glycosides, also have haemolytic activity as well as inhibiting the proteolytic action of trypsin.

Other anti nutritive substances present naturally include oestrogens which may cause problems and phenolic compounds, such as gossypol found in cottonseed meal which can be toxic to non ruminants. Tannins can also adversely affect palatability.

From the foregoing, it is therefore obvious that a considerable amount of research is required before a feedingstuff can be traded internationally and is acceptable to buyers. Thus, a new product cannot be accepted solely on the basis of chemical analysis. Crude protein, ether extract, crude fibre, ash and certain carbohydrate fractions provide only a rough profile. For example, it cannot be assumed that crude fibre corresponds to the total indigestible carbohydrate and that NFE (nitrogen free extract) is entirely digestible. For example, there are some fractions, brought into solution by treatment with acid and then alkali which constitutes the crude fiber determination method which are indigestible in poultry.

It is thus imperative that extensive feeding trials and measurements of digestibility should be carried out. This is particularly important in high protein ingredients whose quality and monetary value depend mainly on the biological availability of certain amino acids which can be considerably reduced by improper processing (e.g. overheating) and storage. Finally, the presence of endogenous toxic factors have been mentioned, but some ingredients can still be potentially hazardous because they carry unwanted contaminants such as mycotoxins, and in the case of animal derived ingredients, nitrosamines and salmonellae.

Having satisfied all the above criteria, it is still necessary to evaluate economically new feeding stuffs. This is normally carried out by what is called parametric linear programming, which is a particular application of linear programming. The most important is "PARAMETRIC COST RANGING", a technique which investigates the competitive and substitution relationship among ingredients. Briefly, this involves varying the price of a particular ingredient while the prices of other ingredients are held constant. From this price range, the quantity in the diet that the particular ingredient will be used is determined. This generates a steplike demand function for the traced ingredient (Fig. 2). It can be seen that the histogram gives the highest price that the ingredient just enters a ration and the increase in usage of successively lower prices. It will be noted that points C, D and E are considerably below the current selling price and are of academic interest only. Thus the economic value of a particular feedstuff is quantified and an estimate of its potential market demand at different price levels can be made, i.e. the buyer is aware of the price sensitivity and the substitutability of an ingredient compared with others under consideration. Because the values of other ingredients can change almost daily, it is necessary for the feed manufacturer to be constantly reviewing his buying programme.

Thus the possible large scale use of the winged bean in livestock feeds in Europe will depend very much on the application and results of the computer techniques outlined above. However, they clearly show that the feed manufacturer is able to use a wide range of raw materials interchangeably. As the prices of individual ingredients change, the formula for different types of feeds will contain more of those ingredients which tend to cheapen the diet, and less of those ingredients which tend to increase the price, although the final formula will depend on the constraints both maximum and minimum, put on certain materials. The effect of this produces an "automatic feedback" into the market, thus introducing some stability in prices (Cowan, 1977).

## COMPARATIVE NUTRITIVE VALUE OF SELECTED OILSEED MEALS AND THE WINGED BEAN

The cakes remaining after extracting oil from oil bearing materials are the major protein sources for the compound feed industry. As has been noted, the principal ones traded internationally are soya, cottonseed, groundnut, sunflower seed, rapeseed, linseed, copra, sesame and palm kernel; together they account for about 95% of the world trade (Breslin 1975).

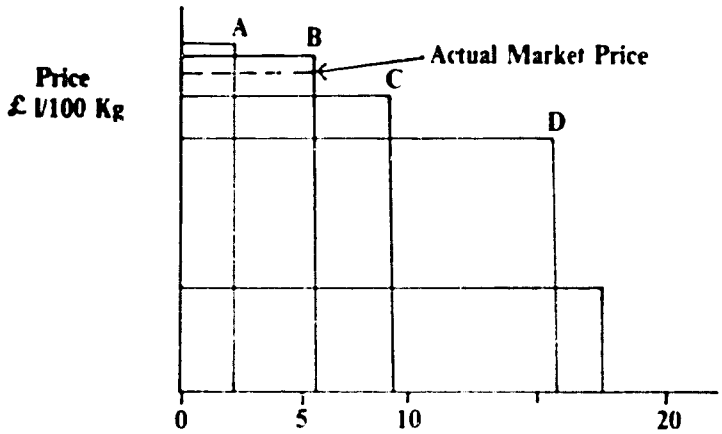


**Fig. 2. Parametric cost ranging for new feedstuffs.**

Oilseeds were originally crushed primarily for their oil, the cake being regarded as a by-product. However, this has in recent years been reversed, and soybeans are grown and crushed mainly to provide the meal for animal feeds. It also completely dominates the world market, representing approximately 56% of the total world production, followed by cottonseed (15%), with the remaining 29% made up of the other seven sources (Table 5).

**Table 5. World production of oilcake, 1973.**

| | % |
|---|---|
| Soybean | 56 |
| Cottonseed | 15 |
| Groundnut | 8 |
| Sunflower | 6 |
| Rapeseed | 7 |
| Linseed | 3 |
| Copra | 3 |
| Sesame seed | 1 |
| Palm Kernel | 1 |
| TOTAL | 100 |

World production of oilcake in 1973 was approximately 56 million tonnes and this has grown steadily, with F.A.O. projecting a demand for 71.4 million tonnes by 1980. Europe is the major market, and it is estimated that the E.E.C. will import approximately 9.5 million metric tons of soyabeans and 5.5 million metric tons of soyabean meal in 1977, i.e. 15 million metric tons to meet the demands of its animal feed and edible oil industries.

Although exporting of oilseeds earns valuable currency, the likely trend in developing countries is towards establishing crushing industries. At the same time, if livestock enterprises develop, internal consumption of the cake will increase. However, the decision as to whether to crush or export must depend on the relative financial return of using the oil and meal internally.

In recent years the price of oilcakes, as well as other feed ingredients have increased sharply, and the possible advent of another source of edible oil and meal from the winged bean could make it a significant competitor of those currently available. F.A.O. (Agriculture Commodity Projections 1970-1980) have forecast an increase in the supply of oilcakes from 45.5 million tonnes in 1965 to approximately 75 million tonnes in 1980, and although the annual growth rate throughout the 1960's was of the order of 5% annually, it has slowed down to approximately 3.5% in the 1970's.

Turning now to the nutritional aspect, firstly the fatty acid composition of different extracted oils should be compared with that of the Winged Bean (Table 6).

Compared to soya and groundnut oils, the total amount of oleic plus linoleic acids is somewhat lower in the Winged Bean. On the other hand, it contains a higher level of linoleic acid. However, it is interesting to the winged bean. On the other hand, it contains a higher level of linoleic acid. However, it is interesting to note the relatively high level of behenic acid which is not found in the majority of the other oils.

**Table 6. Comparison of the winged bean and the fatty acid composition of different extracted oils.**

| | Winged Bean | Soybean | Cotton seed | Ground-nut | Sun-flower | Canadian Rapeseed |
|---|---|---|---|---|---|---|
| 14.0 (Myristic) | 0.1 | 0.1 | 3.3 | 0.4 | — | — |
| 16.0 (Palmitic) | 7.4 | 11.4 | 19.9 | 8.3 | 6.5 | 2.9 |
| 16.1 (Palmitoleic) | 0.1 | — | — 0.7 | — | 0.2 | |
| 18.0 (Stearic) | 2.8 | 5.0 | 1.3 | 3.1 | 3.6 | 1.0 |
| 18.1 (Oleic) | 33.9 | 24.5 | 29.6 | 54.9 | 14.70 | 31.5 |
| 18.2 (Linoleic) | 28.8 | 50.3 | 45.3 | 26.2 | 20.72 | 20.0 |
| 18.3 (Linolenic) | 1.4 | 7.5 | — | — | — | — |
| 18.4 (Parinaric) | — | — | — | — | — | — |
| 20.0 (Arachidic) | 1.3 | 0.4 | 0.6 | 2.4 | — | 0.7 |
| 20.1 (Gadoleic) | 4.0 | 0.6 | — | — | — | 11.4 |
| 22.0 (Behenic) | 15.9 | — | — | 3.1 | — | 0.2 |
| 22.1 (Erucic) | 0.7 | — | — | — | — | 11.4 |
| 24.0 (Lignoceric) | 3.4 | — | — | 1.1 | — | 0.1 |

In terms of livestock feeding, however, while there is a need for essential fatty acids, namely linoleic, linolenic and arachidonic, the majority of cereals are well supplied with them and especially maize, so there is seldom a deficiency. On the other hand, egg size in poultry, for example, can be significantly influenced by their level in the diet. However, the addition of vegetable oils as such to the diet of livestock is expensive and uneconomic. Consequently, should the oil of the winged bean be extracted commercially, its role will most likely be in human nutrition.

The major significance of the oilseed residues in animal feeds lies in the protein content, and more importantly, the levels of individual amino-acids in the particular protein. The figures given in Tables 7 and 8 have been taken from Roberts (1975), although it must be appreciated, there is a considerable amount of published amino-acid data which shows large variations due to the country of origin, variety and particular analytical method used to determine the individuial amino acids.

**Table 7. Oil and protein content of oilseeds.**

| | Oil Content | Protein Content (N x 6.25) |
|---|---|---|
| Soya | 20 | 38 |
| Cottonseed | 20 | 20 |
| Groundnut | 49 | 28 |
| Sunflower | 20 | 23 |
| Rapeseed | 40 | 20 |
| Linseed | 38 | 24 |
| Sesame | 50 | 25 |
| Palm Kernel | 49 | 9 |
| Winged Bean* | 16 | 33 |

***Obtained by the author.**

For monogastric animals lysine or methionine plus cysteine are the first limiting amino-acids. With regard to the former, soya has always been the best of the vegetable proteins, followed by groundnut. However, the protein of the winged bean contains over 20% more lysine than is found in soya, and must therefore be considered a very valuable source of this important amino-acid. On the other hand, its protein is somewhat deficient in the sulphur-containing amino-acids compared to soya. The next limiting amino-acid is

**Table 8. Essential amino-acid content of oilseeds (g/16g N).**

| | Lysine | Methionine + Cysteine | Valine | Tryptophan | Isoleucine | Threonine | Histidine | Leucine |
|---|---|---|---|---|---|---|---|---|
| Soya | 6.3 | 2.9 | 5.2 | 1.3 | 5.5 | 3.7 | 2.4 | 7.4 |
| Cottonseed | 4.2 | 3.7 | 5.0 | 1.6 | 3.9 | 3.5 | 2.7 | 6.1 |
| Groundnut | 4.9 | 2.1 | 5.9 | 1.1 | 4.2 | 3.2 | 2.5 | 7.8 |
| Sunflower | 3.6 | 4.7 | 4.9 | 1.1 | 4.5 | 3.2 | 2.1 | 5.6 |
| Rapeseed | 4.4 | 3.4 | 4.8 | 0.9 | 3.8 | 4.1 | 2.4 | 3.8 |
| Linseed | 3.3 | 3.2 | 4.9 | 1.5 | 5.5 | 3.6 | 2.1 | 5.4 |
| Sesame | 2.7 | 4.2 | 5.0 | 1.6 | 4.4 | 3.3 | 2.3 | 7.1 |
| Palm Kernel | 3.4 | 2.1 | 5.4 | 1.0 | 4.0 | 3.1 | 1.6 | 6.4 |
| Winged Bean* | 7.65 | 1.81** | 4.80 | 1.10 | 4.35 | 4.80 | 2.730 | 7.25 |

*Results obtained by author
**Methionine 0.60 Cysteine 1.21

tryptophan which may be significant in some circumstances, and in this respect the winged bean is poor compared to sesame and linseed, but almost as good as that of soya and groundnut. However, the leucine level compares favourably with soya, groundnut and sesame, although this amino acid is found in relatively high levels in cereals (7 to 11g/16g nitrogen for barley, wheat and maize and 15 g for milo).

In recent years, there has been a small but increasing trend in using whole cooked soyabeans as an ingredient in livestock feeds, but the extracted meal is by far the most common form. The latter has an average protein content of 46 per cent, oil 1 per cent, lysine 2.9 per cent and methionine 0.65 per cent. Assuming most of the oil of the winged bean is removed by solvent extraction (residue in meal less than 1 per cent), the protein content in the meal would increase to approximately 39 per cent. The lysine level would be approximately 2.9 per cent (identical with that in soya bean meal), whereas the methionine content at 0.23 per cent would be significantly lower than the 0.65 per cent in soya. Assuming the metabolizable energy content of soyabean meal to be 2240 kcal/kg and that for the winged bean 2300 kcal/kg (calculated from the formula of Bolton), its opportunity price for inclusion in some livestock feeds has been calculated. It must be stressed that these are based on U.K. type formulae with the prevailing price for soyabean meal of £120 per tonne (equivalent to $228).

| | Value in £ sterling (per ton) | Level in Feed (%) |
|---|---|---|
| Broiler Starter/Finisher feeds | 119 | 8·9 |
| Low energy layer feed | 120 | 2 |
| | 96 | 2½ |
| High energy layer feed | 112 | 0.1 |
| Pig feed and weaners and growers | 120 | 6.5 |

Obviously, these figures will change with the changes in price, availability and formulation constraints placed on other protein sources, but it gives some indication of its value in the U.K. and using tubers, pods and haulm (vine plus leaf), the following data was obtained on samples of dried material

| | Tubers (%) | Pods (%) | Haulm (%) |
|---|---|---|---|
| Oil | 0.50 | 0.60 | 1.30 |
| Crude Protein (Nx 6.25) | 17.40 | 7.35 | 13.85 |
| Crude Fibre | 4.15 | 55.00 | 78.70 |

These results suggest that the dried tubers could also be a useful ingredient in poultry, pig and cattle feeds, although with regard to the first two species, these parts' low protein content compared with seed protein would not make it competitive as a protein source. On the other hand, the dried pods and haulm with much higher fibre levels could prove a useful ingredient in ruminant/horse feeds, although the very high level in the dried haulm would probably restrict its value. Summarizing, in terms of animal nutrition, the important parameters are protein, essential amino-acids and energy, but the evaluation of different sources of these nutrients by the computer to optimize all nutritional aspects to the satisfaction of the nutritionist on the one hand, and the buyer on the other hand, is an on-going dynamic activity. It is, therefore, in this commercial climate that the trading and use of the winged bean in Europe will have to operate.

## FEED STANDARDS IN RELATION TO E.E.C. LEGISLATION

Any new raw material which is likely to be traded on an international scale will be subject to the conditions normally prevailing in commercial contracts between buyers and sellers. The former will need to be satisfied on description and certain features and specifications which the seller will have to agree are reasonable. It is only when agreement is reached on these technical yardsticks that a contract can be completed. Twenty years ago contracts were mainly concerned with nutrient features such as crude protein, crude fibre, oil and ash, but recently certain impurities, contaminants and the presence of natural toxic substances have been included. At the same time, individual countries have introduced laws which lay down specified and quantified features of feed materials which must be complied with. Consequently, buyers in these countries have to insist on the inclusion of these features in their specifications which must be written into commercial contracts.

The introduction of this type of legislation has arisen because of concern for the safety of diets not only for farm animals but their edible products for human consumption. In the E.E.C., the Commission is the dominant influence on all animal feed legislation, and over the next 5 to 10 years the industry will be subject to detailed laws now being drafted. The main areas of control are as follows:

**Raw Materials**
(a) Marketing of straight feeding stuffs
(b) Undesirable substances
(c) Pesticide residues
(d) Salmonellae

**Manufacturers' Products**
(a) Marketing of compounds
(b) Additives
(c) Undesirable substances
(d) Product liability

Under raw materials, the Directive on the "Marketing of Straights" comes into operation in January 1979. It lists 128 different ingredients, stipulating the name, description and compulsory declarations required for each one. However, it does NOT cover raw materials sold to compounders for manufacturing feeds.

The legislation concerning undesirable substances in raw materials and feeds first came into operation in 1976 and is continually being amended. The substances governed by this regulation cover a wide range of toxic elements and compounds and include arsenic, lead, flourine, aflatoxin $B_1$, hydrocyanic acid, gossypol, theobromine, mustard oils etc. Maximum levels are stated and feed manufacturers have to comply with them in the products they manufacture, although some limits of variation above the maxima are permitted.

A draft Directive has recently been published on pesticide residues fixing maximum permitted levels on and in products intended for animal feeding. However, these proposed maxima are not expected to have any dramatic effect on feed formulation policies.

A major piece of new legislation is the Marketing Directive, which includes more extensive labelling requirements and a drastic revision of the forms of declaration and tolerances. It also permits the open declaration of feed formulae or ingredients on labels.

As raw materials account for about 80 per cent of feed manufacturing costs, some of this legislation is likely to hinder a manufacturer's flexibility to use suitable materials. In addition, they could have quite a significant impact on the supply and pricing of feeds. In the case of the winged bean, there does not appear to be any problem from the point of view of the non-nutrient features listed in the "Undesirable Substances" Directive. On the other hand, as the demands for the safety and quality of food for human consumption become increasingly stringent, studies on potentially hazardous contaminants of natural feed ingredients will also increase. Consequently, some new materials currently being used may become unacceptable, and this could lead to an increase in the value of those ingredients which do not have this problem. In this respect, the winged bean is well placed, but there is no doubt that the impact of this type of legislation on the feed industry through its effect on formulation policies could be increasingly restrictive, thus ultimately inflating the price of the end product.

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# Potential Markets for Winged Bean Oil Particularly in Western Europe

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**World food shortage continues necessitating long term development of food industries in developing countries. Ever increasing energy costs makes inevitable an increase of price in protein during the next 6 years. While previous dependence on U.S. soya oil has been lessened by rapid growth in Malaysian palm oil industry, products such as winged bean oil can make similar impact and will be competitive on any present day costing methods against soya oil.**

**Soyabean requires heavy energy inputs and nitrogenous fertilizers, whereas winged bean increases nitrogen content of soil and produces tuber with significant protein content, thus giving plant higher commercial value than soya.**

**Europe continues to be the world's major importer of vegetable oils. Plans must be laid early to market the production of winged bean and its products within Europe, despite the apparent attraction of easy markets in Asia.**

## INTRODUCTION: WORLD FOOD PRODUCTION

Vegetable oilseeds and oils form part of world food production and cannot be considered without some reference to food production as a whole. In 1976, the latest date for which figures are available, FAO estimates overall food production to have risen by 3%. This is a satisfactory figure in comparison with a population growth of 1.9% Moreover, much of this food increase occurred in the Far East, and may well have been at least equalled in 1977, so that it may be felt that some sort of saturation point in food production may now have been reached because by the end of 1977, world food stocks are probably at their highest levels for 5 years. But these bald figures ignore the severe disproportion between the nations possessing good food production and stocks, and those nations whose dietary energy supplies are still substantially below their nutritional requirements. The FAO has calculated that as much as 1,300 million people are involved in this deficiency and the distress is shared almost equally between the Far East and Africa. The problem, therefore, is not what food can be further absorbed, or economically stored in the rich producer nations, such as the U.S.A. and Canada, but at what price the deprived people can be better fed.

It may even be true that stocks are at record levels precisely because the most seriously affected (MSA) nations cannot afford even the basic necessities of life. Moreover, the population growth in the underdeveloped countries is much faster than in medium developed and developed nations so that the annual growth of food production per capita in the developed nations is four times as great. This is why the poorer countries have increasingly imported food from the richer countries. This is to some extent related to the scale on which agricultural land per inhabitant is available to the two groups of territories.

Some years ago, the FAO established figures which shows this comparison of opportunities:

| | Arable Land | Permanent Grass |
|---|---|---|
| More developed regions | 686 | 1,319 |
| Less developed regions | 741 | 1,536 million hectares |

The USSR and Eastern Europe are considered as belonging to the more developed regions, while Mainland China is covered under the figures for less developed regions. Roughly speaking, since the value of permanent grass is much smaller than that of arable land, these figures mean that the poorer countries have up to now had about 10% more effective food producing territory than that available to richer nations.

But this greater food availability has to be set against population growth in the 45 MSA nations where by the year 2000 the population of these nations is likely to outstrip that of the medium developed and developed nations by four times.

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Up to now, the recorded rate of growth in food production during 1970-1976 was for the MSA 2.1% per annum as compared with the remainder of the world at 2.7%. The solution would appear therefore, that the poorer nations must develop indigenous crops using low cost and, wherever possible, crops which can be exported to sophisticated nations prepared to pay hard currency for such essential foodstuffs.

We should now look at the post 1945 phenomenon that has made possible very large supplies of cheap protein and vegetable oils to those able to pay for them. It has been convincingly shown that, when a country increases its GNP indefinitely, a level is reached where the rate of increase in demand for food levels off. For this reason, the producers of the present surpluses of oils and fats, chiefly highly developed or medium developed nations, have competed fiercely for third markets. A "perverse" situation exists in which the organizational power of modern agricultural nations, such as the U.S.A., Russia, Canada, and others, has brought about the paradox that they are the food exporters to nations such as India, Japan, Korea and similar territories with age long traditions of a society heavily dependent on agriculture. In return the highly industrialized nations such as the U.S.A. and Western Europe have become importers of such recent machine age miracles as electronic computers, cameras, television sets, motor cars, *et al.*, all manufactured by the previously mentioned ancient agricultural based communities.

The obvious desirable solution would be for these essentially agricultural countries to become their own food suppliers (especially protein).

There persists, however, the major problem of teaching these ancient agricultural communities the necessary sophisticated organizational and logistic techniques which can bring their agricultural products competitively to world markets. The fundamental problems are the technological nature required by modern farming, and a learning rate within the developed nations that cannot be matched, for example, in Asia. The formidable obstacles and a relatively low degree of success in teaching the underdeveloped countries has been acknowledged with something like despair.

However, based on the very convincing evidence and calculation, the winged bean demonstrates that, without very complex farming organization, it should be possible to grow it on an ever increasing scale in South East Asia and possibly in other tropical territories, using the abundant labor and techniques, long since discarded in the mechanized and sophisticated agricultural nations of the developed world.

## UNCTAD SUPPORT FUNDS

This is not the occasion when the complex interchanges between the developed and the developing nations conducted under the aegis of UNCTAD should be debated. However, in the words of Mr. Gamani Corea, the Secretary General of UNCTAD, the Colombo Plan is an opportunity for a number of developing countries to meet periodically with donor/export countries and to assess global resource flows. The recent conferences in Manila, Colombo and in Mexico City present proposals for a third world system of payments which would prompt exports, so that some of the inherent weakness resulting from market forces could be overcome by the removal of the economic imbalance between the developed and developing countries. This may aid regional development of new types of crops.

## POLITICAL AND ECONOMIC CONDITIONS ENCOURAGING THE DEVELOPMENT OF THE WINGED BEAN

Many developing countries are actively expanding their GNP and their financial resources at a faster rate than the conventionally described "rich" developed countries, and this seems to me another reason why, ignoring the encouragement of UNCTAD, FAO and other agencies, a product such as the winged bean might well be vigorously promoted under the stimulus of normal market mechanisms.

Successful developing countries, e.g. Malaysia, Nigeria, Thailand, have a specific role, precisely because they now have the economic resources to finance within their own borders, the promotion of new sources of protein such as the winged bean at costs which compare favorably with those of the developed nations, because such territories do not need the machinery and energy inevitable in highly paid and industrialized countries. This leads us to consider the history of international development assistance and food aid by United Nations' agencies and the increasing use of energy in modern intensive farming.

Taking a broad picture, total development assistance in 1976 fell below the estimated needs calculated by FAO at the World Food Conference. Allowing for the increased price of manufactured goods, as cor-

rected under the "tractor index", the shortfall in funds was around US$8,000 Million in 1975, as estimated by FAO. With the costs of energy continuing to rise certainly into the mid 1980's, the richer nations will have less to give, and the receiver nations more need for assistance. The result will be a block in the already slow growth of agriculture in the poorest countries, and will point to only one sound way out, SELF HELP by maximizing production of new crops requiring low energy inputs

The demands of modern farming techniques require constant increases in energy on an advancing scale, particularly in nitrogenous fertilizers and machine investment (Table 1). The winged bean, being a legume, contributes fixed nitrogen to the soil and its optimum growing locations, which include nations and terrain offering abundant labor rather than machine-intensive methods, should ensure the winged bean becomes relatively cheaper each year against crops such as the soyabean predominantly produced in the developed nations.

**Table 1. Energy inputs for maize production in the United States.**

| | 1950 | 1954 | 1959 | 1964 | 1970 |
|---|---|---|---|---|---|
| | Thousands of kilocalories per acre | | | | |
| TOTAL | 1,206.4 | 1,548.3 | 1,889.2 | 2,241.2 | 2,896.8 |
| Labour | 9.8 | 9.3 | 7.6 | 6.0 | 4.9 |
| Machinery | 250.0 | 300.0 | 350.0 | 420.0 | 420.0 |
| Fuel | 615.8 | 688.3 | 724.5 | 760.7 | 797.0 |
| Fertilizer | 151.7 | 295.4 | 441.3 | 582.6 | 1,055.9 |
| whereof N | 126.0 | 226.8 | 344.4 | 487.2 | 940.8 |
| Drying | 30.0 | 60.0 | 100.0 | 120.0 | 120.0 |
| Electricity | 54.0 | 100.0 | 140.0 | 203.0 | 310.0 |
| Yields (Bushels) | 38.0 | 41.0 | 54.0 | 68.0 | 81.0 |
| Inputs (Bushels) | 31.7 | 37.8 | 35.0 | 32.0 | 35.8 |

(SOURCE: Food Production and the Energy Crisis, Science, November 1973, p. 443-449).

Since 1954, the U.S. soybean oil industry has received vast support from the American PL480 programmes and some 5 million tonnes were exported in the period 1955-1973. This programme has been heavily criticized and in general it is to be expected that soybean oil will appear less regularly in Third World markets as a part of U.S. Foreign Policy. This will tend to lift the world vegetable oil price.

## POTENTIAL MARKETS FOR WINGED BEAN OIL PARTICULARLY IN WESTERN EUROPE

As our technical colleagues have described in detail, the specifications of the winged bean plant and its oil and protein yields provide the world with a competitor to the soybean and provide an oil at least equivalent in food value for essential domestic fat products as margarine, salad oils and cooking oils.

To examine the future potential markets of winged bean oil, therefore, we should be on good ground if we made reference to the market for soyabean oil and also to those oils and fats which are interchangeable with soyabean oil.

## LONG TERM PRICE LEVEL — SOYABEAN OIL

In order to determine whether the soybean oil industry, strongly established and magnificently organized, will permit the entry of the winged bean, we need first to consider the maximum price competition that soybean oil can provide against winged bean oil.

The enormous demands for soybeans in the last 20 years has not been much affected by the sharp rise in prices during commodity booms following the OPEC decision to quadrupple the price of oil since 1973, and even in the collapse of the commodity prices. Figure 1 shows the price movements in market quotations. Between 1960 to 1972 in Europe, the world's principal export market, the price of soybean oil averaged about

US$240/te FOB Dutch Port. After rising to around US$800/te in 1974, it is today (mid-Jan 1978) priced at about US$520/te FOB Dutch Port

Figure 2 shows the quoted market prices by reference to the cost of imports as corrected by FAO. It shows that today's quotation for SBO at US$520/te FOB Dutch Port (mid-Jan 1978), in terms of the cost which the primary producers must pay for their imports of fabricated goods, should be corrected by about half to measure it against long term benefits to the grower.

This corrected price may be called the 'tractor index price', since in order to plant his new harvest, the farmer will constantly require to refurbish his farm with new tractors and machinery.

It is worth emphasizing that a highly indutrialized agricultural community such as the existing in the U.S.A. or Western Europe with an immense engineering infrastructure of its own, e. for a limited period, ignore the depreciated value of its farm produce.

Nevertheless, in terms of the tractor index, soybeans at US$5/bushel today ex Chicago, are also at their lowest real level for 17 years. This has resulted from aggressive expansion in Brazil, Argentina, Paraguay, among others, so that we can expect no vary rapid rise in soybean prices for a year.

Thus, based on the real return to the U.S. and Brazilian farmer, soyabeans and their products can only increase in price, not least because of the intensive use of energy that all modern farming demands. Looking at the "tractor index" converted prices, therefore, world prices of both beans and oil are today so low in real terms that the only possible trend seems to be upward and, after a period of consolidation around $6/bushel, the price should rise to a base line of US$8/bushel ex Chicago for soyabeans and US$700/te FOB Dutch Port for soya oil by early 1980.

## CASH RETURNS TO THE ASIAN WB FARMER

Calculations show that even if the present low price of soybeans were to decline by some percentage, which seems highly improbable, it will still pay the WB farmer to grow winged bean in competition with soybeans. Moreover, prices which can be paid for the winged bean appear advantageous when measured against payment received for "traditional" Asian crops e.g. maize, rice, cassava.

## WINGED BEAN PRODUCTION PROSPECTS

Given a long term production of the winged bean, we can depend on its profitability against soybean oil. Indeed, there seems no doubt that, if the winged bean were to be planted in some kind of agricultural utopia, its production by the mid-1980's could be theoretically at least five times the present world total output for soybeans, which in 1977 probably reached around 60 million tonnes. However, this is plainly absurd when one considers the enormous efforts exerted by U.S. farmers and Government to expand its soybean industry from virtually nothing in 1946 to around 40 million tonnes in 1977.

The U.S.A. has vast areas of cleared agricultural land, an expertly administered farm planting policy, relative freedom from natural disasters, an immense road and rail network, a large number of international modern harbors and one of the world's best fleets heavily backed by government support. With these resources, the U.S.A. has become an exporter of 75 to 80% of the world's exported soybeans; more significantly, 35 to 50% of the world's imports of soya oil are U.S. in origin.

Based on the evidence, the practical commercial expectation of winged bean production per annum is 500,000 tonnes by 1980, and about 10 million tonnes by 1984, with a gross value of US$2,500 million.

## COMPETITION AGAINST SOYBEAN OIL FROM VEGOILS PRODUCED IN DEVELOPING COUNTRIES

The strength of the soybean oil market based on U.S. efficiency gives a proper yardstick against which we can compute the chances of winged bean oil. Such is the formidable picture presented by the United States that we must ask whether vegetable oilseeds, when produced in developing countries such as those of South East Asia, can succeed in world markets, particularly in Western Europe.

We may refer to the scope of Western Europe which has regularly imported between 10 million and 11.3 million tonnes of soybeans and about 460,000/te of soybean oil, making a combined oil equivalent of about 2½ million tonnes annually, equivalent to 12.5 million tonnes of soybeans. This is about 60% of U.S. ex-

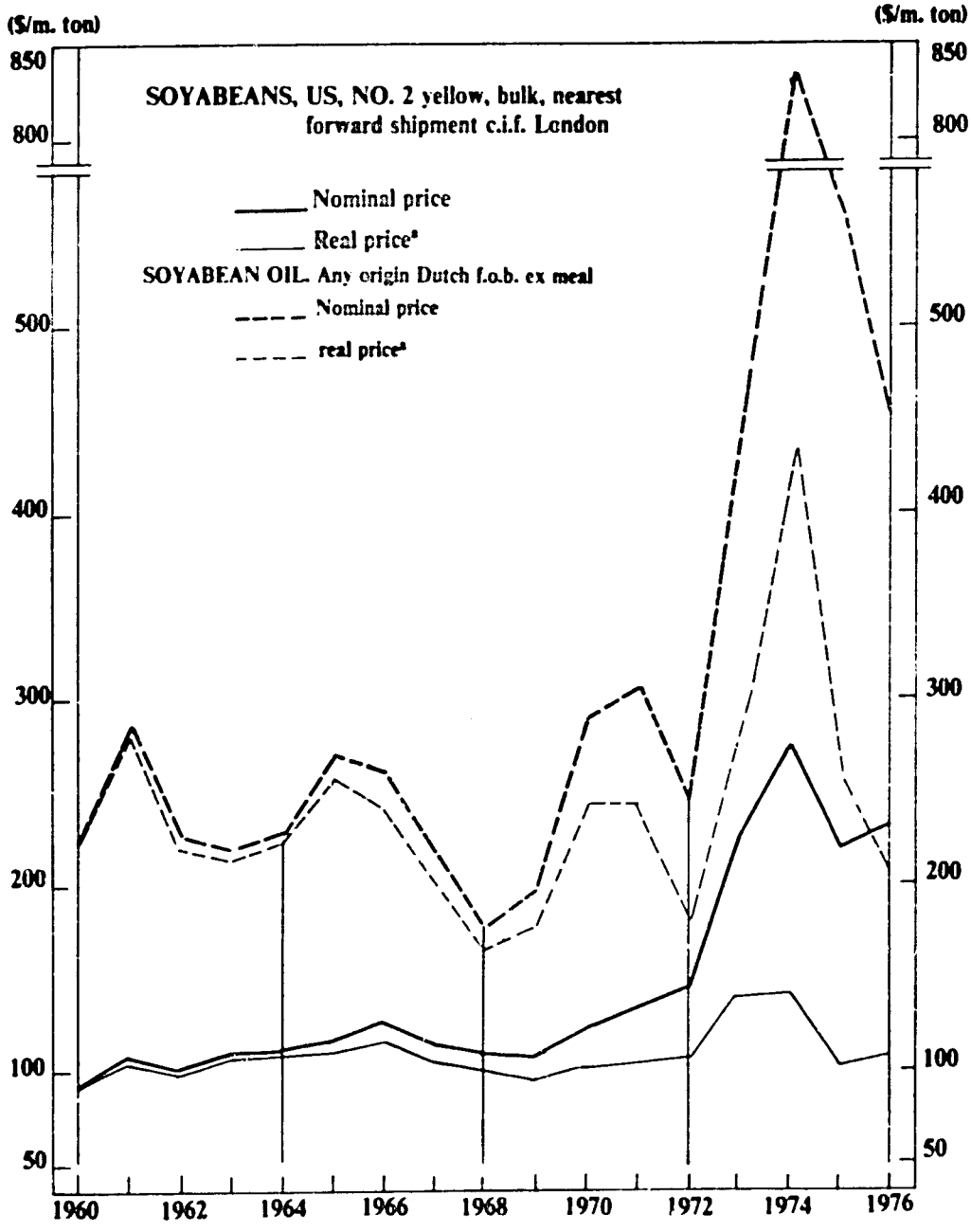


Fig. 1. Annual Prices of Selected Primary Commodities, 1960-1976. (Nominal and real price)

*Nominal Prices divided by United Nations index of export unit values of manufactured goods UNCTAD, Monthly Commodity Price.

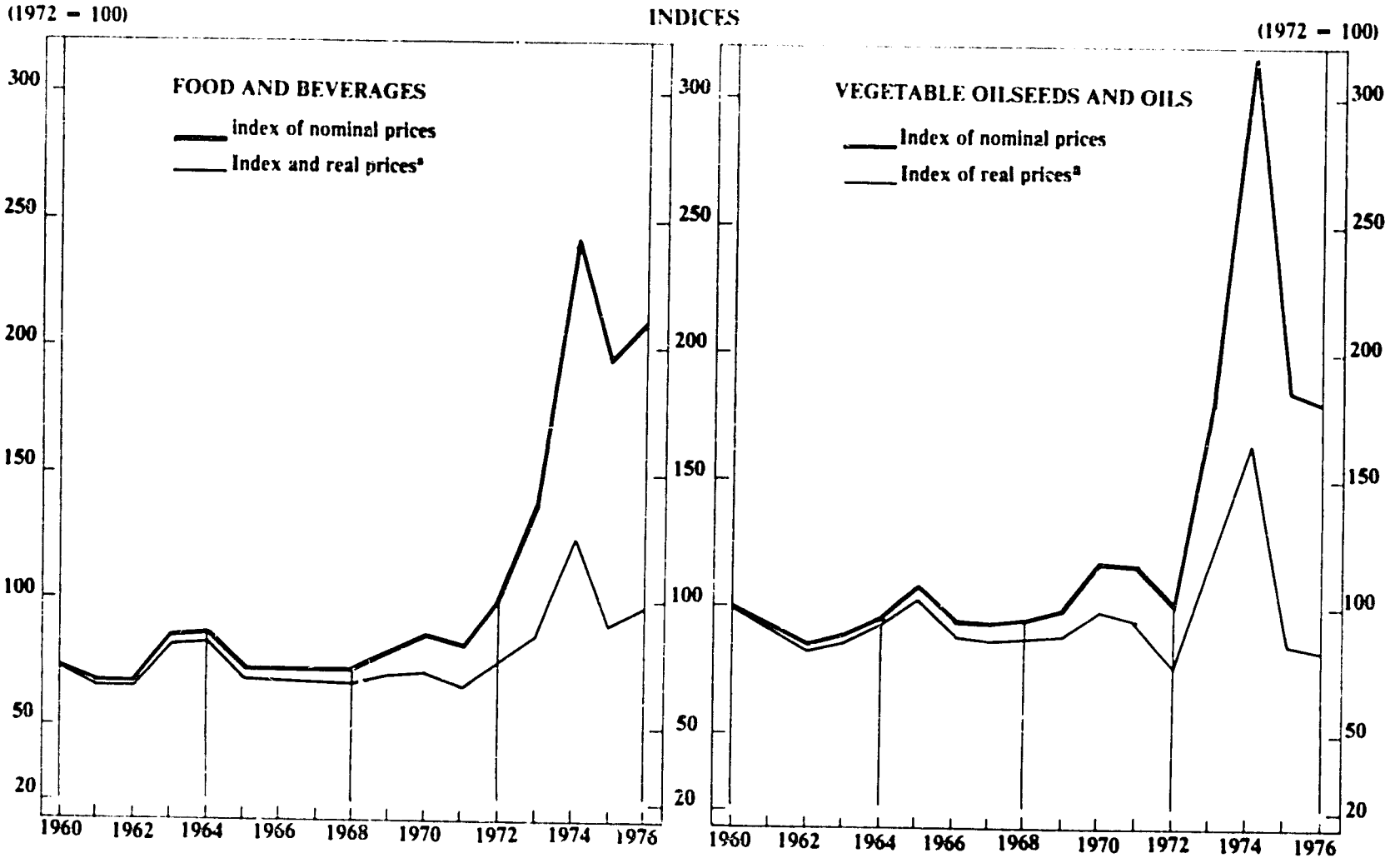


Fig. 2. Annual Prices of Selected Primary Commodities, 1960-1976

[a]Index in current dollar divided by the United Nations index of export unit values of manufactured goods UNCTAD, Monthly Commodity Price Bulletin, Special Supplement, September, 1977.

**Table 2. U.S. soybean exports and imports.**

| CROP YEAR OCT/SEPT | | 1973/74 | 1974/75 | 1975/76 | 1976/77 | 1977/78 |
|---|---|---|---|---|---|---|
| | | | | in 1,000 m t | | |
| 1. Net export availabilities | | 22,900 | 22,300 | 28,800 | 24,500 | 29,218 |
| 2. % + or - | | -- | - 2½% | + 29% | -17½% | + 19¼% |
| 3. Actual net exports | | 20,384 | 19,241 | 24,627 | 23,785 | 25,200 |
| 4. Excess of #1 over #3 | | 2,516 | 3,059 | 4,173 | 715 | 4,018 |
| 5. 4 as % of #1 | | 11% | 13¾% | 14½% | 3% | 13¾% |
| Imports | | | | | | |
| China | Beans | 700 | 340 | 269 | | |
| | Oil | 8 | n/a | n/a | | |
| Indonesia | Beans | — | 13 | 128.5 | | |
| | Oil | -- | -- | -- | | |
| Japan | Beans | 3,161.5 | 3,159 | 3,654 | | |
| | Oil | 17.2 | 18 | 11.5 | | |
| Korea (South) | Beans | 55.8 | 42.2 | 89 | | |
| | Oil | -- | -- | -- | | |
| Malaysian Pen. | Beans | 12.5 | 14.6 | 18.5 | | |
| | Oil | -- | -- | -- | | |
| Philippines | Beans | -- | -- | -- | | |
| | Oil | — | -- | -- | | |
| Taiwan | Beans | 621.1 | 670.5 | 827.6 | | |
| | Oil | 2.0 | 10.3 | 1.0 | | |
| W. Europe | Beans | 10,766.2 | 10,156 | 11,300.6 | 10,985. | |
| | Oil | 465.8 | 466.4 | 460.1 | | |
| W. Europe Beans as % of total exports | | 53% | 53% | 46% | 45¼% | |

Despite this impressive performance, other oils have made a great headway. If we look at lauric oils (coconut oil, palm kernel oil and palm oil), we see that world exports since 1973 have risen from about 2 million tonnes to about 3.3 million tonnes. Almost all of this increase has been contributed by palm oil, a major Asiatic crop, where exports have risen from 1.3 to 2.1 million tonnes.

Malaysia has achieved such confidence that production is planned to increase from around 1½ million tonnes to 4 million tonnes in 1985, by which time Malaysia expects to raise exports by more than double the present figure (1¼ million tonnes to 3½ million tonnes). This increase in exports has not been at the expense of domestic consumption, and there is an important general lesson to be drawn, namely that where a primary producing country with a sufficiently high GNP is also a major exporter of an essential foodstuff, then domestic buyers will be ready to compete with world prices. The important consideration in such a statement is the degree of prosperity within the producer country itself.

Taking Malaysia, Thailand and the Philippines as principal growing areas for winged beans, a substantial volume will certainly find its way into the export market as beans, meal or oil. This is because capital will be found to set up a domestic crushing industry from which valuable foreign exchange will be earned and winged bean oil will tend to find its own level against competing oils, just as has been the case of palm oil.

## EUROPE

The E.E.C. and other Western European countries where major oils and fats are marketed is the biggest single group united by geographical proximity (Table 3).

In South East Asia, only Japan approximates and even then it is fully a third less than the Western European situation (Table 2). It, therefore, seems that Western Europe is the area to which the major long term expansion of vegeoils exports will be directed for some years yet, and it is on Europe's marketing, merchanting, financing, distribution and processing of vegeoils that the world's growers depend.

**Table 3. Major Oils and Fats Disappearance by Major Countries and Areas (1000 M/T)**

| COUNTRY AREA | 1976 77 (est) | 1977 78(est) |
|---|---|---|
| U S A | 7,233 | 7,470 |
| E E C | 8,410 | 8,530 |
| Other Western Europe | 2,236 | 2,300 |
| U S S R | 5,130 | 5,270 |
| Japan | 1,610 | 1,650 |
| India | 3,520 | 3,700 |
| China | 3,300 | 3,400 |
| Other Countries | 16,033 | 16,380 |
| WORLD | 47,472 | 48,700 |

In the great debate between methods of price fixing, there has never been a time of keener interest in the desireability of regular fixed minimum prices against the best realization, as determined by market affairs, than at present. The plight of such commodities as copper, wool, sugar, for example, is again much under review. Nevertheless, there has to be some method considered by all parties, both producer and consumer, which appears fair in adjudicating a contract. It is this function which the European vegeoil market demonstrates.

## SUMMARY

In any good commodity marketing situation, there are a number of universal prerequisites. It has been demonstrated that at least the most important of these could well be met by the winged bean. They are:

1. A social and economic climate promoting enthusiastic producer participation;
2. A steady source of supply on a scale appropriate to the potential market;
3. A wide consumer acceptance of the product;
4. Competitive prices;
5. Marketing, pricing, and distribution facilities that command consumer respect;
6. A strong, well-organized future markets on either or both of the Rotterdamor Chicago models.

## INTERNATIONAL PROTEIN RESEARCH CORPORATION

This company,formed to market the winged bean, has its production members located in Malaysia, The Philippines, and Thailand. The winged bean grows throughout Southeast Asia.

# The Proteins of Winged Bean Seed

*J. M. Gillespie* and *R. J. Blagrove*[1]

**The seed meals of winged bean and soya bean are similar in amino acid composition but their storage globulins are quite different. Analysis in the ultracentrifuge indicates that winged bean seed contains major proteins with sedimentation coefficients of 2S and 6S. Electrophoresis on cellulose acetate resolves three globulins which we have named *psophocarpins* A,B and C. The proteins from these electrophoretic regions have been isolated and partially purified on the basis of differences in solubility with change of pH and ionic strength. *Psophocarpin* A is essentially a single protein comparatively rich in sulphur-containing amino acids while the other fractions are composed of a number of related components which have not been separated. Polyacrylamide gel electrophoresis showed little difference between protein extracts from a number of pure lines of winged bean found in Papua New Guinea except for variation in the proportion of *Psophocarpin* A.**

The winged bean (*Psophocarpus tetragonolobus* (L.) DC.) is at present a little-known tropical legume which shows exceptional promise as a food crop for the humid tropics (Anon 1975). Analysis of the seed proteins (Kapsiotis 1968; Cerny *et al.* 1971) indicates a somewhat better amino acid composition than for most legumes particularly with reference to lysine and the sulphur-containing amino acids. However, the level of cystine and methionine still limits the nutritional value of the seed.

The isolation and characterization of the individual storage proteins from winged beans may assist plant breeders to improve the quality of the seed. For example, in *Lupinus angustifolius* we have found particular proteins which have better than average composition and simple electrophoretic screening procedures have been devised to survey for differences in proportions among genotypes (Blagrove and Gillespie 1975; Gillespie and Blagrove 1975) and to study environmental effects on seed protein quality (Blagrove *et al.* 1976). In this paper suitable methods are described for studying the major groups of proteins present in the seeds of *P. tetragonolobus*. A comparison of the proteins found in a number of genotypes of this species has also been made.

## AMINO ACID COMPOSITION OF WINGED BEAN SEEDS

Amino acid analyses (expressed as residues per 100 residues) of defatted seed meal from winged bean (*P. tetragonolobus*), soya bean (*Glycine max*) and lupin (*Lupinus angustifolius*) are compared below. Only values for the essential amino acids are shown.

| | Winged bean | Soya bean | Lupin |
|---|---|---|---|
| Lysine | 6.77 | 5.65 | 4.47 |
| Threonine | 4.71 | 4.76 | 3.76 |
| ½ Cysteine | 1.67 | 1.82 | 1.76 |
| Valine | 4.48 | 4.24 | 4.52 |
| Methionine | 0.94 | 1.30 | 0.28 |
| Isoleucine | 3.87 | 3.54 | 4.38 |
| Phenylalanine | 4.05 | 3.95 | 3.36 |

The winged bean resembles the soya bean more than the lupin in amino acid composition, particularly in having a moderate content of the sulphur-containing amino acids. However, winged bean contains even more lysine than soya bean, thus increasing its value for supplementing cereal-based diets which are deficient in lysine.

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## EXTRACTION OF THE PROTEINS OF WINGED BEAN SEEDS

In the absence of salt, only small amounts of protein are dissolved at pH values below 5, but as the pH is increased, there is a rapid increase in solubility up to about pH 7 with a slower increase up to pH 10. The pH of the seed meal suspended in water is about 6.6 and at this pH about 60% of the nitrogen is soluble, rising to 75% at pH 10.

In the presence of 10% sodium chloride, as the pH increases from 3 to 5 there is a rapid increase in the amount of nitrogen dissolved up to about 80% with a slow increase from 9 to 11 where a level of about 90% is soluble. At both high and low ionic strength virtually all the dissolved nitrogen is high molecular weight material.

For the studies which follow, proteins were extracted and fractionated by the procedure set out in Figure 1. Full experimental details can be obtained from Gillespie and Blagrove (1978).

10 g defatted seed meal (about 40% protein on DW basis), stir for 4 h at 4°C with 500 ml pH 4.5 buffer (0.2M sodium acetate, 0.25 M sodium chloride, 0.105M acetic acid 0.02% sodium azide), centrifuge.

| Precipitate | Supernatant |
|---|---|
| (Discard) | Add ammonium sulphate to 90% of saturation, stir 2 h, centrifuge. ↓ |
| Precipitate (Complete globulins) | Supernatant |
| Stir with 0.15M phosphate pH 7, dialyse against 0.05M phosphate pH 7, centrifuge. ↓ | (Discard) ↓ |
| Precipitate | Supernatant |
| Crude *psophocarpin A*. Dissolve in acetate-chloride buffer, titrate to pH 4.8 and centrifuge off the precipitate containing impurities. Supernatant contains pure A. ↓ | Dialyse against deionised water in cold for 18 h, titrate to pH 5.4 with imidazole, stir 2 h, centrifuge. ↓ |
| Precipitate | Supernatant |
| pH 5.4 insoluble fraction. Essentially *psophocarpin C* | Essentially *psophocarpin B* |

**Fig. 1. Protein extraction and fractionation.**

## SEPARATION OF WINGED BEAN SEED PROTEINS

It is difficult to assess the total number of protein components present in salt extracts of winged bean seed. In the ultracentrifuge only two major broad peaks are observed with sedimentation coefficients of 2S and 6S. In contrast, most legume seeds contain major 7S and 11S storage globulins (Danielsson 1949). Electrophoresis on cellulose acetate membranes reveals the presence of three components which we have named *psophocarpins* A, B and C in order of increasing mobility. However there are indications from preliminary ion-exchange chromatography on DEAE- and QAE-cellulose that a number of minor protein components are not properly resolved when whole salt extracts are studied electrophoretically.

## AMINO ACID COMPOSITION OF WINGED BEAN SEED PROTEINS

The content (expressed as residues per 100 residues) of essential amino acids in *psophocarpin globulins*, purified *psophocarpin* A and fractions enriched in *psophocarpins* B and C, prepared by the method already outlined are given below.

| | Globulins | Psophocarpins | | |
|---|---|---|---|---|
| | | A | B | C |
| Lysine | 6.72 | 3.53 | 6.42 | 6.87 |
| Threonine | 4.63 | 6.33 | 5.14 | 3.98 |
| ½ Cysteine | 1.57 | 3.22 | 2.52 | 1.27 |
| Valine | 5.73 | 6.79 | 5.97 | 4.93 |
| Methionine | 0.78 | 1.23 | 0.75 | 0.74 |
| Isoleucine | 4.50 | 3.98 | 4.43 | 4.75 |
| Phenylalanine | 4.02 | 4.39 | 3.43 | 3.91 |

There are significant differences between them in many amino acids, particularly lysine, aspartic and glutamic acids, threonine, cystine, methionine and leucine. *Psophocarpin* A is outstanding for its relatively high content of sulphur-amino acids, threonine and valine. It does, however, have a comparatively low level of lysine.

## SUB-UNIT PROTEIN COMPOSITION OF WINGED BEAN GLOBULINS

The polymeric sizes of the isolated winged bean protein fractions have been measured by ultracentrifugation and the number and approximate molecular weights of the sub-units which compose these protein fractions have been studied by electrophoresis in SDS-polyacrylamide gels before and after reduction with *B*-mercaptoethanol

*Psophocarpin* A, and 8S sedimenting species in acetate-chloride buffer at pH 4.5, is disaggregated by SDS to a single monomeric species of apparent molecular weight near 40,000. The polymeric 8S form is probably a tetramer. The 40,000 monomer is composed of two smaller disulphide bonded polypeptides of molecular weights 16,000 and 24,000.

*Psophocarpin* B, a 2S protein fraction, gives a major band of molecular weight 20,000 together with several minor bands of higher molecular weight on SDS-polyacrylamide gels. None of these bands contain components which are disulphide bonded. It is probable that the major 20,000 fraction is normally in the monomeric state.

*Psophocarpin* C, the major 6S component, is dissociated by SDS to give a number of sub-units with molecular weights ranging from 15,000 to 80,000. While reduction has no effect on the electrophoresis pattern of the higher molecular weight *psophocarpin* C sub-units, a minor component of apparent molecular weight 17,000 appears to contain disulphide bonded chains and is replaced by a number of lower molecular weight species after reduction.

## COMPARISON OF PROTEINS FROM A NUMBER OF GENOTYPES OF *P. tetragonolobus*

Although the level of sulphur-containing amino acids limits the nutritional value of winged bean, in comparison with many other legumes, winged bean is relatively rich in these amino acids. However any significant increase in the proportion of *psophocarpins* A and B at the expense of *psophocarpin* C would increase the level of cystine and methionine in the seed. It is not known whether the proportions of these proteins vary between cultivars of the winged bean.

A wealth of genetic diversity has been reported in the winged bean genotypes of the Highlands of Papua New Guinea (Khan 1976). This diversity is exhibited in many of the morphological characters of the plant such as flower, stem, pod and seed colour, pod shape and surface. Unfortunately the seed storage proteins in

the 80 lines we have examined show little diversity. (Blagrove and Gillespie 1978) The SDS polyacrylamide gel slabs for whole extracts of winged bean show up to 20 distinct polypeptide bands but the only major difference between the genotypes was in the proportion of the single band corresponding to *psophocarpin A*. This component was almost absent in some lines. Although it will be possible to select lines which are higher in *psophocarpin A*, any improvement will be limited in scope because the difference between the three types of protein in their content of sulphur-amino acids is not as large as that observed with seeds such as lupin (Blagrove and Gillespie 1975). In the Lupin, a major protein, conglutin B, is devoid of methionine and contains only small amounts of cystine. Unfortunately, amongst the pure lines of winged bean available to us we have not found any differences in the proportion of the proteins which would significantly alter the nutritional value of the seed.

## COMMERCIAL RECOVERY OF WINGED BEAN PROTEIN

The National Academy of Sciences report on the winged bean (Anon. 1975) points to the need for research on the extraction of oil and the use of the residual protein-rich seed meal in food. It is suggested that a protein curd might be produced in the same way that protein isolates are made from the soya bean. Considering the amount of agronomic research that would be needed to transform the winged bean into a commercial crop, it seems unlikely to be used in this way for many years. As with soya bean, most of the protein can be extracted from winged bean meal with dilute alkali. However economic recovery of the protein is likely to prove difficult for we have found that in the presence of the salt produced by neutralization of the alkaline extract only part of the protein precipitates at pH 2. Even if the salt were removed and the protein precipitated at pH 5.4, only a limited recovery (60-70%) would be expected. Further studies are needed to optimize the conditions for commercial extraction of the protein.

## CONCLUSIONS

As studies of the storage proteins of various legume seeds are extended, it is apparent that unless the plants are closely related genetically, the proportions and properties of the seed proteins can differ markedly. Winged bean can be classed with the other legume seeds whose storage proteins appear to be water soluble. This classification is quite arbitrary since if the pH of the winged bean meal-water slurry is below the natural pH of about 6.6 there is a progressive decrease in the amount of soluble protein. It is probable that something more than the inherent solubility of the proteins is involved in this decreased extraction, perhaps the disruption of internal membranes.

Characteristically legume seeds contain a group of very heterogeneous proteins, generally regarded as being metabolic, which are soluble at their isoelectric points in the absence of salt and are thus classed as albumins to distinguish them from the storage proteins which are globulin in nature. We have been unable to identify an albumin fraction from the winged bean. It is most likely to be amongst the components of the pH 5.4 soluble fraction (see fractionation scheme), in which case an upper limit to their proportion can be set at about 15% of the proteins. However, the very small amounts of protein extracted by water from the seed at pH values below 5 suggest that these seeds contain only small amounts of metabolic proteins.

Although the overall distribution of amino acids in *psophocarpins* B and C is similar to other legume seed globulins, for example, legumin and vicilin of the pea (Derbyshire *et al.* 1976), there are marked differences in several amino acids. Whereas for many legumes it is possible to identify legumin-like and vicilin-like proteins with sedimentation coefficients of 11S and 7S respectively, it does not seem possible to do this for the winged bean. *Psophocarpin* C, with a sedimentation coefficient near 7S, would appear most like a vicilin type protein but differs from most of these in its comparatively high content of methionine.

Our results with winged bean emphasize the remarkable range in properties of legume storage proteins. It is not possible to assume that conditions of isolation and characterization of these proteins will apply equally well to all legume seeds. Thus it is hoped that our studies will enable plant breeders to assess the range of protein types present in various winged bean cultivars and assist their efforts to exploit the remarkable potential of this crop.

## ACKNOWLEDGEMENT

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# The Processing and Formulation of Weaning Foods Based on the Winged Bean

*J. Maud Kordylas, Yaa Difie Osei* and *E. Asibey-Berko*[1]

**This experiment set out to process winged beans into flour and to utilize the processed flour in combination with other vegetable protein sources in the formulation of weaning foods. The efficiency of utilization of these vegetable protein combinations were tested by animal feeding trials. Because of variation found to exist in the protein contents of the experimental diets, PER values were considered not to be comparable and therefore may not give accurate evaluation. Protein Conversion Ratios (PCR) based on protein retention in the carcass on dried weight basis and total dietary protein intake also on dried weight basis were therefore used as basis for comparison and evaluation.**

**The basis for the method used in the evaluation of the protein efficiencies of the formulations were discussed. A suggestion has been made that although the winged bean can be utilized as the main source of protein in combination with other cereals in the formulation of weaning foods, it is necessary to provide an adequate minimum protein level which in this case was found to be about 16 percent rather than a higher percentage level. The results of the experiments brought to light that there is an inverse relationship between efficiency of protein utilization (PCR) and the percent dietary protein level. Protein levels in various existing vegetable protein mixtures were reviewed and found to be very high. Doubts were therefore stressed whether there are any benefits to be derived from the practice of making vegetable protein mixture with very high levels of protein.**

## INTRODUCTION

Previous work done in our laboratories in Ghana revealed that the dried matured seeds of the winged bean have a nutritional potential that can be compared favourably with that of the soybean. The quality of the proteins were also shown to be similar to those of the soybean in digestibility and composition (Cerny et al. 1971). Trial feeding of children suffering from kwashiorkor, with a diet in which the winged bean provided the major part of the protein gave children results which showed that the winged bean can be well tolerated by children and that it can be safely utilized as a vegetable protein substitute for milk in the treatment of protein calorie malnutrition in Ghanaian children (Cerny and Addy, 1972).

Although the winged bean has the advantage over the soybean, of possessing a pleasant sweet taste, its skin is tough and difficult to remove and therefore makes direct utilization of the dried seed as human food problematic (Kordylas, 1976). To explore the nutritional potential of the winged bean seed therefore, industrial processing of the seed into easily usable products is highly desirable. This paper reports on a laboratory attempt made in the processing of the dried matured winged been seed into flour and results obtained with trial feeding to laboratory animals of weaning formulations based on the flour.

## EXPERIMENTAL PROCEDURE

### Processing of Seeds

Dried matured winged bean seeds (*Psophocarpus tetragonolobus*) were used for the experiment. A sample batch of seeds was washed, steeped in water overnight, autoclaved, cooled and seedcoats removed by hand. The cleaned seeds were dried and coarsely milled for solvent extraction of the fat. The defatted meal was thoroughly dried till all traces of solvent had been removed before being finely milled and sifted to produce to the winged bean flour. Samples of groundnut (*Arachis hypogea*) and melon seed (*Cucumeropisis edulis*) were given similar treatment to obtain defatted groundnut and melon seed flours respectively. The amino acid composition of the groundnuts and melon seeds were kindly determined for us by the Food Industry Research Institute, Czech Academy of Agriculture, Prague. Samples of maize, rice and guinea corn used in the preparation of the diets were pre cooked, dried, milled and sifted to obtain fine cereal meals. Skimmed milk powder was obtained from local sources.

**Preparation of the Weaning Formulations**

Six weaning formulations were prepared. The protein contents of the first three diets — Diets I, II & III were adjusted to 16 percent, with Diet I containing Winged Bean (WB) and Corn meal (C); Diet II — Winged Bean (WB), Groundnut (G) and Corn meal (C); Diet III — Winged Bean (WB), Melon seed (M) and Corn meal (C). The remaining three diets were prepared to contain 16 percent protein from Winged Bean and 3.3 percent protein from either Corn meal (C) Guinea corn (GC) or Rice (R) to make Diets IV, V and VI respectively with a total protein content of 19.3 percent. A milk diet, Diet VII, in which skimmed milk powder provided 12 percent protein while corn meal supplied the remaining 4 percent was used as the control diet at 16 percent protein level. Codliver oil was added to all the diets at a level of 1% and the total fat was adjusted to 15% level with groundnut oil. All the diets included 10% sucrose and 4% mineral mixture and provided between 404 to 406 calories per 100 gm. Since a lot of different sources of protein were introduced into the diet formulations, the moisture and crude protein on both wet and dried weight basis were determined on all the diets in order to find some common basis when evaluating the various protein combinations.

**Testing of the Weaning Formulations**

Groups of hooded weaning rats obtained from the Food Research Institute rat stock were matched with respect to litter, initial body weight. These were utilized as test rats for the various winged been cereal weaning formulations. The rats were placed in individual cages, four rats per group, food and water were provided ad lib and food consumption was recorded daily while the rats were weighed three times per week. The feeding experiment was continued for a total of 30 days at the end of which, the animals were sacrificed and their bodies dried to determine body moisture and protein contents of the carcasses. Carcass fat was also determined by difference.

## RESULTS

**Composition of the Vegetable Protein Seeds**

Composition of the vegetable seeds used as protein sources in the formulation of the diets are shown in Table 1. After solvent extraction of the oil from the seeds, crude protein content of the flours produced were found to be 70.0 g per 100 g for the melon seed flour, 57.2 g per 100 g for the groundnut flour and 57.3 g per 100 g for the winged bean flour. Seed coat, cours grits and oil were obtained as a by-products. Analyses done on the seed coat and grits obtained from the winged beans gave 7.0 g and 42.4 percent protein respectively (Table 1).

**Table 1. Composition of the vegetable seeds used as protein sources in the formulation of the diets: g/100g.**

| Name | Moisture g | Crude Protein N × 6.25% | Fat g | Carbohydrate g | Fibre g | Ash mg | Calcium mg | Iron mg |
|---|---|---|---|---|---|---|---|---|
| Melon Seed (*Citrullus colocynthis*) | 5.2 | 22.9 | 54.4 | 14.2 | 2.4 | 3.4 | 130 | – |
| Melon Seed Flour | 4.5 | 70.0 | 6.2 | – | – | 7.0 | – | – |
| Groundnut (*Arachis hypogaea*) | 4.5 | 23.4 | 47.9 | 22.0 | 2.3 | 2.2 | 83 | – |
| Groundnut Flour | 6.3 | 57.2 | 4.6 | – | – | 4.5 | – | – |
| Winged Bean* (*Psophocarpus tetragonolobus*) | 9.7 | 37.3 | 18.1 | 25.2 | 5.4 | 4.3 | 200 | – |
| Winged Bean Flour | 4.9 | 57.3 | 2.2 | – | – | 3.8 | 3.8 | – |
| Winged Bean Seed Coat | (By product) 46.3 | 7.0 | 0.7 | – | – | 1.8 | 21.0 | 11.0 |
| Winged Bean Grits | (By product) 4.9 | 42.4 | 8.4 | – | 1.2 | 3.7 | – | – |

*Cerny, et. al. (1971).

Table 2 gives the amino acid composition of the melon seed and groundnut seed as compared with that of the winged bean. It can be noted that although the lysine contents of the melon and groundnut seeds were lower than the winged bean, the methionine level in the melon seed was twice as high as that obtained in the winged bean. This was used as basis for including a diet composed of winged bean and melon seed mixtures, hoping that the methionine of the melon seed would supplement that of the winged beans.

**Table 2. Amino acid composition of vegetable seeds used as protein sources — melonseed, groundnuts and winged bean (g/16gN).**

| Amino Acid | Melon Seed | Groundnut | Winged Bean* |
|---|---|---|---|
| Arginine | 13.9 | 8.7 | 6.5 |
| Histidine | 2.6 | 2.1 | 2.7 |
| Lysine | 3.2 | 2.8 | 8.0 |
| Tyrosine | 3.3 | 3.4 | 3.2 |
| Tryptophan | N.D. | N.D. | N.D. (Not Done) |
| Phenyl Alanine | 5.8 | 4.7 | 5.8 |
| Cystine | 0.5 | trace | 1.6 |
| Methionine | 2.5 | 0.6 | 1.2 |
| Serine | 4.4 | 3.8 | 4.9 |
| Threonine | 4.1 | 2.3 | 4.3 |
| Leucine | 6.7 | 5.7 | 9.0 |
| Isoleucine | 4.2 | 3.0 | 4.9 |
| Valine | 6.2 | 4.7 | 4.9 |
| Glutamic Acid | 17.7 | 15.5 | 15.3 |
| Aspartic Acid | 8.8 | 9.7 | 11.5 |
| Glycine | 5.0 | 5.2 | 4.3 |
| Alanine | 5.0 | 3.5 | 4.2 |
| Proline | 5.0 | 3.8 | 6.9 |

*Cerny et al (1971).

## Protein Intake

Results for moisture, protein content based on wet and dried weight of the diet, mean diet intake and mean protein intake (dried weight basis) of the groups of rats put on the various diets are shown in Table 3. It can be pointed out that although the diets were carefully mixed to contain either 16 or 19.3 percent protein, the actual protein levels as analyzed showed differences which ranged from 0.18 to 3.02 from the supposed protein levels. There were variations in the moisture contents of the various diets, which also affected the final protein contents when determined on dried weight basis. The mean protein intake of the groups on dried weight basis over the 30 days experimental period are shown to vary from 33.8 to 52.8 with the highest protein intake of 52.8g corresponding to the highest food intake by the milk control group.

**Table 3. Moisture and protein content of the diets in relation to intake and protein efficiency.**

| | I<br>WB + C | II<br>WB + G + C | III<br>WB + M + C | IV<br>WB + C | V<br>WB + GC | VI<br>WB + R | VII<br>MILK + C |
|---|---|---|---|---|---|---|---|
| Protein g/100 g (Calculated) | 16.0 | 16.0 | 16.0 | 19.3 | 19.3 | 19.3 | 16.0 |
| Moisture g/100g (Analyzed) | 8.98 | 7.81 | 9.07 | 6.92 | 7.82 | 4.82 | 4.75 |
| Protein g/100 (Dried wt basis) | 18.08<br>19.86 | 16.34<br>19.89 | 17.74<br>19.51 | 16.28<br>17.49 | 21.90<br>23.75 | 18.73<br>19.62 | 16.18<br>16.99 |
| Total Diet Intake Mean + SD g Moisture | 216.5 ± 11.9 | 243.5 ± 36.7 | 217 ± 23.8 | 206.3 ± 25.8 | 224.8 ± 20.2 | 180.6 ± 25.1 | 326 ± 26.9 |
| Total Diet Intake Mean + SD G | 19.4 ± 1.1 | 19.0 ± 2.9 | 19.8 ± 2.2 | 12.9 ± 3.0 | 17.8 ± 1.6 | 8.2 ± 1.2 | 15.5 ± 1.3 |
| Protein in Total Diet Intake (Dried wt basis) Mean + SD | 19.2 ± 2.0 | 44.6 ± 6.2 | 38.6 ± 3.9 | 49.2 ± 3.8 | 33.8 ± 6.2 | 52.8 ± 4.1 | |

WB: winged bean G: groundnut GC: Gelaea corn
C: corn meal M: melon seed R: rice

## Growth

Figure 1 shows the growth curves obtained for the various groups of rats put on the different dietary formulations over the 30 days experimental period. The mean weight gains and mean final body weights are shown in Table 4. An attempt was made to determine the composition of each rat body as obtained at its final weight and these are presented as mean body moisture, dried carcass protein and dried carcass fat (by difference). It can be seen that for each group of rats the sum total of the body moisture, carcass protein add up to the final body weight. It is also interesting to note that in almost all cases the ratio of body moisture to dried carcass protein to dried carcass fat is 4:1:1 as shown in parenthesis in Table 4.

**Table 4. Moisture, protein and fat content of the body in relation to weight and weight gains**

| Diet | Initial Body Weight Mean g | Final Body Weight Mean ± SD g | Weight Gained Mean ± SD g | Body Moisture Mean ± SD g | Dried Carcass Mean ± SD g | Dried Carcass Protein Mean ± SD g |
|---|---|---|---|---|---|---|
| I — WB + C | 42.6 | 101.2 ± 9.0 | 58.6 ± 4.2 | 66.9 ± 1.4 (1.0) | 16.7 ± 1.8 (1.0) | 17.5 ± 1.5 (1.0) |
| II — WB + G + C | 41.8 | 106.7 ± 25.5 | 64.9 ± 19.2 | 69.8 ± 13.7 (3.8) | 18.6 ± 3.8 (1.0) | 18.3 ± 5.0 (0.98) |
| III — WB + M — C | 42.0 | 96.1 ± 8.8 | 54.1 ± 8.9 | 63.6 ± 7.2 (3.9) | 16.2 ± 1.6 (1.0) | 16.4 ± 1.0 (1.0) |
| IV — WB + C | 41.6 | 98.6 ± 18.7 | 57.1 ± 14.2 | 65.8 ± 12.8 (4.0) | 16.3 ± 3.5 (1.0) | 16.5 ± 4.0 (1.0) |
| V — WB + GC | 41.9 | 104.4 ± 13.0 | 62.3 ± 7.9 | 70.6 ± 7.1 (4.1) | 17.3 ± 2.0 (1.0) | 16.5 ± 2.2 (0.95) |
| VI — WB + R | 42.5 | 80.5 ± 11.1 | 38.5 ± 7.2 | 54.2 ± 6.7 (4.1) | 13.2 ± 1.6 (1.0) | 13.4 ± 3.5 (1.0) |
| VII — Milk + C | 41.8 | 157.3 ± 31.4 | 115.5 ± 27.5 | 103.8 ± 23.1 (4.0) | 26.2 ± 5.8 (1.0) | 27.3 ± 3.0 (1.0) |
| Final Body Wt M P F — Ratio | | | | 4 | 1 | 1 |

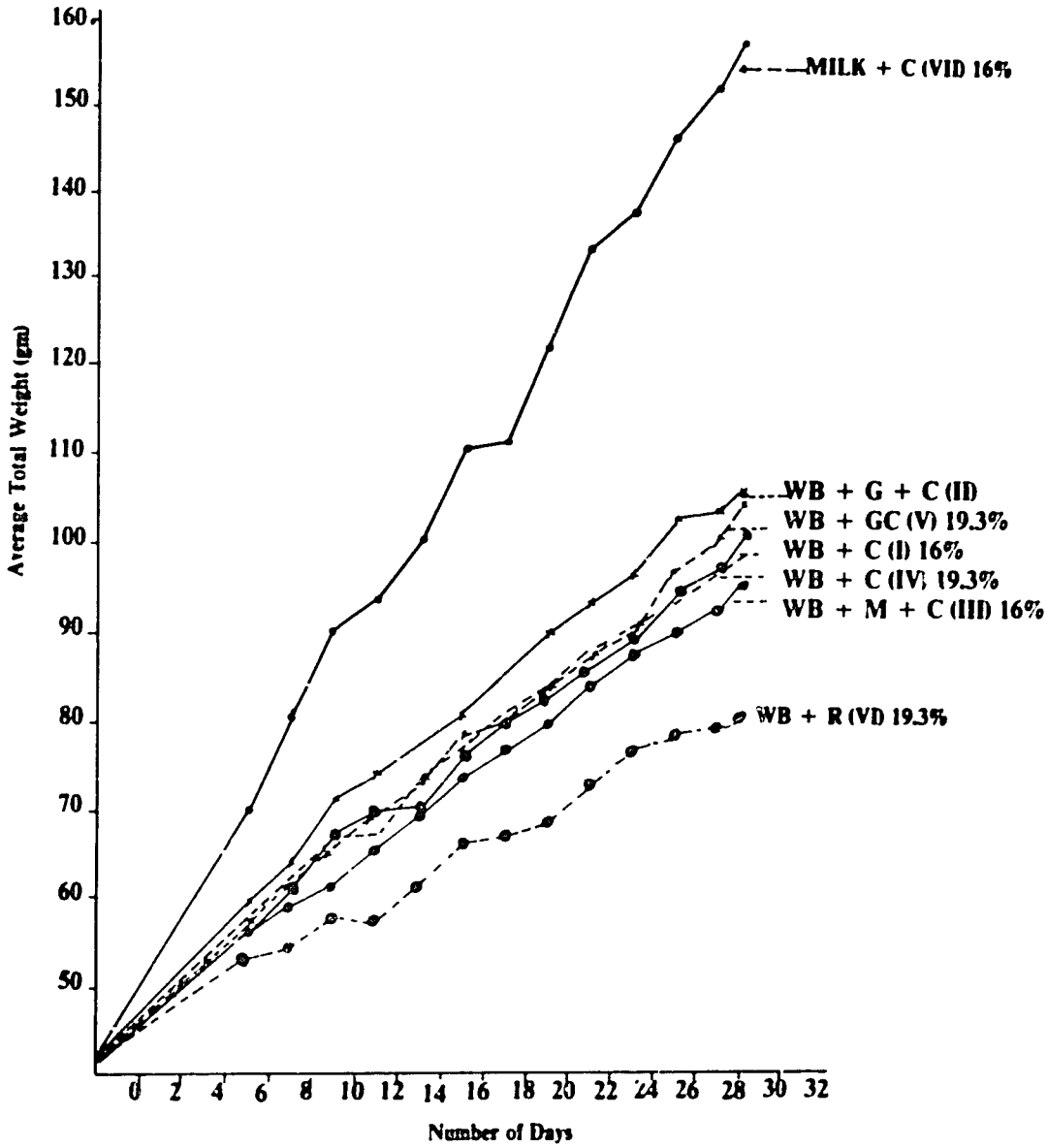


**Fig. 1. Growth curves of the group of rats under various weaning formulations (WB—winged bean: C—corn meal; G—groundnut; M—melon seed: R-rice).**

**Evaluation of Protein Efficiency**

The PER as calculated for the various diets are shown in Table 5. According to the values obtained the order of efficiency of the protein combinations as given in the diets are: Diet VII milk control (16.189 P) → Diet IV WB + C (16.28% P) → Diet I, WB + C (18.08% P) → WB + G + C (18.34% P) → WB + M + C (17.74% P) → WB + GC (21.90% P) → WB + R (18.73% P).

Protein Conversion Ratio (PCR) based on dried carcass protein and total dried dietary protein intake were calculated for each of the groups, the results of which are shown in Table 5. The amounts of dietary protain needed to deposit one gram of carcass protein were determined for each group and the results are also shown in Table 5. The figures in parenthesis in Table 5 compare the order of efficiency of protein utilization in the diets as determined by PER, PCR and weight gain.

Table 5. Relationship between protein intake and carcass protein.

| Diets | I<br>WB + C | II<br>WB + G + C | III<br>WB + M + C | IV<br>WB + C | V<br>WB + GC | VI<br>WB + R | VII<br>MILK + C |
|---|---|---|---|---|---|---|---|
| PER | 1.65<br>(3) | 1.58<br>(4) | 1.53<br>(5) | 1.62<br>(2) | 1.38<br>(6) | 1.24<br>(7) | 2.30<br>(1) |
| Protein Intake, g (Dried wt) | 39.2 | 44.6 | 38.6 | 33.6 | 49.2 | 33.8 | 52.8 |
| Carcass Protein, g (Dried wt) | 16.7 | 18.6 | 16.2 | 16.3 | 17.3 | 13.2 | 26.2 |
| PCR | | | | | | | |
| Carcass Protein / Protein Intake | 0.426 ± .038<br>(3) | 0.417 ± .030<br>(5) | 0.420 ± .032<br>(4) | 0.481 ± .051<br>(2) | 0.352 ± .030<br>(7) | 0.390 ± .068<br>(6) | 0.496 ± .129<br>(1) |
| Protein Intake per gm carcass protein | 2.35<br>(3) | 2.39<br>(5) | 2.38<br>(4) | 2.07<br>(2) | 2.84<br>(7) | 2.56<br>(6) | 2.01<br>(1) |
| Weight gained, g | 58.6<br>(4) | 64.9<br>(2) | 54.1<br>(6) | 57.1<br>(5) | 62.3<br>(3) | 38.5<br>(7) | 115.5<br>(1) |

## DISCUSSION

### Basis for the Method of Evaluation of Protein Efficiency Used in this Study

Since various combinations of proteins were fed and there were some variations in the protein contents of the different diets (Table 3), it was felt that the conventional PER as usually calculated (based on weight gain and protein intake) could not be accurately used to evaluate the efficiency or the quality of the protein combinations as given in these diets. According to Allison (1955) PER varies with protein content of the diet, the ratio increasing to a maximum and then decreasing as the level of dietary protein is raised. The protein, therefore must be fed at an adequate but not excessive level, since at high levels, the weight gain does not increase proportionately, with the protein intake. It has also been suggested that methods that precisely define protein retention are likely to yield more accurate results than PER values. An attempt was therefore made in this study, to evaluate the protein efficiency on the basis of carcass protein retention.

Although water content of foods does not contribute to nutritive value in the usual sense, energy value tends to vary inversely with water content. As water content increases, the protein, carbohydrates and fats that contribute to the value of the foods tend to be present in relatively less amounts. This fact is usually ignored when preparing diets for protein efficiency evaluation. Although care is taken to balance the major nutrients in the diets, the moisture content is more often ignored, hence the protein intake per unit of diet eaten may invariably differ, thus not giving the experimental animal groups the chance of equal proteins intake per unit diet.

Although the moisture content of the experimental diets in this experiment was not initially balanced, care was taken at the end of the experiment to determine the moisture contents in order to calculate the mean protein intake per group on dried weight basis thus giving some absolute basis on which to make comparisons (Table 3) between the efficiency of the dietary proteins eaten in relation to retained carcass protein.

With the ratio of 4:1:1 (Body Moisture: Dried Carcass Protein: Dried Carcass Fat) found to exist with various Body Weights analysed at the end of the experiment, (Table 4), it could be assumed that this ratio

may exist throughout the growing period. The initial dried carcass protein for each rat, could therefore be calculated from this ratio; this, subtracted from the final dried carcass protein would give the value of dried carcass protein, which could then be directly related to the sum total of dietary protein eaten, metabolized and retained during the experimental period. Absolute conversion values could then be calculated for each diet and used as a more accurate basis for comparison of the dietary protein combinations fed in the experiment.

It was however felt that since the mean initial weights of the groups did not differ much at the beginning of the experiment, and since no initial dried carcass protein was determined at the beginning of the experiment, the final dried carcass protein analysed for, could be utilized for the calculations to give comparable though not absolute values for evaluation of the efficiency of utilization of the dietary protein. Thus Protein Conversion Ratios (PCR) were calculated for each rat by dividing the final dried carcass protein by the total dried dietary protein consumed during the experimental period. The mean and standard deviations of these ratios obtained and shown in Table 5 gave the efficiency of conversion of one gram of dietary protein eaten into carcass protein to be in the order of 0.496 for the Milk Control group Diet VII (16.18% P) 0.481 for Diet IV (WB + C, 16.28% P) 0.426 — Diet I (WB + C, 18.08% P) 0.420 — Diet III (WB + M + C, 17.74% P) 0.417 — Diet II (WB + C + Cr) 0.390 — Diet VI (WB + R, 18.73% P) 0.352 — Diet V (WB + GC 21.90% P). Comparing the PER and PCR values, it can be seen that the evaluation of the first three diets corresponded in efficiency when both methods were considered. Diet III which was given a fourth position with the PCR evaluation, however was considered fifth with the PER evaluation. The positions of Diets V and VI, were also reversed with the PER evaluation making winged bean and rice combination a much inferior mixture, at the protein level fed, to the Winged Bean and guinea corn mixture.

The ratio of 4:1:1 also revealed that whether the dietary protein came from animal or vegetable sources, the same ratio of body moisture to dried carcass protein to dried carcass fat, in relation to body weight was maintained during the growing period. For this ratio, which could be equated to growth, to occur, the quality of the protein in the diet must be optimum and in such levels that only some minimum amount would be required to provide the necessary tools for the ratio of 4:1:1 to be achieved in the shortest possible time.

The lower the protein quality, the more would need to be eaten, hence the longer the time needed for this growth to be achieved. Determination of the minimum dietary protein eaten per gram of carcass protein deposited may be used as a basis for comparison and evaluation of efficient utilization of the protein given. Thus dividing the total amount (dried wt basis) of dietary protein intake over the specified period, by the deposited carcass protein produced over the same period (Final dried carcass protein — Initial dried carcass protein) would provide the amount of dietary protein eaten for retention of one gram of carcass protein. Using the same reasoning as before, such values were calculated based on the final carcass protein to obtain the figures shown in table 5. Diet VII needed about 2.01 gms of dietary protein to be eaten gm carcass protein as compared with 2.07 for Diet IV, 2.35 for Diet I, 2.38 for Diet III, 2.39 for Diet II, 2.56 for Diet VI and 2.84 for Diet V. The Diet with the least dietary protein intake her gram carcass protein deposited thus showed the fastest growth rate. It is suggested that if all the dietary components, protein level, carbohydrate, fat, energy and moisture had been properly balanced in the experimental diets given, the growth rates alone might have reflected the protein quality.

**Relation between Percent Dietary Protein Level and Efficiency Utilization**

Most weaning formulations based on vegetable protein sources have protein contents higher than 16 percent. Some examples are soy corn mixture made in Brazil with 30 percent protein; groundnut and wheat preparation produced in India with 42 percent protein. A mixture of groundnut, millet and milk produced in Senegal has between 18 to 20 percent protein. Cotton seed, soya, rice, sorghum and wheat mixture made in Central and South America has between 25 to 35 percent protein. In South Africa, a mixture of soya, groundnut, fish protein, maize and wheat germ preparation produced there has 22 percent protein. Another product produced in Rhodesia containing maize, soya, groundnut, fish and skimmed milk in 23.4 percent protein and Uganda has a product made up of groundnut, skimmed milk and maize flour which contains 20 percent protein (Orr and Adair, 1967).

In preparation the weaning formulations tested in this experiment, a deliberate attempt was made to evaluate the efficiency of utilization of two protein levels, that at 16 percent and 19.3 percent. As indicated in table 3, the actual protein levels of the prepared diets tested varied from 16.18 to 21.90 percent. This,

therefore, provided sufficient dietary protein percent range to enable an assessment of the relationship between dietary protein level and the efficiency of utilization of the dietary protein. Fig. 2 illustrates the relationship between percent dietary protein content and Protein Conversion Ratio (PCR). The graph reveals a definite inverse relation between the protein content of the diet and the efficiency with which it was utilized by the body, with the highest efficiency ratios being associated with the lowest percent protein levels, those nearest 16 percent in this case. The same point was further illustrated by the fact that Diets I and IV which were both composed of winged bean and corn meal were not rated with the same efficiency although they were of similar composition with respect to protein quality. Diet IV with the lower protein content (16.28%) was shown to have a better protein efficiency than Diet I with the higher percentage protein level (18.08%). (Table 3 & 5).

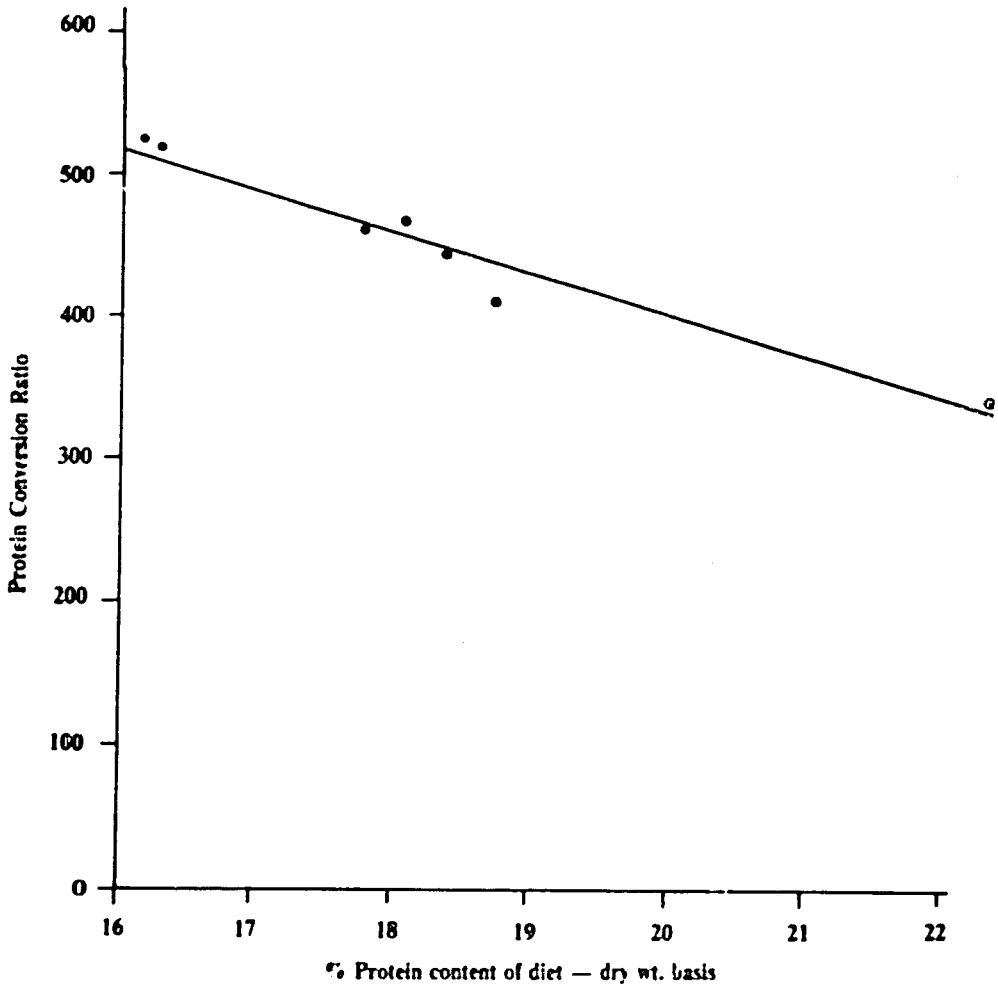


**Fig. 2. Relationship between protein content of diet (dry wt. basis) and protein conversion ratio.**

These results, therefore reveal that not only does the efficiency of utilization of dietary protein in the body depend on the quality of the proteins in the diet, but may also be dependent on some desirable protein level. Such a desirable level must be ascertained in order to make the most optimum combination with available proteins so that the maximum efficient utilization could be obtained.

The fact that a definite inverse relationship has been shown in this study to exist between the percentage dietary protein level and the efficiency of utilization therefore, puts some doubts on whether there are any benefits to be derived from the practice of making vegetable protein mixtures with very high levels of protein.

## CONCLUSION

It can be concluded that weaning formulations can be made from the winged bean as the main source of protein in combination with other cereals. The minimum percentage protein level needed in the weaning formulation to give maximum protein efficiency, however must be determined on the mixtures formulated since the results of this experiment brought to light that there is an inverse relation between the efficiency of protein utilization and the percentage level of dietary protein. Sixteen percent protein level in this case was found to give better efficiency of protein utilization than the higher dietary protein levels. Doubts have therefore been stressed on whether there are benefits to be gained with the practice of making vegetable protein mixtures with very high levels of protein.

## ACKNOWLEDGEMENT

The authors wish to acknowledge the help given to them by Mrs. P. Lokko with the animal experiments. Mr. Antonio, for his help with the chemical analysis, Miss Nelson, Mr. Abeka and Mr. Asiem for their technical assistance.

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# A Simple Technique To Make Dried Winged Bean Seeds Edible

*Franklin W. Martin* and *Ruth M. Ruberte*[1]

Recent interest has been expressed on the winged bean due to the high protein content of all plant parts (Masefield, 1973, Anon., 1975). In our own tests, protein contents of 64 introduced lines varied from 29.2 to 40.9%. Such measurements have led some investigators to compare the winged bean to soybean as a potential high protein crop for the tropics.

Yet little effort has been made to utilize the dried winged bean seed. Normally, the winged bean is used for its succulent young pods which is comparable to string beans, and for its tuberous roots. Less frequently the leaves are cooked as a spinach-like vegetable. Seeds of more mature but still green pods are sometimes removed from the pod and boiled or parched. Probably no region of the tropics use the seeds regularly as food.

Accounts of usage of mature seeds are fragmentary and do not give a clear picture. Seeds are parched in Java (Burkill, 1935) but probably only immature seeds are used. They are used for making a vegetable curd similar to tofu from soybean, but our experience showed that such curds are definitely inferior to those of soybean. The long time necessary for cooking after soaking (4 hours or more) has been suggested as an obstacle to the use of the dried seed. Furthermore, the heavy seed has been suggested to cause abdominal pains. In West Africa, Cerny, et al. (1971) reported that people are accustomed to the "nutty" flavor of the beans. Surely, the evidence is persuasive that dry winged bean seeds are difficult to eat.

These early findings were confirmed in tests of 20 different lines of winged bean seeds at the Mayaguez Institute of Tropical Agriculture. Seeds left to soak absorbed water slowly, and some not at all. Three or four hours were required to cook soaked beans, yet some remained hard and unswollen. Cooked beans were harsh and nut-like, acceptable as an occasional food, but not attractive to the eye or the palate. When cooked beans were ground into soups and flavored with other ingredients, an acceptable product was obtained. Although variety differences were seen, these were not sufficient to permit selection of lines of acceptable value (Ruberté and Martin, 1977).

The technique reported here is an extension of a simple technique used widely by housewives to reduce the cooking time of hard, dry beans, i.e., the addition of sodium bicarbonate to the soaking water. The origins of this technique are not known but apparently precede experimental testing. More recently, the addition of salts to the water for soaking was used by Rockland and Metzler (1967) to develop quick cooking dried lima beans, as well as other beans. The technique we developed for winged bean is based on small scale experiments followed by the consumption of the bean in normal proportions. Only the recommended technique is given here.

To cook dried winged bean seeds, measure the volume of the quantity to be cooked. Rinse the beans and add 5 volumes of water. To the water add 1% sodium bicarbonate sold as soda or baking powder. Boil the beans and simmer for 3 minutes. Remove from heat and soak the beans in the solution overnight. The following day, discard the soaking water, rinse twice with fresh water and boil the beans in about double their volume of fresh for 25 minutes.

The beans treated in this fashion are very soft. Even the seed coats are pliable and edible. Such beans have a mild and agreeable flavor comparable to that of other beans. Tests so far suggest that people who eat

[1]Mayaguez Institute of Tropical Agriculture, Mayaguez, Puerto Rico.

beans regularly accept such beans readily. Beans softened and cooked in this fashion can be flavored or cooked into many other traditional bean dishes.

Treatment with sodium bicarbonate appears to stimulate the hydration of the seed coat and embryo so that both take up water rapidly and facilitate cooking. Rockland and Metzler (1967) found that the protein quantity and quality of lima bean is not diminished by treatment with sodium bicarbonate. Careful tests must be made, however, to see if the treatment damages the Vitamin B content.

Not all lines of beans are equally suitable for cooking with this technique. In many, a few seeds remain hard, and many are intermediate. In these lines, however, the softened seeds can be separated from the hard seeds with a large mesh screen. No solution has been found for the residue of hard seeds.

Jaffe' and Korte (1976) have shown that cooked winged bean seeds support normal growth in rats. At present there is no evidence to suggest any toxic effect of cooked seeds in humans. Our own extensive use demonstrates no short term toxic effects with cooked winged bean seeds.

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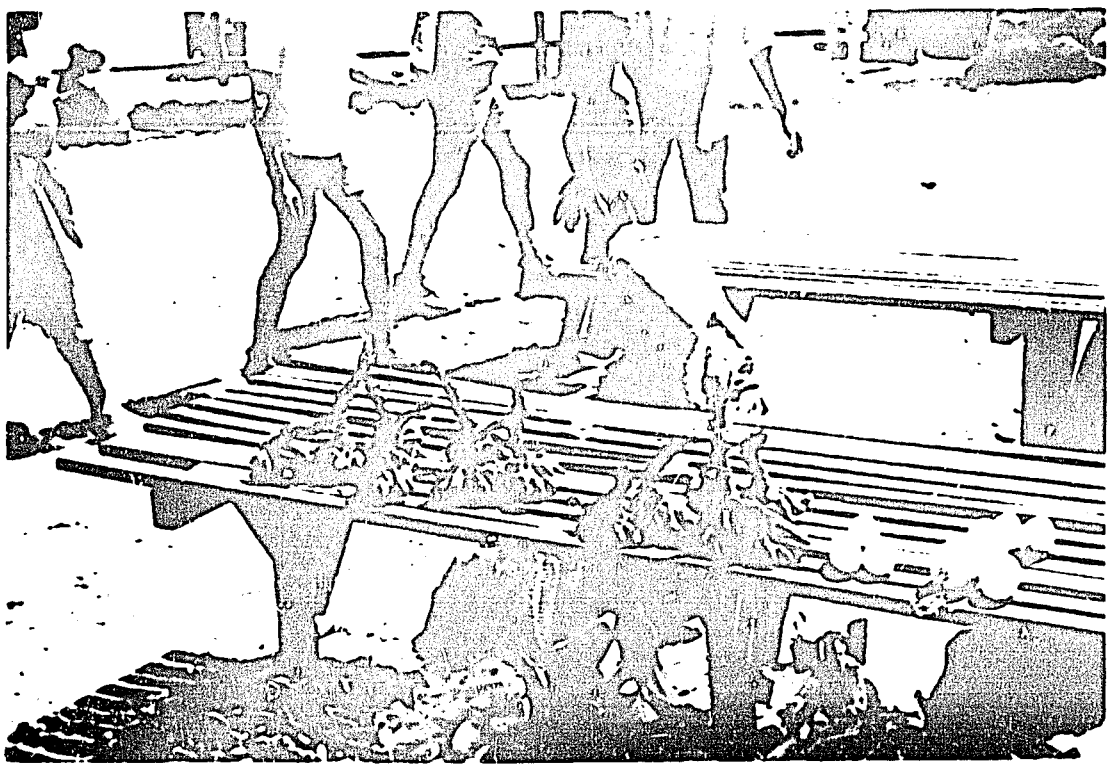
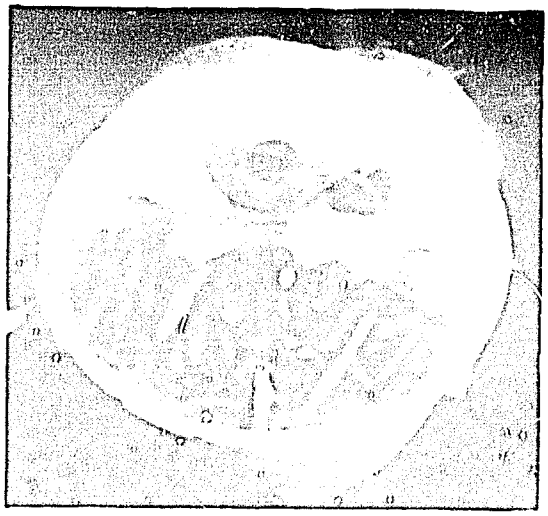


*Selling winged bean tubers in Papua New Guinea.*

1



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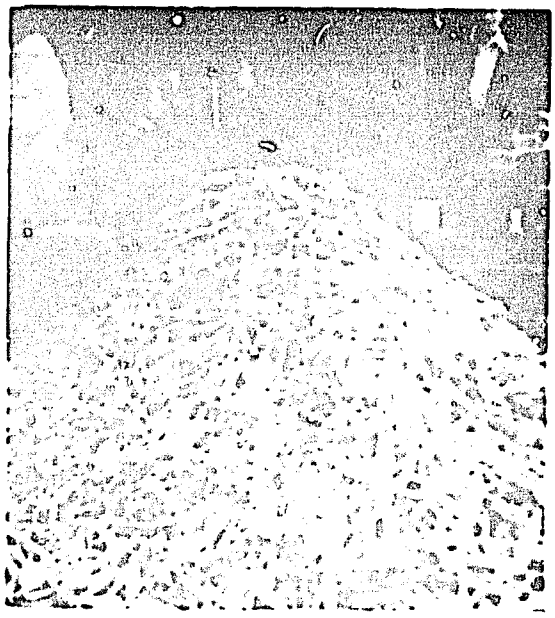
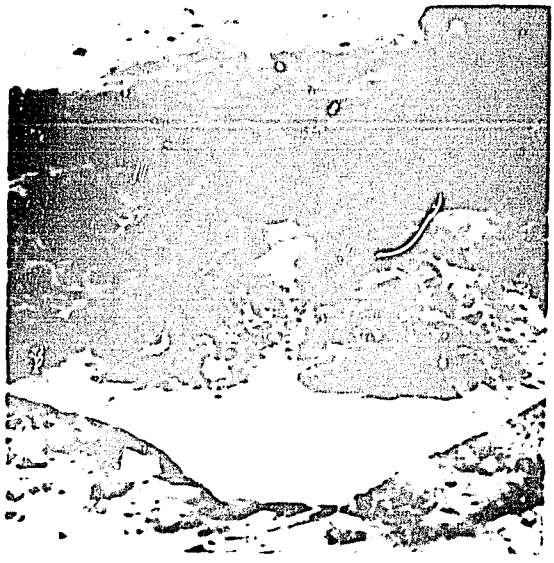


*1. Marketing of tubers in Burma. 2. A heap of tubers also in a Burmese market. 3. Pods sold together with indigenous vegetables in Papua New Guinea. 4. The leaves, vines and flowers are also marketed as in some areas in Papua New Guinea*

3



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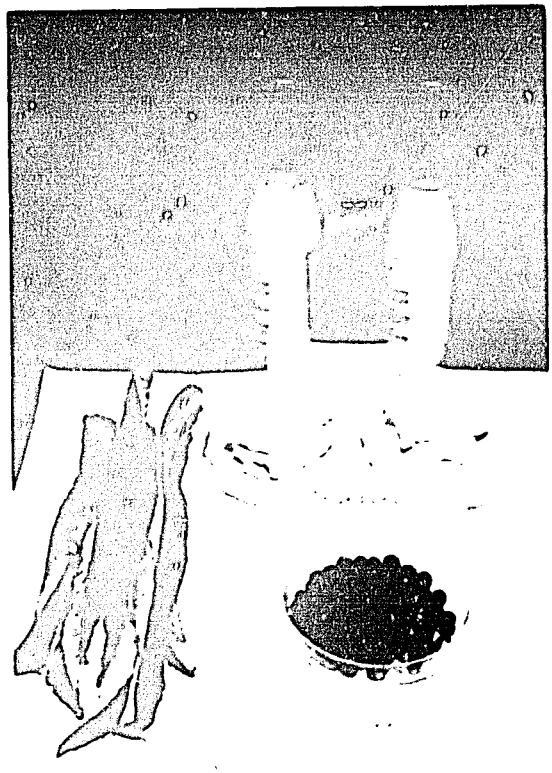

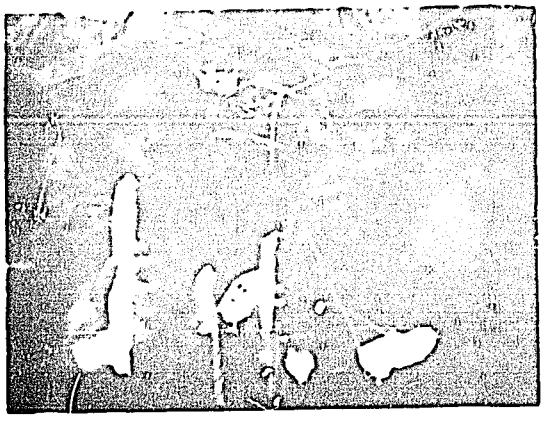

3

*1. Drying the winged bean seeds in the Ivory Coast. 2. Winged bean milk and curd prepared in the Philippines 3. Eating raw young pods at Papua New Guinea. 4. Marketing of tender pods as vegetables in the Philippines.*

# Country Papers

- *Winged Bean in Southern Asia*
- *Winged Bean in India: Its Present Status and Prospects*
- *Preliminary Studies on the Cultivation of Winged Bean in Pakistan*
- *Research Work on Winged Bean in Papua New Guinea*
- *Research Status and Uses of Winged Bean in Malaysia*
- *Some Varietal Observations on the Winged Bean in Malaysia*
- *Winged Bean in Australia: Personalities, Opinions and a Little Research*
- *Winged Bean in Nepal*
- *Some Information on Winged Bean in Costa Rica*
- *Observations and Experiences with Winged Beans in Puerto Rico*
- *The Status and Uses of the Winged Bean in Ghana*
- *Progress on Winged Bean Research in Thailand*
- *Evaluation of Agronomical Behaviour of Winged Bean in El Salvador*
- *The Winged Bean in the Philippines: Its Current Status and Potentials*
- *Winged Bean Culture in Korea*
- *Bangladesh Country Report on Winged Bean*
- *Observations on Winged Bean at CIAT: 1976-1977*

# Winged Bean in Southern Asia

*A. Claydon*[1]

## INTRODUCTION

This report contains notes on the winged bean collected from a recent trip to five countries in Southern Asia. In order to make the report more complete, information published earlier from these countries has been included with references.

A coded list of subjects treated is given below:

1. The winged bean plant
   - 1a) Name of plant
   - *1b) Special names for individual plant parts
   - 1c) Parts of country (area) where grown
   - 1d) History in country (area)
   - 1e) Publications in the country prior to current wave of research (1973)
2. Food uses and availability
   - 2a) Workers studying the dietary role of winged bean
   - 2b) Parts eaten, mode of cooking, name of dish, etc.
   - 2c) Overall dietary importance of winged beans, including any taboos
   - 2d) Appearance in local markets, and prices
   - 2e) Any bad effects after eating
   - 2f) Medicinal uses
   - 2g) Storage times
3. Agronomy
   - 3a) Husbandry
     - i) where planted
     - ii) soil preparation
     - iii) nutrition
     - iv) planting distances
     - v) depth of planting
     - vi) number of seeds per hole
     - vii) support
     - viii) dressing
     - ix) weeding
     - x) water treatment
   - 3b) Planting seasons and times
   - 3c) Soil conditions where grown
   - 3d) Altitudes where winged beans grown
   - 3e) Times of harvesting

[1]Chemistry Department, University of Papua New Guinea

* Note code for winged bean plant: i) shoots, ii) leaves, iii) flowers, iv) tender pods, v) mature pods, vi) unripe seeds, vii) ripe seeds, viii) roots.

3f) Growth statistics of local varieties
Days from planting to:
ii) germination
iii) flower appearance
iii) tender pod harvest
iv) ripe pod harvest
v) root harvest
3g) Photosensitivity
ii) seasons restricted to flowering
iii) time of day flowers open
3h) Duration of plant
3i) Nodulation
ii) extent of nodulation
iii) size and appearance of nodules
iii) type of nitrifying bacteria present
3j) Available local varieties
ii) number found
iii) pod colour
iii) pod size and shape
iv) seed colour
v) seed size/weight
vi) leaf type
vii) flower colour
viii) tuber colour
ix) tube size
3k) Growth vigour and productivity
3l) Workers concerned with agronomy
3m) Introduced varieties, origin, (where grown now)

4. **Biological Competition**
4a) Weeds
4b) Fungal and bacterial diseases
4c) Virus and related diseases
4d) Helminths, etc.
4e) Insect pests
4f) Higher animal and bird predators
4g) Pest problems on winged bean storage
4h) Workers concerned with plant protection

5. **Current chemical, biological and nutritional work**
5a) Proximate composition
5b) More detailed composition
5c) Biological nutritive value
5d) Pharmacological research
5e) Toxicological research

6. **Winged bean processing**
6a) Workers concerned in processing research
6b) Protein extraction and concentration
6c) Oil extraction and refining
6d) Use of protein, starch, etc. in other foods
6e) Winged bean (unfermented) curd and milk
6f) Fermented products

**Development of winged bean as food or feed**

7a) Chief contact
7b) Germplasm collection
7c) Varietal selection Purposes specially considered
7d) Taxonomy
7e) Storage and viability
7f) New cooking methods
7g) Available publications arising from current research
7h) Other references in this survey

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| West Irian | p. 388-389 |


## SRI LANKA

1a) Dambala (1)
1b) iv) pod. Dara dambala (four winged bean) (2)
1c) All over
1d) Indigenous, some records in folklore
1e) None

2a) Not known
2b) iv) Chopped immature pods, cooked either in coconut milk (malum) or tempered in coconut oil (teli); as a vegetable curry to be eaten with rice (3)
viii) Roots eaten very sporadically
2c) Home garden crop, harvested maybe all year round. Consumption generally low. No taboos
2d) Not known (probably not expensive)
2e) Not known
2f) Pod useful in diabetes
2g) Not known

3a) ii) Garden and vegetable field border crop
iv) No fixed spacing (3)
viii) Trails — 1.5-3.0 m high
x) Can be allowed to shrivel up in dry season Will germinate from root next wet season
3b) October-November (end of long wet season) and April May (end of short wet season)
3c) No special soil preferred
3d) 0-650 m
3e) August October, January March
3f) iii) Days to flowering depend on length of day. Rigid photosensitivity (see 3g)
iv) Ripe seed 110-130 days after planting
3g) ii) Highly critical Flowering only in March-September
iii) Flowers open in evening (8-12 p.m.)
3h) 3-4 years, depending on soil pests
3i) i) Profuse nodulation on main and axillary roots (3)
3j) ii) 8-10 types of seed collected from different areas
iii) Pod colour always green
iii) Medium size (20cm) pod length
iv) Seed colours mid-brown
vii) Flowers white, blue and blue-purple
3k) Very rigorous vegetative growth. Yields unknown

**Sri Lanka continued. . .**

3b) Dr. Gunawardena, Central Agricultural Research Institute, PERADENIYA. Dr. N. Vignarajah, Agricultural Research Station, MAHA ILLUPPALLAMA
3m) Nigeria, Papua New Guinea, (Peradeniya and Maha Illuppallama)

4a) Not recorded
4b) Not recorded
4c) Not recorded
4d) Nematodes suspected in limiting plant life. *P. pallustris* reported susceptible to nematode attack **(4)**
4e) Not recorded
4f) Not recorded
4g) Not known
4h) Dr. E. Fernando, Central Agricultural Research Institute, PERADENIYA

5a) Dr. E.R. Jansz, Ceylon Institute of Scientific and Industrial Research, COLOMBO (seed)
Dr. Mervyn Pulle, Faculty of Agriculture, University, PERADENIYA (seed proteins)
5b) Dr. S. Balasubramaniam, Department of Botany, University, PERADENIYA (pod & seed)
Dr. S. Tirimanla, Ceylon Institute of Scientific and Industrial Research, COLOMBO (amino acids and vitamins)
Dr. M. Pulle, Faculty of Agriculture, University, PERADENIYA (gel electrophoresis)
5c) None
5d) No current research
5e) Dr. Balasubramaniam (see 5b) (saponins etc.)

6a) Mrs. Breckenridge, Central Institute of Scientific and Industrial Research, COLOMBO

7a) Dr. C.R. Panabokke, Deputy Director, Agriculture (Research), Dept. of Agriculture, PERADENIYA
7b) Dr. H.M.W. Herath, Dept. of Agricultural Biology, University of Sri Lanka, PERADENIYA
7c) Yield, photosensitivity, bush variety
7d) None
7e) Not yet considered
7f) Not yet considered
7g) Anon (1975) **(1)**
7h) Burkill (1906) **(2)**
Herath (1975) **(3)**
Paul (1954) **(4)**

## THAILAND

1a) Thuaphluu
viii) Root = Hua
1c) Widespread, but mainly in N. and N.E. (dry) provinces
1d) History of crop in Thailand unknown
1e) See Craib (1931) **(5a)**

2a) —
2b) iv) Chopped immature pods, usually boiled
viii) Roots eaten very rarely
2c) Backyard crop
Consumption generally low
2d) Pods 50 Bh/kg (Bangkok, 1977) Seed (for planting) 1 bh. For 10
2e) Not known
2f) Not known
2g) Not known

3a) ii) Home garden crop
3b) After wet season
3c) 0-800 m
3e) Anytime but particularly in the winter (dry season)
3f) iii) Pods 2-4 months
3g) ii) Normally photosensitive
iii) Flowers open usually in morning
3h) Perennial
ii) Profuse nodulation
iii) Middle to large size nodules
iii) Probably common cowpea type
3j) ii) about 50 varieties
iii) Predominantly green, with some peripheral red colouring
iii) Long and short pods
iv) Green to dark brown seed

**Thailand continued...**

v) Seeds mostly large
vii) Leaves mostly ovoid but, in some varieties, lanceolate
vii) Flowers white to dark blue
viii) Tubers not well studied

3k) Growth vigorous. Yields high but not recorded

3l) Dr. Narong Chomchalow, Applied Scientific Research Corporation of Thailand, BangKhen, Bangkok 9

3m) Indonesia, Papua New Guinea (26 lines), Hawaii and Florida (Bangkok)

4a) Not recorded
4b) Few diseases
4c) Few diseases, little leaf seen
4d) Not known
4e) Not recorded
4f) No record
4g) Not known
4h) —

5a) See **(6a)**
5b) See **(6c)**

6a) Mr. Somyos Chanyavilas & Mr. Darunee Thananunkul, Institute of Food Research and Product Development, Kasetsart University, Bangkok 9

6b) —

6c) Dr. Arwooth Nalampang & Mrs. Vimolsri Devapalln, Oilseed Laboratory, Division of Agricultural Chemistry, Department of Agriculture, BangKhen, Bangkok 9

6d) —

6e) Mrs. Ubalsri Cheowsakul, Deputy Director, Industrial Research Department, ASRCT, BangKhen, Bangkok 9
(Seed coat removed by soaking 3 nights in water or 5% $NaHCO_3$) and then by abrasion. Protein pptd in 2N HCL. Use green or white seed. Flavour of milk not as acceptable as that of soyabean milk).

6f) None

7a) Dr. Narong Chomchalow, Research Director, Agricultural Products Research Institute, Applied Scientific Research Corporation of Thailand, 196, Phahonyothin Road, BangKhen, Bangkok 9

7b) Contact above

7c) Yield, physiological characteristics

7d) None

7e) Not yet studied

7f) Not yet considered

7g) Chomchalow N. (1976) (In Thai only) **(5)**
Craib W.C. (1931) **(5a)**

## BURMA

1a) Pe saung-ya (Burmese)
Hto pong (N. Shan States) **(2)**
Ku bemya (Karen Hills) **(2)**

1b) iv) Pod — pe saung ya-thin
viii) Root — pe mylt

1c) Widespread, particularly in Central and Lower Burma

1d) Believed to have been in the country for a long time

1e) Burkill (1906) **(2)**
Thomstone & Sawyer (1914) **(6)**

2a) —

2b) iv) Tender pods occasionally eaten with unripe seeds
vii) Ripe seeds believed to be intoxicating **(6)**
viii) Roots boiled (with rice straw) to color red or eaten raw

2c) Hill garden (taungya) and field crop. Peeled small roots very popular as snacks which are sometimes dipped in salt and oil

2d) Roots: 3-5 Kyats/kg

2e) Combination of roots with cocoa produces intoxicating effects which might even lead to death

2f) (Kentung) Root used to make poultice for the

**Burma continued...**

head and neck in case of vertigo **(2)**

2g) Raw roots can be stored 2-3 months, but cooked roots, only a few days

3a) i) Hill garden (taungya) and open field crop (delta regions) — especially after paddy and before sugarcane. **(2)**
ii) Ridges 20-25 cm high
iii) Rice/fallow, farmyard manure or wood ash
iv) 7-15 cm x 60 cm
v) 10 cm planting depth
vii) Plants allowed to trail to produce roots; may be supported by stakes or tree stumps up to 4 m high for pod production
vii) Apparently much care taken with weeding
viii) Watering and irrigation practised when necessary, especially after planting. Excess of water left in the fields when plants have flowered or fruited reduces number of tubers

3b) June-August (beginning of wet season)

3c) All soils from clay to sand but loam or sandy loam preferred for small tuber formation **(2)**

3d) 0-2000 m

3e) iv & vii Pods and seeds: November-December
viii) Roots: December-March (dry season)

3h) Perennial, but usually planted annually

3i) i) & ii) Profuse nodulation of very large size especially on fallow ground

3j) i) Not known but some are better tuberforming. **(2, 6)**
ii) Predominantly green pods
iii) Long and short podded varieties (15-20 cm & 10-12 cm)
iv) White or greenish yellow to deep brown seed
v) Seeds 8-10 cm long. 100 seed weight — 28.35 g. **(6)**
iv) Leaves short ovoid to sub spherical
vii) White to lilac blue flowers
viii) Tubers cream inside, brown outside
ix) Tuber size 10-15 cm long x 2-4 cm wide preferred

3k) Root yields: 2500-6000 kg/ha **(2)**

3l) Dr. Kaung Zan, Director, Agricultural Research Institute, Gyogon, Insein P.D., Rangoon

3m) Papua New Guinea (1 line)

4a) Not recorded

4b) Not recorded

4c) Not recorded

4d) Nematode suspected on plains if planted on virgin soil, or after fallow (excrescences, Burkill p. 60) **(2)**

4e) —

4f) Not recorded

4g) Not recorded

4h) Not known

5a) —

5b) —

5c) —

7a) Dr. Kaung Zan, Director Agricultural Research Institute, Gyogon, Insein, Rangoon

7b) Burkill U.H. (1906) **(2)**
Thomstone & Sawyer (1914) **(6)**

## WEST MALAYSIA AND SINGAPORE

1a) Kacang botor **(2)**
(Kacang botol)

1b) —

1c) Widespread, but less common in Singapore **(7)**

1d) Long-standing crop (first recorded by Koenig in Malacca, 1778**(8)**. Apparently introduced more recently to Singapore **(7)**.

1e) Burkill (1966) **(8)**
Ridley (1922) **(9)**
Bunting & Milsum (1930) **(10)**

2a) —

2b) ii) Young leaves, eaten raw or steamed

**Malaysia & Singapore continued...**

iv) Tender green pods cooked (with chillies) or eaten raw as salad
viii) Roots rarely eaten

2c) Backyard crop for home consumption (of pods)
2d) Pods sold in the markets occasionally and only by a certain sector of vendors
2e) Not recorded
2f) Leaves used in a compound lotion for smallpox **(12)**
2g) Not known

3a) i) Home gardens and forest clearings **(13, 14)**
ii) Raised beds
iv) 2 rows per bed, 60-90 cm between rows and 60 cm between plants
viii) 2 m high stakes

3b) All year round, especially June-July
3b) High altitude limit not known
3e) viii) Especially September-December
3f) i) Germination 6-8 days after sowing **(11)**
ii) 10-11 weeks after planting
ii) 10-11 weeks after planting
iii) Commercial harvesting of pods 13-23 weeks after sowing
iv) Commercial seed harvesting 19-24 weeks after sowing
v) 27-48 weeks after sowing

3g) Apparently not photosensitive
3h) Perennial, usually planted annually
3i) i) Moderate to excellent nodulation even when planted in virgin forest **(14)**
ii) Weighs up to 0.6 grams 68-370 nodules per plant **(11)**. Colour pink to light brown. Slow growing, more active in limed soils **(14)**
iii) Common slow-growing cowpea type rhizobium **(6)**

3j) i) Several varieties look similar, to each other. All forms tubers, **(10, 11)**
ii) Pods predominantly green including the wings
iii) 14.3-24.3 cm long, rectangular
iv) Pale brown (cream) to very dark brown seeds
v) 100 seed weight 34.3-38.9 g; 8-15 seeds per pod
vi) Opened flowers blue with green calyx

3k) Vigorous growth (especially vegetative). Green pod yield = 35.5 tons/ha (744g/plant); seed yield = 4590 kg/ha (102 g/plant); fresh weight tuber yields (plot for green pod production) = 4980 kg/ha (110/plant); (plot for seed production) = 2246 kg/ha (50 g/plant) **(11)**
3l) Mr. Wong Kai Choo, Universiti Pertanian Malaysia, Serdang, Selangor
3m) Papua New Guinea, Nigeria

4a) Not recorded
4b) Not recorded
4c) Not recorded
4d) Not recorded
4e) Not recorded
4f) Not recorded
4g) Not recorded
4h) —

5a) Wong Kai Choo, Universiti Pertanian, Malaysia, Serdang, Selangor**(11)**
5b) See above
5c) Wong Kai Choo (1975) **(11)** (Chicks respond to diets with 50/50 cooked winged bean seed/soyabean equally well as to 100% soyabean)
5e) Faculty of Agriculture,
Universiti Pertanian, Serdang,
Selangor, Malaysia

6a) Wong, Kai Choo & Ch'ng Guan Choo, University Pertanian, Malaysia, Serdang, Selangor. (livestock and poultry feed)
6e) Ch'ng Guan Choo, Faculty of Agriculture, Universiti Pertanian, Malaysia, Serdang, Selangor. (winged bean curd & milk)

7a) Mr. Wong Kai Choo, Universiti Pertanian Malaysia, Serdang, Selangor
7b) Dr. B.S. Jalani, Biology Department, National University of Malaysia, Jalan Pantal Baru, Kuala Lumpur 22-12
7c) See above
7d) Some *Psophocarpus palustris* found used as a cover crop **(10, 16)**
No ongoing research
7e) —
7f) Ching Guan Choo, Universiti Pertanian Malaysia, Serdang Selangor

Malaysia & Singapore continued...

7g) Lim (1976) (7)
Wong Kai Choo (1975) (11)
Wong Kai Choo (1973) (13)
Masefield (1973) (14)
Shamsuddin & Yaacob (1976) (15)
Broughton & John (1976) (16)

7h) Burkill (1966) (8)

## INDONESIA: SUMATRA AND WEST JAVA

1a) Kecipir (Bahasa Indonesia) Jeat (Sundanese — W. Java) Kechang belimbing, Kechang embing (Palembang, S. Sumatra) Brung (Berastagi, N. Sumatra)

1b) iv) Long pods = Kecipir welut (cf. Dutch ell)
vii) Ripe seed = Botor

1c) Grown in all parts, sporadically

1d) Grown since time immemorial

1e) Hayne (1927) (17)
Ochse & de Jong (1941) (18)
Soesono (1966) (10)
Sunarjono (1972) (20)

2a) Mrs. S. Guhardja, Dept. of Home Economics, IPB, Faculty of Agriculture, Bogor, W. Java

2b) ii) Young leaves and
ii) Sometimes flowers in raw or cooked side dishes 'sambal' 'rumbah', 'kluban' and 'lalab'
iv) Pods chopped or whole and unripe
vi) Seed used in side dishes and soups, especially 'sayurasem' (sour soup) (21)
Leaves, shots and pods infected with *Synchytrium psophocarpi* (false rust) — 'jaat marungkat' or 'jat keked' — a delicacy eaten boiled (17)
vii) Ripe seed not often eaten but may be shallow fried in oil or roasted, decorticated, and eaten as a snack; when mixed with rice, it can be known as "sangrai' (Sundanese)
viii) Roots not eaten

2c) Important vegetable (20), but consumption seasonal and fairly low

2d) Seed (for planting) in markets 500-5,000 rupiah/kg

2e) Ripe seeds give one a heavy-head feeling (22)

2f) An infusion of the leaves is traditionally used for eye and ear infections. Leaves ground with 'adas pulo pulosari' (aniseed ground with *Alyxiastellata* bark) for external use on boils, called 'catetet' (17). Seeds cleanse blood and are useful for treatment of venereal disease (20)

2g) Not known

3a) i) Home and village gardens, also borders of rice fields high ground and lowland plains
ii) Raised beds or field dikes
iii) Compost or manure recommended on fallow land only. A second fertilizer treatment (artificial or manure) given when plants are 10 cm high improves yield (20)
iv) Plant 60-100 cm × 20-30 cm (23)
v) 1-2 seeds/hole
vi) Stakes 1-½ to 2 meters high
vii) Mulching considered useful
viii) Weed carefully
xi) Do not over water

3b) Plant after end of rainy season (March-May) (20), because if you sow at the beginning of the rainy season (November) the plants develop too much vegetative growth and yields are decreased (19)

3c) No special soil preference. Ideal pH limits 5.5-6.5 (20)

3d) No information on upper limit or cultivation

3e) Around August

3f) i) 6 days for germination
ii) Flowering 2-4 months after dry-season planting, otherwise 9 months if planted at beginning of wet season (19)
iii) Pods harvested 3-½ months after sowing
iv) Seeds available after 4-5 months

3g) i) Photosensitivity not studied (vide supra; wet season planting)
ii) Flowers open between 9-10 a.m. and remain open the rest of the day

3h) Perennial but planted annually in the paddy fields

3i) Nodulation not studied closely

3j) i) About 100 varieties collected from all over Indonesia

**Sumatra & W. Java continued...**

ii) Pods pale green or deep green. Sometimes red colour develops on wings **(21)**
iii) Pods rectangular or flat with four different kinds of wing shape. Length 12-70 cm
iv) Creamy white to dark brown
vi) 5-7 mm in diameter
vii) Leaves deltoid, ovate and lanceolate
viii) Blue or purple flowers (Short to medium pod lengths), and white flowers (longer pods) **(20)**

3k) Vigorous growth, especially in wet season. Green pod yield from 1-5 tons/ha **(20)**

3l) Dr. S. Sastrapradja, Lembaga Biologi Nasional, J. Ir H. Juanda 7, BOGOR, W. JAVA
Professor G.A. DeNeve, Faculty of Natural Sciences, Padjadrajan University, BANDUNG, W. JAVA

3m) Papua New Guinea, Nigeria, etc.

4a) *Imperata cylindrica*
4b) *Synchytrium psophocarpi* (false rust) **(24)**
4c) Little leaf
4d) *M. incognita* suspected
4e) *Lampides* sp. (caterpillar) *Valanga nigricarnis* (grasshopper) *Sphinglose* sp. (larvae) *Myzus persicae* (a) (aphid) Leaf suckers from rice crop *Leucoptera* sp. (leaf blotch miner)
4f) Bullocks, goats if planted by rice fields
4g) Not studied
4h) Dr. S. Adisoemarto, Assistant Director, LBN, Jln. Juanda 11, BOGOR
Dr. A. Saono, Lembaga Biologi Nasional, Jl. Ir H. Juanda, 11, BOGOR
Dr. H. Sutarno, Treub Laboratory, Lembaga Biologi Nasional, Jn. Ir. H. Juanda 11

5a) Dr. S. Sastrapraja, LBN, Jl. Juanda, BOGOR (seed protein content) **(21)**
Padmono S. Citroreksoko, Pusat Penelitian Botani, LBN, BOGOR (protein contents of seed varieties) **(26)**

5b) (Gel electrophoresis of seed proteins). Dr. S. Sastrapraja

5e) (HCN in seed) **(20)**

6a) Drs. Hermana, Pusat Penelitian dan Pengembangan (G121), Jalan Semboja, BOGOR, W. Java

6f) Hermana, P.P.P., Bogor (Soak seed, remove coat by abrasion, soak again overnight, boil 1 hr., inoculate 36 hrs. like tempe. Harder than soy tempe, better fried)

7a) Dr. S. Sastrapradja, Director Lembaga Biologi Nasional,Jalan Dr. H. Juanda, 7, Bogor, W. Java

7b) Dr. S. Sastrapdraja (see above)

7c) See above

7d) *P. palustris* found as cover crop in rubber and tea plantation **(27)**. Its seeds and pods are sometimes eaten **(27)**.

7g) Sastrapradja & Aminah Lubis (1975) **(21)**
Hartiningsih (1973) **(23)**
Adisoemarto (1977) **(25)**
Citroreksoko (1977) **(17)**
Hayne (1927) **(17)**
Schse & de Jong (1941) **(18)**
Soesono (1966) **(19)**
Ridley (1927) **(9)**
Bunting & Milsum (1930) **(10)**
Burkill & Haniff (1930) **(12)**

## CENTRAL & EAST JAVA, MADURA & BALI

1a) Kecipir, Keceper (Madura) Kelongkang (Bali)

1b) Seed – Botor
Root – Umbi kelongkang (Bali)

1c) All over, chiefly at low altitude

1d) Traditional crop

1e) Hayne (1927) **(17)**
Rumphius (1747) **(22)**

2b) ii) shoots, iii) leaves
iv) whole immature pods and
vii) unripe seeds used in 'lalab (steamed) 'urab' in Bali) and 'pecal' (spiced vegetable mixture)
viii) Ripe seeds fried, roasted or boiled. Tempe made out of seeds
viii) Roots not eaten (but have medicinal use)

2c) Of seasonal importance, usually in home gardens

*Winged beans on the fence of a house near Yogyakarta, C Java.*

**C & E Java, Madura & Bali continued...**

Pods popular with children (Bali)

2d) Seeds not as expensive as peanuts

2e) iii) Raw leaves, and
iv) Pods sometimes produce dizziness and nausea. Pods sometimes cause flatulence
vii) Roast seed in excess produces dizziness

2f) ii) Juice from shoots used for the teeth
iii) Leaf juice relieves morning dyspepsia
iv) Pods goods for the blood and for slimming diets
viii) Root balled with sugar lumps 'batu gula' good for treatment of thrush

3a) i) Home & upland garden or field border crop
ii) Ridging if grown upland otherwise planted on the paddy field dikes
iii) Only excess (rice) fertilizer used
iv) 20-30 cm × 50-60 cm (between ridges)
vi) 2-3 seeds/hole
vii) 1-½ to 2 m stakes
viii) - x) very little mulching weeding or watering

3b) Planted at beginning or end of (short) rainy season, (October-March) and (often) after the rice harvest before the rains appear. (September) (28)

3c) All types of soil

3d) Not much grown over 500 m

3e) iv) Pods: April-May and June-July
vi) Seed: September (if wet season planted)

3f) i) 1 week to germination
ii) Flowering after 1-½ months
iii) Pods after 2-3 months

3g) i) Probably photoinsensitive
ii) Flowers open 8 am — 2 pm

3h) Perennial crop, but planted annually

3i) Nodules no bigger than those of other legume (Bali)

3j) i) Total number of varieties not known. None reported as tuber-forming

**C & E Java, Madura & Bali continued...**

ii) Green & green purple pods, sometimes wingless
iii) Pods mainly 15-25 cm long, but some varieties up to 70 cm
iv) Seeds white to dark brown
v) Ovoid leaves, mostly
vii) Pure white (21) blue and purple flowers

3k) Vigorous growth, yields not estimated

4e) White lice, caterpillars, stem suckers
4f) Cows, goats but not birds
4h) Y.B. Sumardiyono, & Drs. Supratago, Plant Protection Laboratory,
Faculty o. Agriculture, Gadya Mada University, YOGYAKARTA, Central Java.

6a) Ir.S. Sudarmadji. Agricultural Product Processing Division, Faculty of Agricultural Technology, Gadjah Mada University, Bulaksumur, Yogyakarta

7a) Contact Dr. S. Sastrapradja
7g) Mardjuki (1973 (28)
Nitis (1977) (29)
Alimoeso (1975) (30)
7h) Sumarjono (1972) (20)
Rumphius (1747) (22)
Reciborski (1898) (24)
Ochse (1961) (27)

*Winged beans growing as a garden escape in a main street in Nlungkung, Bali.*

## INDONESIA: SULAWESI & THE MOLUCCAS

1a) Kecipir, Biraro (Manado & Ternate)
Botor **(22)**, Baboto (Ambon)
Culebet (Banda)
1b) No special names
1c) More kecipir grown in N. Sulawesi than South. More grown in Ambonese uplands than on coast
1d) Rumphius (1747) believed winged bean was brought from Java or Bali to Ambon
1e) Rumphius (1747 actually written between 1660-1702) **(27)**
Hayne (1927) **(17)**

2a) —
2b) iv) Pods (often chopped) used in side dishes & stews — lalab etc., — also fried with coconut milk 'tumisantan' (Ambon)
viii) Roots reported eaten cooked by Rumphius and apparently stillaten in some parts of Ambon nowadays
2c) Important in N. Sulawesi and seasonally elsewhere
2d) Seeds (2. Sulawesi) 400 rupiah/kg
2e) vii) Seed gives a heavy head **(17)**
2f) iv) Pods good for the blood

3a) ii) Home and upland gardens or field borders
iii) No fertilizer or manure added
iv) 30-50 cm × 50-70 cm spacing
v) 1-3 cm planting depth
vii) 1-3 seeds/hole
viii) 2 m stakes or fence
viii) & x) no mulching or watering
ix) Weeding at 10 day intervals
3b) Planted at end of rainy season: April-May (W. Sulawesi; July-August (E. Sulawesi & Sangihe Islands) or all year round (Ambon) especially April-September
3c) No special soil requirements
3d) Upper altitude limit not known
3d) iv) Pods in July (W. Sulawesi) and September (E. Sulawesi and Sangihe)
3f) ii) Germination in 3-5 days
iii) Flowering after 1-2 months
iii) Pods ready in 2-3 months and
iv) Seeds 3-4 months after planting. Pods not dehiscent except if you pick them and lay them in the sun **(22)**
3g) No photosensitivity noted
iii) Flowers open in morning at 9 am
3h) Perennial, but often planted annually. One plant seen in Telagakodok village, Ambon believed to be over 3 years old
3i) No study on nodules. Good to plant vegetables like cabbage after winged bean
3j) ii) Total number of local varieties not known. Rumphius reports tuber formation **(22)**
iii) Green pods, developing purple colour in the wings with maturity
iii) Pods mainly short (15-25 cm), 7-10 seeds **(22)**
iv) White to dark brown seeds
v) Leaves mostly ovoid, lanceolate (Telagakodok, Ambon)
3k) Growth vigorous
3m) Papua New Guinea (1 line)
Ujung Pandang and Ambon)

4a) Weeds like 'alang-alang'
4b) Mildew
4c) Little leaf (virus)
4d) —
4e) Etiella zynchineas (stem borer) **(31)** mites, aphids, ants & caterpillars. Leaf (blotch) miner.
4f) Sometimes rats & mon-

7g) Drs. Amiruddin (1977) **(31)**
7h) Rumphius (1747). (V.S.) **(22)**

## WEST IRIAN

1a) Kecipir
Kacang belimbing (Blak)
Papare (Jayapura)
Sarisre (Marind)
1b) No special names
1c) Grown in villages rather than near towns. Eastern side of Blak
1d) Long established crop **(32)**

**West Irian continued...**

1e) Massal & Barrau (1956) **(32)**
Hayne (1927) **(17)**

2b) iii) Leaves sometimes boiled
iv) Immature pods and
vii) Green seeds boiled in a stew or cooked in the fire, or steamed to make gado-gado, lalab and kluber
vii) Ripe seeds and
viii) Roots, not eaten much in the lowlands or in the highlands. Can be roasted
2c) Not known
2d) Pods, 1,000 rupiah/kg Jayapura market
2e) Not known
2f) Not known

3a) ii) Home village or subsistence garden crop, particularly in the uplands
iii) Not composted
iv) 30-40 cm between plants
vii) 1.5-2.0 m bamboo stakes fences
viii) Not usually mulched
ix) Weeded or
x) Watered
3b) Planted all year round (but mainly in the wet season)
3c) Grown on all soil types
3d) Upper altitude limit probably about 2000 m
3e) Available most of the time
3f) i) Germination in 3-5 days
ii) Flowers after 40 days
iii) Pods ready in 2-3 months
3g) Not photosensitive (?)
3h) Perennial (?) but gardens usually planted annually
3i) No information
ii) Local varieties mostly green or green with red wings
iii) Pods 15-20 cm long
iv) Seeds light to dark brown, 3 distinct kinds
vi) Leaves ovate and sometimes lanceolate
vii) Flowers white to purple
3k) Growth vigorous
3m) Papua New Guinea (Jayapura)

4a) Little competition from grass and weeds
4b) No fungal diseases known
4c) No viral (etc.) diseases noted
4e) *Nezara* sp. & rice stemborer **(33)**
4f) Mice, etc. from rice fields

7g) Kalew (1977). **(35)**
personal communication (Sorong)
7h) Massal & Barru (1956) **(32)**
Barrau (1958) **(33)**
Ibid — (1958) "A reconnaissance survey in the field of economic botany in Western Melanesia" Mimeo p. 17
Helder (1970) **(34)**

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Dr. Udju Djurjaman, ITS, Surabaya, E. Java
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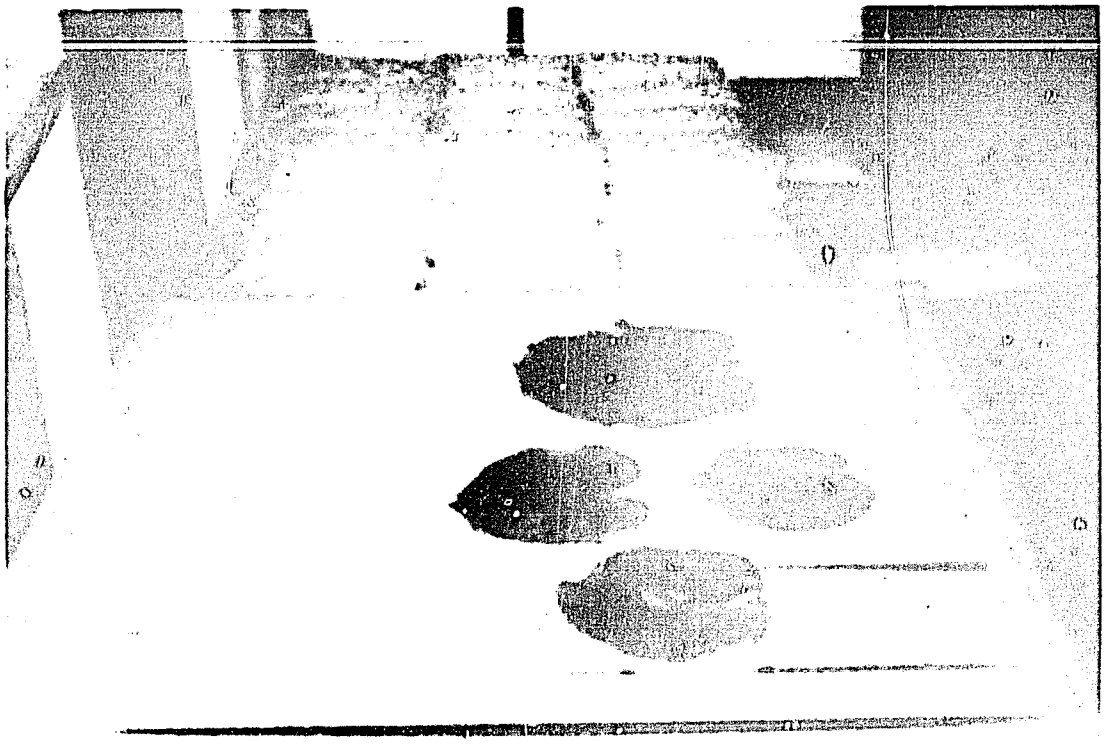
*Winged bean tubers sold in bundles in Papua New Guinea.*



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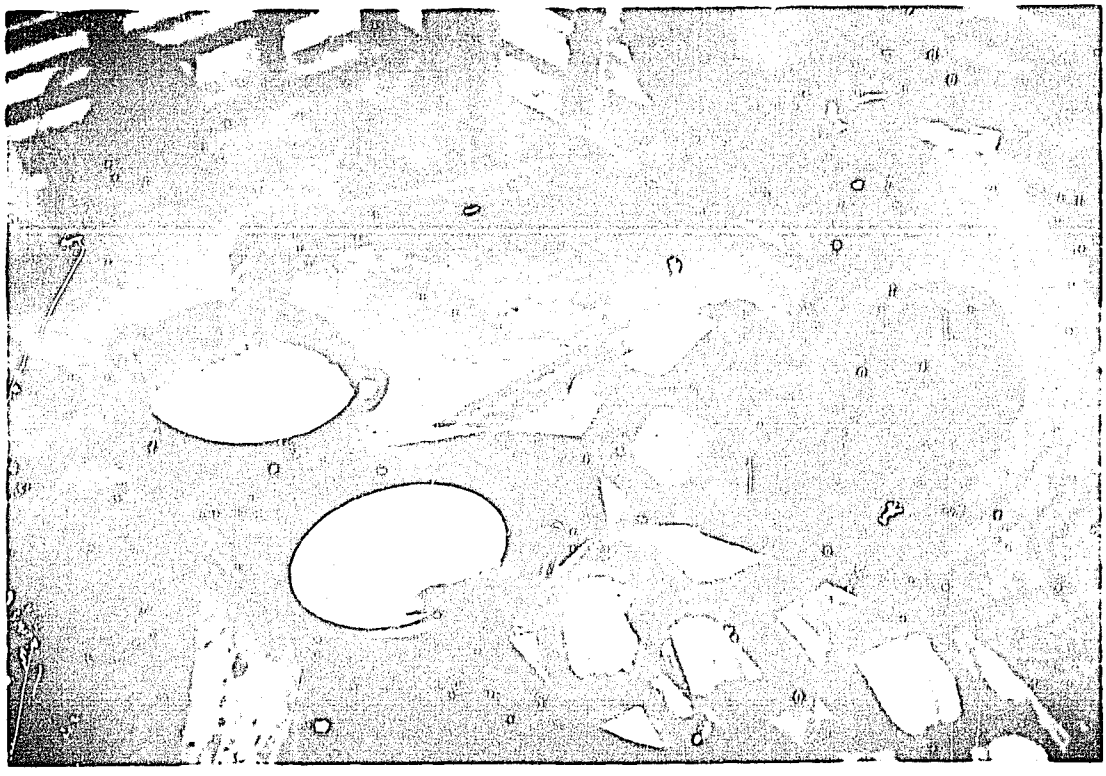

2.

*1. Tempeh fermented in plastic bags. 2. Winged bean tubers hulled and boiled in the Ivory Coast.*

# Winged Bean in India: Its Present Status and Prospects

*K.P.S. Chandel, R.K. Adora, B.S. Joshi* and *K.L. Mehra*[1]

**The National Bureau of Plant Genetic Resources has assembled over 70 collections of winged bean through plant exploration carried out in India and abroad, and supplemented the germplasm further by its international contracts. This germplasm is maintained at New Delhi and Amravati Stations of the Bureau. Evaluation of this material has revealed promising genotypes for green pods, grain & tuber yield and high protein content (over 30% in pods, 12% in tubers). Research is being carried out to develop suitable types for different agro-climates to popularize this crop in tropical and sub-tropical regions of India.**

## INTRODUCTION

In India, the winged bean (*Psophocarpus tetragonolobus* (L.) DC.) is presently grown by the tribal people in the northeastern region, primarily in Assam, Manipur, Mizoram and Meghalaya states. To some extent, it is also cultivated in certain parts of Tamilnadu, Goa, Karnataka and Maharashtra, especially around the cities wherein the produce is brought for consumption as a green vegetable.

The winged bean was introduced in 1799 into the Botanical Garden of Sibpur, Calcutta. Burkill (1906) surveyed the area of its cultivation and adaptation in India and observed that the crop was almost absent in the Punjab; ripened seed was found with some difficulty in the plains of Uttar Pradesh; but was a little more at home in Madhya Pradesh where it was oftentimes grown in the village gardens. The crop has been successfully introduced in and around villages of several cities, viz: Nagpur, Poona, Bombay, Ratnagiri, Goa, Mysore, Madras and Calcutta. The area of its successful cultivation, however, could not extend beyond its initial places of introduction during the last sixty years since earlier introduced varieties were not able to compete with other indigenous and exotic legume species used for grain and/or vegetable purposes.

Although from time to time exotic collections of winged bean were tested in the country, systematic efforts towards assembling germplasm from various countries of Southeast Asia and from Research Institutes in Africa were initiated in mid 60's by National Bureau of Plant Genetic Resources, India, a central, sole agency for the introduction of plant material from abroad. Further, during plant explorations conducted by the bureau in the northeastern region since 1970's, it was observed that several tribes of different ethnic groups grew winged bean mainly around their dwellings and occasionally in the fields supported by bamboo or other shrubs and trees. Sometimes winged bean is grown more like cucurbits along the walls and hut tops. Some tribes consume both the green pods as cooked vegetable and the seeds when roasted. The local cultivars exhibited variation perhaps due to culinary preferences in seed, pod and other plant characters. The available variability was collected with a view to test its adaptation in newer areas and to undertake systematic plant improvement work at this bureau.

## GERMPLASM EVALUATION

Germplasm collections (52 ) comprising of 30 indigenous and 22 exotic accessions from Indonesia, Papua New Guinea, Nigeria and Ghana) were maintained and evaluated during the last 5 years at two locations viz: National Bureau of Plant Genetic Resources, New Delhi and at its Regional Station, Amravati (Maharashtra). A few accessions were supplied to the Indian Institute of Horticultural Research, Bangalore, Agricultural University, Pantnagar, U.P., and the Agricultural University Udaipur, Rajasthan, aiming to test their agronomic potential in these regions and to intensify research efforts. Selected cultivars were also sent to the National Institute of Nutrition, Hyderabad, for use in undertaking studies on nutritional aspects. Furthermore, in answer to the growing international interest in the scope and potential of the winged bean as a

[1]**National Bureau of Plant Genetic Resources, New Delhi, India.**

protein rich crop (Anon. 1975), germplasm were also supplied to research Institutes in Nepal, Sri Lanka, Indonesia, and Papua New Guinea, to enrich their germplasm collections and to make possible their efficient exploitation. Recently, our genetic resources have been further enriched through collections (21 samples) made in 1977 by one of us (R.K. Arora) from the kitchen gardens, fields and village markets in Java. Thus, a total of 73 collections have been assembled for evaluation as straight introductions and for use in the breeding programs.

The entire germplasm collection built in successive years was evaluated during the last few years to study the expression of various plant characters and adaptability of different genotypes under Delhi (28° 35'N & 77° 12'E, alt. 228 m) and Amravati (21° N & 77° 30'E, alt. 343 m) conditions. Table 1 presents the promising accessions of winged bean.

**Table 1. Some promising genotypes of winged bean.**

| Accessions | Source | Pod | Promising genotypes | | | Tolerance to Frost |
|---|---|---|---|---|---|---|
| | | | Seed | Tuber | Forage | |
| I.C. 15018 | Kerala | | | | + | |
| I.C. 17004 | Manipur (India) | + | | | | |
| I.C. 17006 | Manipur (India) | + | + | + | | |
| I.C. 25100 | Mizoram (India) | | | | | + |
| I.C. 25102 | Mizoram (India) | | | | | + |
| F.C. 27884 | Ghana | | | + | + | |
| F.C. 27885 | Ghana | + | | + | + | |
| F.C. 27886 A | Ghana | + | + | | | |
| F.C. 38823 | New Guinea | | + | | | |
| F.C. 38824 | New Guinea | + | + | | | |
| F.C. 38825 | New Guinea | + | + | | | |
| F.C. 38955 A | New Guinea | + | + | | | |
| F.C. 38957 | New Guinea | + | | | | |
| F.C. 38958 | New Guinea | | | + | | |
| F.C. 38959 | New Guinea | + | | + | | |
| F.C. 114673 | Indonesia | | | + | + | + |
| F.C. 114074 | Indonesia | | | | + | + |
| F.C. 116886 | Nigeria | | | + | | |

## OBSERVATIONS

### Green Pods

Nine accessions observed as promising for green pod production were semi dwarf with short condensed internodes, early flowering (97 days) and had medium long (15 to 20 cm), tender pods of pale green or light green colour.

### Grain Yield

Six collections were identified as high grain yielders.

### Tuber Yield

Seven high tuber yielding accessions flowered late under Delhi conditions and were low pod and grain yielders.

### Fodder Yield

Five accessions with viny habit, prolific and quick vegetative growth and broad foliage of light to dark green colour were found suitable for green fodder production.

### Frost Tolerance

Four accessions were tolerant to frost under Delhi conditions. Furthermore, Table 1 also depicts that while some cultures were promising for specific characters, others were useful for multiple purposes.

## NUTRITIONAL VALUE

Table 2 presents the nutritive quality of four promising accessions. As compared to the exotic material tested, the samples from Manipur had higher protein and phosphorus contents in the seed.

In the case of tubers, the indigenous collections had comparatively low protein values.

Apart from the analysis of seeds and tubers, the green pods of five exotic strains were also analysed for protein content, which ranged from 14.08 (E.C. 38826, Ex. Papua New Guinea) to 18.05 (E.C. 27886, Ex. Ghanna).

Table 2. Nutritional analysis of the winged bean (*Psophocarpus tetragonolobus*)[a]

| | | Moisture % | Protein % | Ash % | Iron mg | Iron after peeling the epidermis (mg) | Phosphorus mg | Calcium mg | Fat (Ether Extract) mg |
|---|---|---|---|---|---|---|---|---|---|
| E.C. 17664 | Seed | 12.0 | 32.5 | 4.8 | 9.1 | | 556.5 | 388.0 | 15.4 |
| | Tuber | 67.5 | 8.5 | 3.5 | 5.3 | 1.6 | 202.1 | 151.4 | 1.6 |
| E.C. 17666 | Seed | 11.4 | 36.7 | 4.8 | 7.7 | — | 704.7 | 345.1 | 19.1 |
| | Tuber | 46.8 | 9.8 | 3.0 | 4.5 | 2.5 | 216.2 | 158.7 | 1.7 |
| E.C. 27886 A | Seed | 10.1 | 29.1 | 5.4 | 8.2 | — | 631.1 | 390.4 | 15.8 |
| | Tuber | 42.1 | 12.2 | 4.0 | 15.4 | 3.0 | 196.0 | 323.6 | 2.5 |
| E.C. 38826 | Seed | 12.2 | 36.7 | 4.3 | 9.3 | — | 569.0 | 299.0 | 19.8 |
| | Tuber | 42.4 | 11.2 | 4.7 | 24.4 | 3.3 | 357.4 | 427.4 | 2.5 |

[a]Analyses done by the National Institute of Nutrition, Hyderabad.

## FUTURE PROGRAM OF ACTION

We intend to undertake plant exploration activities in three agro ecological, phytogeographical belts viz: (a) humid tropical tracts, Bombay southwards to Kerala, (b) parts of eastern ghats in Tamilnadu and (c) the northeastern region including plains of West Bengal and Assam. Augmentation of germplasm collection from South East Asian countries and other research institutes engaged in winged bean studies would be taken up with emphasis on procurement of diverse genotypes especially those with dwarf bushy habit with early maturity and high yielding ability. Germplasm collections with better tuber attributes would be required from Papua, New Guinea. Research could be intensified to determine the agronomic and ecological requirements of this crop with a view to boost its production/cultivation in India. The promising germplasm already screened by this bureau and materials obtained through international efforts would be multiplied and tried at different locations (New Delhi, Amravati, Akola, Trichur, Shillongi to pick up desirable genotypes suited to different agro ecological regions covering humid tropical, sub tropical to sub humid subtropical tracts. To popularize this crop, seeds of selected cultures will be distributed to the farming community, involving extension agencies.

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# Preliminary Studies on the Cultivation of Winged Beans in Pakistan

*Dr. M. Aslam*[1]

## INTRODUCTION

Summer legumes, viz. *Vigna radiata* (Moong) and *Vigna mungo* (Urd) are grown annually on an area of about 281,000 acres with a total production of 552,000 tons. Their importance does not lie in acreage but as a source of protein in the diet of the common man. Although substantial progress has recently been achieved in increasing production of major crops like wheat, rice, cotton, sugarcane and maize in Pakistan yet the production and acreage under *moong* and *urd* for the last decade has remained static although the demand for edible legumes has been on the increase with an increase in population. The low productive potential of *Vigna* species is due partly to their susceptibility to Yellow Mosaic Virus (YMC) and partly to poor culture. We have naturally been on the look out for either resistant varieties of these crops or other crops which may replace them. The winged bean (*Psophocarpus tetragonolobus*) seem to possess some potential as a future summer legume crop in Pakistan at least in those areas where YMC limits the cultivation of soybean.

Faisalabad where the preliminary studies have been made is located in the heart of a riverine tract irrigated by a network of canals, using the diverted river water through a network of large and small dams. Faisalabad is situated about 31.5° north latitude and 73° east longitude. The land is a rolling plain only 200-300 feet above sea level. The soil is mostly alkaline with a pH ranging between 7 to 9. The information of maximum, minimum and mean monthly temperature and rainfall is provided in Table 1. The average rainfall is about 25 cm annually, summers are very hot until heavy downpours of monsoon in July-August bring some relief. Winters are cold with frosty nights in December and January. The information on average monthly daylength is given in Table 2. The daylength varies between 10 to 14 hours during the years.

**Table 1. Temperature, humidity and rainfall data of Faisalabad during the year 1977.**

| Month | Max (C°) | Min. (C°) | Humidity (%) | Rainfall (mm) |
|---|---|---|---|---|
| January | 20.73 | 4.4 | 80 | — |
| | 17.12 | 3.75 | 87.5 | 5.5 |
| | 18.92 | 4.75 | 83.75 | 5.5 |
| February | 21.66 | 6.16 | 75.4 | — |
| | 25.73 | 7.65 | 79.0 | — |
| | 23.69 | 6.90 | 77.2 | — |
| March | 29.03 | 10.66 | 74.13 | — |
| | 32.03 | 15.93 | 74.43 | — |
| | 30.53 | 13.26 | 74.28 | — |
| April | 31.43 | 18.0 | 75.13 | 7.80 |
| | 33.83 | 18.7 | 66.66 | 16.30 |
| | 32.63 | 18.35 | 70.89 | 24.10 |
| May | 32.46 | 18.85 | 69.46 | 34.14 |
| | 39.15 | 23.59 | 68.50 | 8.2 |
| | 35.80 | 21.22 | 68.98 | 42.34 |
| June | 40.06 | 24.03 | 57.73 | 26.1 |
| | 38.23 | 25.76 | 62.13 | 11.8 |
| | 39.14 | 24.89 | 59.93 | 27.9 |

[1]Director of Research, University of Agriculture, Faisalabad.

**Table 1.** *continued . .*

| Month | Max (C°) | Min. (C°) | Humidity % | Rainfall (mm) |
|---|---|---|---|---|
| July | 37.03 | 25.3 | 76.40 | — |
| | 36.62 | 24.87 | 75.12 | 91.8 |
| | 36.80 | 25.1 | 75.70 | 91.8 |
| August | 36.56 | 25.8 | 74.4 | 67.9 |
| | 36.99 | 25.4 | 75.4 | — |
| | 36.80 | 25.6 | 74.9 | 67.9 |
| September | 34.36 | 22.96 | 78.93 | 66.8 |
| | 35.24 | 23.22 | 67.46 | 11.2 |
| | 34.8 | 23.1 | 73.2 | 78.0 |
| October | 34.96 | 21.08 | 70.66 | — |
| | 32.41 | 18.06 | 72.75 | — |
| | 33.68 | 19.5 | 71.7 | — |
| November | 30.95 | 15.74 | 77.06 | — |
| | 23.61 | 10.81 | 82.80 | 2.8 |
| | 27.28 | 13.27 | 79.93 | 2.8 |
| December | | | | |

**Table 2. Average daylength month during the year 1977.**

| Months | Average Day-length/Month |
|---|---|
| | HRS — MTS |
| January | 10 — 25 |
| February | 11 — 10 |
| March | 12 — 5 |
| April | 13 — 3 |
| May | 13 — 48 |
| June | 14 — 14 |
| July | 14 — 1 |
| August | 13 — 20 |
| September | 12 — 19 |
| October | 11 — 45 |
| November | 10 — 50 |
| December | 10 — 12 |

## MATERIALS AND METHODS

Seeds of the following varieties were obtained from sources as detailed below in June 1976:

| VARIETY | SOURCES |
|---|---|
| 1. K11 | Florida (USA) |
| 2. UPS122 | Papua (N.G.) |
| 3. UPS31 | Papua (N.G.) |
| 4. Type 1 | Nigeria |
| 5. Type 3 | Nigeria |
| 6. Type 6 | Nigeria |
| 7. Type 7 | Nigeria |
| 8. Type 8 | Nigeria |
| 9. Type 14 | Nigeria |

The first planting was done on July 20, 1976 after the moon had started on ridges 30 cm apart right after monsoon had started. The germination and growth in all varieties were good except in Type 7 where growth very slow. The second planting was done in spring on March 11, 1977 and the third planting was done on July 10, 1977 during summer. A buffer area of about 90 cm was kept between two varieties to avoid intermixing between intertwining branches. It was also intended to determine the comparative effectiveness of different support systems for the trailing plants of the winged bean in comparison with sowing on ridges without the trials. Three different types of supports were provided i.e., bamboo sticks, and planting of the winged bean in between jute or sorghum.

## RESULTS AND DISCUSSION

All the varieties studied grew very fast though the rate of growth varied to some extent with the variety and time of sowing. There was no marked difference in growth among Nigerian varieties but the development of varieties of US origin was rather slow. UPS 31 in this respect was definitely poor in growth, had small leaves in 1976 as well as in spring and summer sowing of 1977. The leaves also showed some effect of virus attack. The K11 type attained maximum vegetative growth and vigour when sown in spring and the plants continued to set pods even by the end of November. K11 had 50% green pods even by the end of December and in this respect it was rather late in maturity than the other varieties like Type 1, UPS 31, UPS 22 and Type 14. However the total production of pods from K11 was about 3 times more than the other varieties. UPS 31 was the poorest of all in this respect.

Due to the intense heat and water stress conditions in July, August and September the performance of Type 1 was adversely affected while K11 survived the stress. Some of the Type 1 and UPS 31 plants remained very stunted and did not grow well. All the varieties planted in spring started to flower by the end of September. The plants were in full bloom in October and during this period vegetative growth almost stopped. Pod formation continued up to the end of December. Some of the pod characteristics of different varieties which have been recorded are presented in Table 3.

**Table 3. Pod and seed characteristics of different varieties of the winged bean (March planting).**

| Culture | Pod Size (cm) | Pod Weight (cm) (Dried) | No of Grain Pod | Grain Weight Pod | Wt. of Dry Shelled Pod | 100 Grain Weight (GMS) |
|---|---|---|---|---|---|---|
| K11 | 22.3 | 8.95 | 11 | 3.73 | 5.22 | 20.0 |
| Type 1 | 21.2 | 7.27 | 11 | 3.46 | 3.81 | 32.5 |
| Type 6 | 23.5 | 8.74 | 12 | 4.05 | 4.69 | 33.0 |
| Type 14 | 15.3 | 4.62 | 12 | 2.33 | 2.29 | 19.2 |
| UPS 122 | 26.2 | 10.65 | 16 | 5.03 | 5.62 | 30.7 |
| Mixture Light Brown | 22.4 | 8.58 | 12 | 3.65 | 4.93 | 32.5 |
| Mixture Black | 17.5 | 5.69 | 11 | 2.53 | 3.16 | 22.0 |

Among the summer plantings sown in June in between jute, the winged bean made such an excessive growth that by the end of September with its high winds and rains, all the jute plants lodged and in about a month the plants were covered by a dense growth, the varieties even got all mixed up.

Type 6, UPS 122 and Type 1 plants also made such an excessive growth on sorghum plants that with heavy fruit setting in November, the sorghum plants were uprooted. Only the bamboo laths withstood the thick growth and heavy bearing.

It was observed that the varieties tested were definitely photosensitive and it was observed that flowering occurred in October and November irrespective of the time of planting. The flowering behavior of the varieties at different sowing dates was observed and is presented in Table 4.

**Table 4. Effect of daylength on time taken to flower in winged bean.**

| Variety | No. of days taken to flower from the date of sowing | |
|---|---|---|
| | Sowing in March | Sowing in July |
| 1 K11 | About 180 days | 90 95 days |
| 2 UPS 122 | 195 days | 75 85 days |
| 3 UPS 31 | 200 days | 75 85 days |
| 4 Type 3 | — | 90 days |
| 5 Type 1 | 190 days | 90 days |
| 6 Type 6 | — | 100 days |
| 7 Type 8 | — | 75 80 days |
| 8 Type 14 | 190 days | 85 105 days |
| 9 Type 7 | Very late with poor growth, no pod set | |

The support provided by bamboo laths was found to be the best. However it was found that if plants were allowed to grow on ridges and on plant trash and if the distance between ridges was kept at 90 cms, the pod setting was not at all affected as compared to plants provided with support.

The young pods were also cooked and were found to make for a delicious vegetable dish. A chemical analysis of seeds was also done to determine total protein and fat percentage. It was observed that the protein in the seed varied from 30 to 35 per cent and the fat varied from 13 to 16 per cent. Cytogenetic studies are also being conducted. Preliminary observations have shown the presence of 9 bivalents at the metaphase of the meiotic division. The entire data is being analysed and will be available in about 2 to 3 months. Almost the entire spring sown crop has been harvested, but the pods of the July planting are still green.

The winged bean is self-pollinated and being a short day plant it has been observed to do best in Pakistan when sown from June 15 to July 15. Spring planting does not seem to be favorable as the land remains occupied for too long. Among the available varieties; Type 1, Type 14, K 11, Type 6 and UPS 122 seem to be promising. Being late in maturity about 10 per cent of the pods in K11 do not mature and are lost due to the cold front in December. A variety which matures earlier than K11 but equally a good yielder will be most suitable. More varieties will have to be imported to select suitable genotypes. The winged bean unfortunately needs to be supported under irrigated conditions to avoid spoilage of pods. Maize and sorghum do not seem to be suitable as support crops. A suitable cropping pattern for a mixed planting of the winged bean with sugarcane or other crops will have to be looked into.

## CONCLUSION

Winged bean was planted for the first time in Pakistan on an experimental basis, although it is generally considered to be a crop of the tropical countries. From the varieties that have been tested, it has been shown that summer planting in July would be most suitable, however any future variety for Pakistan must mature within 90 days of planting so that another crop could be grown on the same land. A late crop of wheat in December of a spring crop of either maize, moong or potatoes could follow. Mixed sowing with jute or sorghum does not seem to be practicable and further studies are needed.

The experiment has proven that the crop could be grown in irrigated areas with artificial irrigation, although there is a possibility of its success in rainfed areas as well. The green pods could be used as a vegetable, and the seeds as food. Since the oil content of the seed is quite high, the winged bean could be used for meeting the vegetable oil needs of the country.

# Research Work on Winged Bean in Papua New Guinea

*V. Kesavan*[1]

## INTRODUCTION

The winged bean (*Psophocarpus tetragonolobus* (L.) DC.) is a traditional legume of Papua New Guinea (PNG). Its potential in maintaining soil fertility through abundant nodulation and as a source of protein for human nutrition was recognized in 1973 by the Faculty of Agriculture, University of PNG. This recognition coincided with the interest raised by Prof. Masefield, University of Oxford, U.K. and the National Academy of Sciences, U.S.A.

Dr. I. N. Khan, plant breeder at the Faculty of Agriculture, initiated a comprehensive programme on winged bean improvement. Since then a team of researchers at the University of PNG and the Department of Primary Industries (DPI) has worked with this crop, covering the areas of agronomy, physiology, genetics, breeding, nodulation, nutritional chemistry, pathology and plant protection. This team approach has resulted into the rapid understanding of the basic processes involved and the environmental and genetic manipulations required to tap the potential of the winged bean.

## RESEARCH PROJECTS

The following is a resume of work done on the winged bean in PNG, identifying the projects and the names of personnel involved. The results obtained in these projects are also briefly outlined. The projects undertaken by the University of PNG and the Department of Primary Industries are financed, respectively, by the Research Committee of the University and the Government of Papua New Guinea except when stated otherwise.

## PROJECTS AT THE UNIVERSITY OF PAPUA NEW GUINEA

**Genetics and Physiology of Tuber Production** (A.A. Bala and R.A. Stephenson)

Results indicated that reproductive pruning promotes tuberization and environmental factors, such as temperature and altitude, are important. Tuber yield is polygenic with greater additive genetic effects.

**Effect of Temperature on the Size and Development of Tuber** (A.A. Bala)

This is a new project. In 1978, controlled environmental studies has been undertaken.

**Studies on Genetics and Adaptation of Winged Bean** (W. Erskine and V. Kesavan)

The five qualitative characters were found to be simply inherited with linkage between stem and calyx colour. Natural crossing varies from 0 to 7.67%. Yield and related characters show continuous variation with considerable heterosis for yield.

**Genetic Resources: Exploration, Collection, Evaluation and Conservation** (V. Kesavan and A.A. Bala)

This project funded by the International Board of Plant Genetic Resources, FAO, Rome, has added 80 new accessions into the present collection of 130 pure lines. Expeditions are planned to explore areas that were not covered in the past. A promising accession with tolerance or resistance to false rust has been identified.

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**Studies in Induced Mutations** (V. Kesavan)

This project aims to obtain a dwarf mutant through the use of gamma rays and chemical mutagens. About 45,000 $M_2$ progenies were screened so far. As yet, no dwarf mutant has been spotted. This project is funded by the International Atomic Energy Agency, FAO, Vienna.

**Studies on Growth and Development in Winged Bean and Their Application to Plant Breeding and Management Practices** (R. A. Stephenson)

Growth analysis has shown that selection for early maturing types with superior growth rates leading to higher yields is possible. The optimum plant density was 150,000 plants/ha. Pod removal studies are in progress.

**Studies in the Improvement of Winged Bean: Variation and Inheritance of Seed Protein Content and Horticultural Potential** (V. Kesavan)

Protein content, monitored in 100 pure lines, varied from 24 to 32%. An $F_2$ population derived from a diallelle cross is being analyzed for protein to understand the inheritance of this character. The yields of green pods varied from 11-15 ton/ha. Yield and yield related characters showed greater general combining ability, indicating scope for selections with higher and early yield.

**Advanced Yield Trials at Various Locations in PNG** (R. A. Stephenson, V. Kesavan, A. A. Bala, J. Kaulo, J. Yogiyo, B. Siki, J. Bohn, Mrs. M. Herman and K. C. Wilson)

This is a new project, financed by the New Guinea Biological Foundation. Ten elite varieties will be tested at five locations for two seasons in PNG to select suitable varieties for the local grower. The Department of Primary Industries' personnel are actively engaged in this cooperative programme.

**Field and Controlled Environment Studies on Growth and Production** (J. Kaulo and R. A. Stephenson)

Another new project to supplement the advanced yield trials. The effect of temperature on growth, development and yield of seeds and tubers will be studied.

**Studies in the Biology, Epidemiology and Control of False Rust** (M. Drinkall)

Morphology of the fungus *Synchytrium psophocarpi* has been described. Sporangia germinated rapidly over a wide range of temperature (5 to 30°C) and humidity (84 to 100%) and remain viable up to 20 days when stored at 50°C. A disease survey revealed widespread damage in the highlands of PNG. Artificial inoculation techniques were standardized to study the genetics of resistance. Studies on fungicidal control showed promising results.

**Studies on the Biology, Epidemiology and Control of Diseases of the Winged Bean** (I. V. Price, now at the Hawkesbury College, N.S.W., Australia)

The biology and epidemiology of *Cercospora* leaf spot was investigated. A fungicide benoyl inhibited germination at 0.2 ppm. Two new diseases, namely powdery mildew (Oidium) and collar rot were recorded.

**Studies on the Root-Knot Nematode** (D. Lange)

The species *Meloidogyne incognita* was identified as the causal agent. A population of six larvae was sufficient to cause galls. Larval invasion occurred immediately after germination and the life cycle was completed within four weeks.

**Studies on the Nutritional Value and Development of the Winged Bean** (A. Claydon)

Ripe seed with 37% crude protein is very similar to soybean and of comparable biological value. Fresh tubers had 10.9% protein, probably higher than any other root crop. Storage studies indicated that root tubers could be stored for at least two months under conditions of low temperature (29°C) and higher humidity (74%).

**Relationship between Cation Exchange Capacity (CEC) of the Root and Yield** (D.P. Drover)

A new project in which the CEC of 4 week old seedlings of 10 selected varieties will be studied to understand whether there is any correlation between CEC and seed and tuber yields.

**Projects by the Department of Primary Industries (D.P.I.)**

In addition to the above projects at the University of P.N.G., the following personnel from the Department of Primary Industries are also actively involved in winged bean research. The role of the DPI in extending results to the farmers need not be emphasized.

John Bohn: **Advanced Yield Trials, Adaptation, Germplasm Evaluation and Extension in the Highlands.**

Terry Aldous: **Vegetable Trials to Assess Green Pod Production in East Britain.**

Jan Van S. Greve: **Studies on Stored Product Pests of Winged Bean.**

R.P.T. Elmes: **Cross Inoculation Relationship of Winged Bean and Its Rhizobium.**

The results show that *P. tetragonolobus* belongs to the cowpea cross inoculation miscellany and is promiscuous with regard to nodulation by *Rhizobium*.

## CONCLUSIONS

The research work on winged bean undertaken by the staff members of the University of PNG and the DPI reflects the importance of this crop in PNG. However, there are a number of areas of research that has to be explored and expanded. Some of these problems are outlined below:

1. Basic studies on the role of temperature, photoperiod and male sterility to enhance tuber production.
2. Cytogenetical studies on the genus *Psophocarpus*.
3. Biology, epidemiology and control of insect pests. This area has received minimal attention in the past.
4. Studies on the genetics of resistance and integrated pest control.
5. Studies on cropping systems, using winged bean. The abundant capacity for nodulation and forage potentials of this crop has not yet been fully utilized.
6. Nutritional studies, cooking quality and methods to realize the maximum biological value.
7. Outreach programs to extend the results of research to the farmers.

# Research Status and Uses of Winged Bean in Malaysia

*B. S. Jalani* and *K. C. Wong*[1]

## INTRODUCTION

A survey of winged bean production in Malaysia shows that it is essentially a small farmer's enterprise. In terms of popularity, it is one of the country's most commonly cultivated leguminous crops. It can be found frequently around the houses in the villages as well as in the big towns. Yet winged bean has not departed from its age old status as a backyard subsistence crop.

Data on winged bean production is not available. This is partly due to two main reasons: (1) no attempts have been made to conduct such survey, and (2) data collection on the farms is hampered by the fact that farmers do not produce winged bean in pure stands. Rather, they intercrop their winged bean with other crops or even plant them along the fence.

## RESEARCH

There are records which show that the winged bean had been observed in Malaysia as early as the latter part of the 18th century where Burkill (1966) noted that Koening saw it in Malacca in 1778. Ridley (1922) and Bunting and Milsum (1930) carried out studies on its distribution, cultivation and utilization in Malaysia. Masefield (1957) published his studies on nodulation of annual leguminous crop in Peninsular Malaysia. These observations point out that the winged bean has long been a standing crop and its potential uses had long been realized in Malaysia. Unfortunately, there were no follow up research of the above studies until recently. The lack of enthusiasm for such research can be reasonably attributed to three factors: (1) lack of research manpower, (2) lack of research funds, and (3) not being in the priority list. At present, research on the winged bean is conducted in the following disciplines: (1) Agronomy, (2) Genetics and Breeding, (3) Biochemistry, (4) Crop Protection, and (5) Microbiology. Other disciplines such as Economics, Physiology and Food Technology and Utilization are expected to follow soon.

## STAFF FACILITIES AND RESEARCH CENTERS

There are three categories of staff conducting research in Malaysia:

(1) Full time research personnel. These include plant breeders, agronomists, botanists and biochemists of various organizations such as the Malaysian Agricultural Research and Development Institute (MARDI), the Rubber Research Institute of Malaysia (RRIM) and the Institute of Medical Research (IMR).

(2) Teaching research personnel. Most of them are lecturers/professors who spend part or most of their time conducting research. These personnel are mainly in the biological or agricultural sciences from the National University of Malaysia, the University of Agriculture Malaysia, and the University of Malaya.

(3) Staff from the Ministry of Agriculture. They are mainly agronomists and extension staff at the Federal Experimental Station (FES).

At present, the bulk of research on winged bean in Malaysia is being conducted at the National University of Malaysia, the University of Agriculture Malaysia and the University of Malaya. MARDI and FES functions as multiplication centers and supply seeds to schools and other organizations as well as individuals.

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Researchers from the various organizations get together to discuss and exchange information and cooperate among one another in research. The government recently set up a body called the National Research Council (NRC) to coordinate all research activities in Malaysia.

## RESEARCH FINDINGS

Results of various experiments conducted in Malaysia are still meager and preliminary in nature. Some notable work on the winged bean are summarized as follows:

### Performance of Winged Bean in Malaysia

Performance studies were conducted by following the standards used by Wong (1975) where data was recorded from replicated plots, each measuring 3.2 m x 3.2 m with seeds planted 45 x 45 cm and with one plant per planting point. The plants were supported on trellis. The results on green pod, seed and tuber production have been reported by Wong (1975). Other performance studies have also been studied by Wong and the results are available in another paper presented in this workshop/symposium.

### Composition and Nutritional Value

Wong (1975) studied the composition of seed, tuber and green pod as well as the amino acid content of the tubers and seeds. No analysis has been carried out yet on the foliage of the crop. The results show that the winged bean has comparable nutritional value too if not better, than soyabean and cassava for seed and tuber, respectively.

### Feeding Trials on Chicks

A preliminary trial carried out to evaluate the winged bean seed as a source of protein for feeding chicks. The following comparisons were made on day old Hubbard broiler chicks (Wong, 1975):

Diet A: Control diet (100% soyabean protein).

Diet B: 50% soyabean + 50% winged bean protein; winged bean meal, raw.

Diet C: 100% winged bean protein, winged bean meal, raw.

Diet D: 50% soyabean + 50% winged bean protein, winged bean meal, autoclaved at 15 lbs. pressure for 15 min.

Diet E: 100% winged bean protein, winged bean meal, autoclaved at 15 lbs. pressure for 15 min.

Chicks were fed with the above diets for four weeks except diets B, C and E, which were discontinued after two weeks as the chicks were performing badly. Preliminary results on diets A and D showed that winged bean seed meal could successfully replace 50% of the protein from soyabean meal in chick rations. However, the ration containing 50% winged bean meal (diet D) showed poorer performance compared to full soyabean meal (diet A). This was probably due to trypsin inhibitors not completely destroyed by the above autoclaving. With proper processing techniques and complete removal of the trypsin inhibitors, the performance of winged bean meal in chick rations could be better demonstrated.

### Crop Protection

It has been generally observed that most of the winged bean accessions are infected by diseases or attacked by insects and pests. The most common disease is false rust (*Synchytrium psophocarpii*) which infect the various parts of the plant, e.g., pods, stems and flowers (Jalani, 1977). Chee (1976) conducted a trial on the effectiveness of various fungicides at RRIM Experimental Stations, Sg. Buloh, Malaysia. He found that there were no significant differences among "brands" of fungicide and it seemed that even at doses lower than the recommended level, the disease was fairly well controlled. This is probably due to the fact that false rust has not developed any resistance to these fungicides.

The most common pests are pod borers, snails and rats. No studies have yet been carried out on the extent of their damage and their control.

### Germplasm Collection

The collection and evaluation of indigenous genetic material has been initiated. These collections come mainly from the various parts of Peninsular Malaysia, and very few are recorded from East Malaysia (Sabah and Sarawak). However, an expedition to East Malaysia to collect this material is being planned and will be carried out during the second half of 1978. It is hoped that more collections will be made in the Peninsular Malaysia in order to increase the number of accessions as well as to get more representative samples of the population.

The germplasm collection also includes recent introduction obtained from outside Malaysia. The coun

tries of origin are Papua New Guinea, Indonesia, Nigeria, Kenya, India and Malawi.

The materials collected from Malaysia are rather homogeneous. Wong (1975) observed that there is a seed color variation which ranges from light brown to dark brown, and Jalani's collection seems to concur his findings. However, Jalani's collection shows that there are three distinct shapes of leaf, viz. deltoid, ovate and lanceolate leaflets. This seems to be similar to those found in Java (Sastrapradja and Lubis, 1975). The color of the young pod is green, including the wing. The shapes of the pod are in the ratio of 95% and 5% for rectangular and semi flat, respectively, and none were "flat on sides" or "flat on suture" (Khan, 1976). Pod length ranges from 9.0 cm to 26.5 cm with a mean of 17.8 cm. Seed numbers between 4 to 15 per pod with a mean of 11.5 per pod while 100 seed weight ranges from 34.1 to 40.5 gm with a mean around 37.3 gm. The stems are consistently green in color and the flowers are blue, with green calyx. Further evaluation and multiplication of these germplasm collections will be carried out soon.

**Other Research Programs**

An initial study on the relationship of fertilizer and nodulation as well as its mineral content has been conducted by Z. Samsuddin and O. Yaacob (1976).

An initial study on the utilization of winged bean seed as human food in the form of curd and "milk" is being carried out by G.C. Ching.

Studies on forage aspects, cropping system and modification of growth habit are being conducted by J.C. Lew.

Studies on rhizobium and nodulation of winged bean have been carried out by M. Ikram and J. Broughton and some of the results was presented in the Working Seminar of the potential winged bean, Los Banos, Laguna, Philippines, January 1978.

Preliminary studies on induced mutation breeding by chemical and physical mutagens have been carried out by B.S. Jalani with the aim of obtaining determinate or bush type mutants and other desirable characters.

## USES OF WINGED BEAN IN MALAYSIA

It is generally known that various parts of the plant have been used for human consumption. In addition, however, we have observed and noted that it has been used for medicinal purposes.

**Human Consumption**

(a) Young parts. Young pods, leaves, shoots and flowers are being used as vegetable. They are either eaten raw as salad or cooked with spices. It is worthwhile to note here that there is a "pungent" odor, especially among young/green pods, which discourages people from eating them.

(b) Mature seeds: They are consumed either parched or fried.

(c) Flowers. They are also being used in food coloring, especially for making local cakes. However, such use is rarely made.

(d) Tubers. They are consumed either boiled or fried. It is interesting to note that very few people know that winged bean produces tuber which can be consumed.

**Medicinal Purposes**

(a) The tubers, either dried or fresh, are boiled in water and the latter is used as "tonic," especially for women after giving birth. Sometimes, the tuber is used in conjunction with other plant materials for "ubat perlok" to be used as "tonic."

(b) The mature seeds when used with other ingredients are said to help cure impotency.

(c) The young leaves, rolled or meshed with betel leaves, have been used to reduce swelling and pain caused by insects or stings.

(d) Meshed young leaves, shoots and flower buds have been used, when applied to the scalp, as a stimulant for hair growth.

## FUTURE WORK

Research on winged bean in Malaysia is still at an infant stage and the results shown are preliminary in

nature. It is hoped that in the future there will be more research done on this crop. The funds for developing research on winged bean are available and can be secured through the international bodies as well as the local research institutes and universities. We are very optimistic that, because of the new interest in this crop, there will be variety/varieties suitable for large scale planting in the very near future.

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# Some Varietal Observations on the Winged Bean in Malaysia

*Jonathan C. Lewis*[1]

**A small number of winged bean lines were collected from Peninsular Malaysia and grown in small plots for seed multiplication on deep woody peat soil of Johor, Malaysia. Also included for seed multiplication were 3 Indonesian lines, UPS-31 (Papua New Guinea) and K-12 (University of Florida). Observations were made on the vegetative vigor, period of maturacion, tuberization, seed yield and nodulation and other phenotypic characteristics. All of the Malaysian lines collected were identical in all phenotypic traits examined. The plant can be described as a climbing vine with flowers similar to long beans, green stems, a very high vegetative vigor and a very long maturation period for an annual crop (first seed harvest after four months).**

**In comparison, UPS-31 was considerably earlier, of very little vegetative growth and of a very low seed yield. K-12 was somewhat in between, being about 1 month earlier than the Malaysian lines, of moderate vegetative vigor and good yield. It was concluded that immediate use of these Malaysian varieties of winged bean could be as, a forage legume, a cover crop for the numerous oil palms and rubber plantations, and as a seed crop to substitute for soybeans. Unfortunately, these varieties are not adapted for large scale mechanized planting and would probably be of most value to the small holder for protein meal production.**

## INTRODUCTION

The winged bean, *Psophocarpus tetragonolobus* has been described in recent literature to be nutritionally similar in terms of amino acid and fatty acid content to soybean (NAS, 1975). The seed yields a high quality protein meal, and a very light, high quality oil similar to safflower oil or corn oil. The winged bean is ecologically adapted to the humid tropics where soybean production, although possible, is considered difficult for inexperienced farmers. A full study including forage uses, and seed production is being initiated. The following observations is a summary of some trials made in west Johor peat soils of Malaysia strictly for seed multiplication.

## TRIAL I

A Malaysian variety of winged bean originally imported from Thailand was multiplied at the Crop Production Centre, Serdang Malaysia (Vegetable Seed Production) on a lateritic soil.

The beans were planted at a spacing of 2 x 2 feet and trellis similar to long bean production. A total area of 2.14 ha was planted, and was fertilized (total NPK/ha) by basal dressing at 500 kg/ha malameal (organic) and by top dressing at the 4th and 8th month with malameal at 1000 kg/ha and urea at 30 kg/ha.

**Observations**

1. First seed harvest: 132 (128-235) days after sowing
2. Last harvest: 291 days after sowing
3. Seeding duration: 140 days
4. Yield of selected seed: 2438.23 kg/ha

## TRIAL II

The following lines were collected for seed multiplication in 144 sq. foot plots on deep woody peat soil:

1. Indonesian I 785

[1]U.S. Peace Corps Volunteer, Crop Protection Officer, Pejabat Pertanian Daerah Pontias, Johor, Malaysia.

2. Indonesian II 867A (2)
3. Indonesian III 799 1A.1 (1)
4. Bumbong Lima, Perak, Malaysia
5. Kuantan, Pahang, Malaysia
6. Pontian, Johor, Malaysia
7. Pontian, Johor, Malaysia

The beans were planted at a spacing of 3 x 2 feet on trellises. Mild rust infection was controlled with Benlate and Manzate. Diazinon was used to control general insect attacks. Generally, it was found that a regular spray program was not necessary except before maturity. Sufficient control was maintained by monitoring diseases timely control. Basal fertilizer was applied at 2.75-50 lb NPK/acre and top dressing was conducted every two months with 25 lb of urea/acre/month.

In general, all of the Malaysian lines collected and Indonesian III were found to be phenotypically similar.

No differences could be found between those lines and the Malaysian winged bean lines described by Wong Kai Choo (1975). Indonesian I and II did not perform well on the peat soil due to copper deficiency and other unknown factors.

**Observations**

1. **Germination.** All varieties gave 90% or higher germination within two weeks. All of the plants were set back in their development by 3 to 4 weeks due to topping by chickens.
2. **First harvest:** 108 days — All Malaysian lines and Indonesian III.
3. **Yield (dry seeds).** 3333 lbs/acre extrapolated yield for the Malaysian lines and Indonesian III.
4. **Phenotypic description**
   a) **Malaysian lines (#4-7), Indonesian III (#3):** After only a few weeks of growth, the plants began showing an extremely vigorous vegetative growth. Many vines eventually developed from one plant due to extensive branching along the older parts of the plant. The plant seemed capable of climbing to any height for which adequate support was provided (up to 15 feet).

      Flower colour was blue. The shape of the leaves were ovate with a tapering tip and had a diameter of about four to five inches. The stems were green and become woody at the base when the plant was over three months of age.
   b) **Indonesian I, II (# 1-2):** Neither of these varieties performed well nor did they flower. These plants did not withstand the topping damage by chickens. After two months, some vegetative growth did occur. Two leaf types were noted: ovate and elongated. Copper deficiency was suspected and all plants were given additional copper fertilization and foliar sprays. Although there was a good response to copper, recognizable in the form of increased vegetative vigor and greening of the leaves (previously yellowish green), no sign of flowering occurred.

## TRIAL III

Several more lines (below) were grown for seed multiplication in 500 sq. feet on deep woody peat soil.

1. UPS 31, University Papua New Guinea
2. UFK 12, University of Florida U.S.A.
3. M 1, University Pertanian Malaysia
4. M 3, University Pertanian Malaysia
5. M 4, University Pertanian Malaysia
6. FFS, Federal Crop Production Center, Serdang
7. MARDI, Jalan Kebun Station, Malaysia

The seed was planted at a spacing of two feet by six inches in small ridge. For the first two months, a spray program using Manzate, Benlate, Diazinon and an oil based sticker was followed.

**Observations**

1. **Germination.** All varieties gave 95% germination within two weeks.
2. **Date of flowering.** UPS31 10 weeks after sowing, UFK12 12 weeks after sowing, M1, M3, M4, FFS, MARDI 14 weeks after sowing.
3. **Yield.** UPS31 Negligible, UFK12, M1, M3, M4, FFS, MARDI 2175 lbs/acre, estimated yield.

4. **Phenotypic description.**
   a. **UPS31:** A rather small and early plant with very low vegetative vigor. It had blue flowers, purple stems and black seeds. The leaves were also extremely small being only one inch in diameter and ovate in shape. This is the only plant which did not fill in the chicken wire fence used as trellis. No tuberization was noticed.
   b. **UFK12:** Essentially the same as the Malaysian lines described above except that vegetative vigor was slightly lower. Its tubers were very small at about 2-3 inches long even after 10 months. Yield was negligible.
   c. **M1, M3, M4, FFS, MARDI:** All identical in every noticeable character. Same as the description for the Malaysian lines in Trial II except that tuberization occurred only to a very small extent (yield was negligible) similar to those found for UFK 12. In the previous trial, tubers were not looked for so it is unknown if those lines (Malaysian) will or will not tuberize.
   d. **All lines were found to nodulate heavily without inoculation.** Soybean grown on a new field of this deep woody peat soil, although inoculated with the proper inoculum showed a very low rate of nodulation.

## TRIAL IV

The purpose of this trial was to answer two questions: (1) Will the winged bean compete with grass, planted as a grass-legume pasture mixture? and (2) If the winged bean does compete well with the pasture, can it persist well under grazing by cattle?

### Design

The basic design of this trial was to plant winged bean in combination with a grass-legume mixture (Guinea and *Centrosema*) in the normal manner practiced by the Majuternak ranches in Malaysia. Notes were taken on the density of the three species present in the area before and after a period of grazing.

| | |
|---|---|
| Total area planted | 0.43 acres |
| Planting date | November 23, 1977 |
| Fertilizer | 600 cwt/acre CIRP |
| Planting material | 10 lbs/acre winged beans |
| Soil type | Sandy clay pH 4.5, cleared secondary jungle |
| Inoculum | Cowpea family |

### Observations

Forty days after planting, the winged bean was growing well (12-15 cm high), while that of the Guinea grass and *Centrosema* were just being planted.

Final results of this trial will be completed with four months. This trial is part of a larger program to stimulate the use of the winged bean in Malaysia. A trial is being planned to test the compatability of winged bean as an intercrop with sorghum ratoon crop grown for fodder would be enriched with protein from the seed and foliage of the winged bean.

## CONCLUSION

The winged bean selections grown in these trials were found to be very vigorous and had a very long maturation period when considered as an annual. They are similar to one Indonesian line from the National Biological Institute in Bogor, courtesy of Dr. S. Sastrapradja in most growth characteristics. The purpose of these observations was to determine if the winged bean can be grown where other crops are unsuitable. The major crops in Malaysia are rubber and oil palm. The observations from these plantings indicate that the winged bean (local varieties) is a crop easy to grow on peat soil and elsewhere. It suffers from two major drawbacks: 1) its long maturation period and 2) its need for support to produce a high seed yield. Owing to the high protein content of all its parts, some observations were made on Majuternak land to evaluate its usefulness as a pasture legume, as a sorghum intercrop and as a green crop cattle feed. It is recommended that the utilization of seeds, in view of their remarkable nutritional similarity to soybeans should be investigated. There is also a possibility for the production of protein meal from the winged bean to replace the vast imports

of soybean meal (Wong Kai Choo, 1975). Such an investigation should be aimed at the small holder, especially those working on soils not highly profitable for oil palm and rubber.

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# Winged Bean in Australia: Personalities, Opinions and a Little Research

*G. E. Eagleton*[1]

**The winged bean (*Psophocarpus tetragonolobus* (L.) DC.) is not a new introduction in Australia, but it has never been studied before.**

**Since 1976 there has been an upsurge of interest in the crop's potential, but only the agronomic work of Robertson, *et al.* (1978) and the studies of Gillespie and Blagrove (1978) on seed proteins could be regarded as significant Australian contributions to winged bean research. Consequently, the potential role of the winged bean in Australia is unknown.**

## INTRODUCTION

The winged bean (*Psophocarpus tetragonolobus*) (L.) DC.) has been known in the Darwin area of Northern Australia since before World War II (Miller, personal communication). No one is sure how it got there. Perhaps it came with the Indonesian or Chinese communities. Macassan seafarers were in contact with Australian aborigines well before the European's coming (Berndt and Berndt, 1964). It seems unlikely, however, that the winged bean was introduced before this century.

During the immediate post war period, winged beans clung tenaciously to a few backyard fences, but little attention was paid to them until 1976 when interest was aroused by reports from Papua New Guinea (by Khan, 1976 and Khan, et al., 1977) and by publicity given to it by the U.S. National Academy (N.A.S., 1975). Several individuals began to introduce seed from Khan's collection, including Stern, Robertson and Millington in Western Australia, Wood and Hobman in Queensland, Benson in the Northern Territory, Desborough in N.S.W., Broue in the A.C.T., and a number of farmers. At the same time, a few specialized studies such as the collaborative work of Brock with the University of Papua New Guinea on mutation breeding and the work on seed proteins of Gillespie and Blagrove commenced.

Since all these studies are recent, the amount of information available is scanty. This review will be concerned firstly with evaluating the limited information available on the winged bean's potential as a crop in Australia, then will briefly consider more specialized studies.

## CROP POTENTIAL IN AUSTRALIA

Evaluation of winged bean as a crop began in 1976.

Robertson, *et al.* (1978) grew the entire U.P.N.G. collection and a few introductions from Thailand and Indonesia at Kununurra in the North of Australia during the 1976/77 season. Irrigation was supplemented to rainfall but no physical plant support was provided.

Initial losses due to poor establishment and waterlogging were experienced. Once established, vegetative growth was vigorous (particularly among Indonesian and Thai lines) and effective ground cover. Though plants were slow in maturing (the earliest line took 63 days to flower) seed yields of up to 3.6 t/ha were obtained by hand harvesting. Pod shattering was judged to be a major barrier in the mechanical harvesting of winged bean grain.

Other workers have had less success. Desborough (personal communication) planted two contrasting Papua New Guinea lines at Grafton, N.S.W., in December 1976. Both lines required approximately 90 days for flowering and 160-165 days for pod maturation. Tuber production was negligible. Tuber production was also poor in the Papua New Guinea lines grown by Hobman at Innisfall in North Queensland, while seed production was judged to be well below that of soyabean (Williamson, personal communication). In Darwin,

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Benson planted 25 Papua New Guinea lines under irrigation in the dry season of 1976 but they did not perform well (Miller, personal communication). One other line sown in June 1976 did better, cropping well in the wet of 1976/77 and regenerating in 1977/78.

From these studies the initial reaction of workers is that the winged bean has little to offer to Australian farmers at present. However, many would support the contention that the greatest potential for the winged bean is under village farming systems where it can be fully utilized and its climbing habit is not a serious disadvantage. In this context, Millington has suggested the plant's possible role in Northern Australia where poor health and high infant mortality among Australian aborigines is often attributed to malnutrition (CSIRO, 1977).

The disadvantages of its indeterminate growth habit should not be over stressed. In forage and cover crops it is an asset and need not detract from seed production potential (Robertson, *et al.*, 1978). Many lines are capable of perennial growth (Eagleton, *et al.*, 1978). We should not too quickly dismiss the value of these characteristics.

## SPECIALIZED STUDIES

In more specialized fields of study there have been some useful, if isolated, contributions.

### Protein Chemistry

Gillespie and Blagrove (1978) have examined the seed storage proteins which the independent studies of Craig (personal communication) and Kuo (personal communication) have located in discrete bodies within cells of the cotyledons. Amino acid composition differs only slightly from soya bean in having lower sulphur amino acids but higher lysine content. On the other hand the molecular structure of the seed proteins is quite different from soya bean. Electrophoresis techniques have resolved the proteins into three main components but an examination of 80 lines does not suggest that there is great scope for plant breeders to upgrade the nutritional quality of seed protein.

Kortt (personal communication) has extended these studies to include an examination of anti-nutritional factors (proteinase inhibitors and lectins).

### Diseases

The work of Price, on the diseases of winged bean in Papua New Guinea (Price, 1976; Price, 1977; and Price, 1978) does not need emphasis. In Australia, Price maintains a continuing interest in the false rust (*Synchytrium psophocarpii*) of winged bean through his association Drinkall of the University of Papua New Guinea. He is also collaborating with Gibbs in studies on viruses affecting winged bean.

### Rhizobia and Mineral Nutrition

Very little knowledge is available on the rhizobial associations with the winged bean (Elmes, 1976; Ikram and Broughton, 1978). Zulkifli is continuing the work he started in Malaysia with Othman (1977). Together with Dilworth and Loneragan he has begun to screen rhizobial isolates for their compatibility with winged bean.

### Plant Breeding

A preliminary screening of germplasm is being carried out by Eagleton, *et al.* (1978) for photoperiod and temperature responses in reproductive development. A diallele cross between contrasting lines has been initiated to determine the genetic basis of these responses.

### Genetics

Brock has been collaborating with the University of Papua New Guinea, since 1975 (Khan and Brock, 1975; Kesavan, *et al.* (1977). These studies have refined radiation dose levels and treatment regimes for artificial induction of mutations but are now essentially undertaken by the University of Papua New Guinea. One long-term objective of this work is the production of a determinate line and the outcome of this could depend on the long term future of the winged bean in Australia.

## CONCLUSION

Although the winged bean has been viewed by many as a plant with great potential (N.A.S., 1975), the general consensus of opinion is that more advanced lines will have to be developed before it can be effectively utilized in the Australian context. Many researchers would like to see the day when the winged bean makes a significant agricultural impact on the Asian Pacific region of which Australia is part.

## LIST OF RESEARCH WORKERS

| Name | Institution | Field of Interest |
|---|---|---|
| Benson, C. Mr | Department of Northern Territory, N.T. | Field Evaluation |
| Blagrove, R. Dr | CSIRO Division of Protein Chemistry, Victoria | Protein Chemistry |
| Brock, R. Dr | CSIRO Division of Plant Industry, A.C.T. | Genetics |
| Broue, P. Mr | CSIRO Division of Plant Industry, A.C.T. | Plant Introduction |
| Craig, S. Mr | CSIRO Division of Plant Industry, A.C.T. | Microscopy |
| Desborough, P. Mr | Department of Agriculture, N.S.W. | Field Evaluation |
| Eagleton, G. Mr. | University of Western Australia, W.A. | Plant Breeding |
| Gibbs, A. Dr | Australian National University, A.C.T. | Virology |
| Hobman, R. Mr | Department of Primary Industry, Queensland | Field Evaluation |
| Hocking, P. Dr | Murdoch University Western Australia | Plant Nutrition |
| Khan, I. Dr | Department of Agriculture Western Australia | Plant Breeding |
| Kortt, A. Dr | CSIRO, Division of Protein Chemistry, Victoria | Protein Chemistry |
| Kuo, J. Dr | University of Western Australia, W.A. | Microscopy |
| Millington, A. Dr. | Office of Regional Administration and the North West, W.A. | Field Evaluation |
| Price, T. Dr | Hawkesbury Agricultural College, N.S.W. | Plant Disease |
| Robertson, G. Dr. | Department of Agriculture, Western Australia | Field Evaluation |
| Thurling, N. Dr | University of Western Australia, W.A. | Plant Breeding |
| Warren, J. Mr | Department of Agriculture, Western Australia | Field Evaluation |
| Wood, I. Dr | CSIRO Division of Tropical Crops and Pastures, Queensland | Plant Introduction |
| Zulkifli Shamsuddin, Mr | Murdoch University, Western Australia | Rhizobia |

## ACKNOWLEDGEMENT

The author wishes to thank those persons who contributed to this profile and hopes that none is seriously misrepresented by the interpretations given.

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# The Winged Bean in Nepal

*B. B. Mathema* and *H. M. Sreshta*[1]

Nepal is an agrarian country with about 92.7% of its population engaged in agriculture. Plant protein is the major source of protein in the daily diet of average Nepalese. Grain legumes and vegetable legumes are important in Nepalese agriculture not only because Nepalese get their major supply of protein from legumes but also because legumes fit into their existing cropping system. Legumes are cultivated not only in monoculture but also as mixed crop intercrop or relaycrop with major cereal crops like rice, corn and wheat.

The area under legume crops is estimated to be 70,000 hectares and production per hectare is about 500 kilograms. Commonly cultivated legumes include chick pea (*Cicer aurietinum*), lentil (*Lens esculentum*) pigeon pea (*Cajanus cajan*), soybean (*Glycine max*), black gram (*Vigna mungo*), cowpea (*Vigna sinensis* and *Vigna catjang*), horse gram (*Dolichos biflous*), mung bean (*Vigna radiata*), broad bean (*Vicia faba* var. *gigantum*), french bean (*Phaseolus vulgaris*), sword bean (*Canavalia gladiata*) and several other species of bean in the hills. However, cultivation of winged bean *Psophocarpus tetragonolobus* (L.) D.C. has not been observed so far at Nepal, although it is reportedly grown in adjoining northern states of India.

The first record of introduction of winged bean in Nepal was during 1977. Fourteen winged bean varieties introduced from India were planted at the Ag. Botany Division plot at Khumaltar, Kathmandu valley situated at 1300 meter altitude. Planting was done at three different dates: 22 April, 7 May and 23 May of 1977 (Table 1).

Table 1. Winged bean: some recorded observations in Nepal.

| Entry No. | Varieties | Days to 1st Flower | | | Ave. Pod Length in cm | | | Ave. No. of seed pod | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 22 April | 7 May | 23 May | 22 April | 7 May | 23 May | 22 April | 7 May | 23 May |
| 1 | IC 15017 | 80 | — | — | 14.6 | — | 15.1 | 12.0 | — | 12.4 |
| 2 | IC 15018 | 75 | — | — | 24.2 | 16.6 | 13.7 | 15.1 | 14.1 | 9.7 |
| 3 | IC 17002 | 85 | 91 | — | 18.9 | 12.9 | 13.3 | 14.6 | 10.5 | 11.3 |
| 4 | IC 17004 | 76 | 83 | — | 18.0 | 13.1 | — | 11.6 | 9.3 | — |
| 5 | IC 17005 | 82 | 86 | — | 16.6 | 15.3 | — | 12.0 | 4.9 | — |
| 6 | IC 17006 | 77 | 81 | — | 17.3 | 14.9 | 11.4 | 11.9 | 11.2 | 11.0 |
| 7 | EC 27884 | 78 | 84 | — | 18.8 | 13.4 | — | 14.8 | — | — |
| 8 | EC 27886 | — | 86 | — | 23.7 | 17.0 | — | | — | — |
| 9 | EC 27886 A | 86 | 86 | — | 18.3 | 18.1 | 10.8 | 14.2 | 14.2 | 11.4 |
| 10 | EC 38821 $P_2$ | 76 | 81 | — | 17.3 | 15.9 | 15.8 | 11.0 | 12.0 | 11.0 |
| 11 | EC 38821 $P_4$ | 69 | 78 | — | 14.2 | 14.2 | 13.1 | 11.9 | 9.7 | 10.0 |
| 12 | EC 38955 | 71 | 85 | — | 11.2 | 10.1 | 10.4 | 11.0 | 9.3 | 9.9 |
| 13 | EC 38957 | 84 | 88 | — | 14.0 | 17.7 | 10.5 | 12.5 | 10.6 | 11.0 |
| 14 | EC 38958 | — | 88 | — | 21.9 | 23.1 | — | 16.1 | 13.4 | — |
| | MEAN | 78 | 84 | — | 17.8 | 13.0 | 12.7 | 13.0 | 11.7 | 10.7 |

*Average of ten pods
— Not available

Each variety was planted in rod rows 2.5 meter long and 0.75 meter apart. Seeds were planted on raised beds to protect the plants from waterlogging from the heavy downpour of monsoon rain. All the varieties germinated and grew well. The mean number of days to 1st flower for the first and second planting dates were 78 and 84 days, respectively. Entry no. 11 (Ec 38821 $P_4$) flowered earliest at both planting dates.

[1]Agronomist and Agricultural Botanist respectively, Department of Agriculture, Kathmandau, Nepal.

Average pod length and average number of seeds per pod were generally greater for earlier planting dates compared to later plantings. Yield could not be recorded because young green pods were harvested and tested for vegetable purposes. The use of young green pods for vegetable purposes was found to be very encouraging.

Under Khumaltar conditions, pods do not mature at the same time, which is a handicap if winged bean is cultivated in monoculture for grain production purposes. The plants displayed an annual growth habit and performed poorly during the cold months of November and December. There was no tuber formation. Staking was necessary to protect the plant from incessant and heavy rains. The winged bean plant was found to be relatively free from insect pests and diseases during the summer season.

Results of this preliminary study indicate that winged bean can be grown in such places as the midhills of Nepal, where the climate is similar to Kathmandu valley during summer. It also indicates that the winged bean could also grow better at the southern valleys and Terai plains where climate is much warmer all year round. However, testing of winged beans under different cultural and agronomic systems under various ecological regions of Nepal and under diverse locations in each region will be necessary to determine how widespread the cultivation of winged bean can be spread in the country.

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# Some Information on Winged Bean in Costa Rica

*Gustavo A. Enriquez*[1]

## INTRODUCTION

Most Latin American countries have large extensions of land under the humid tropics. The climatic conditions of some of these countries are modified by high mountains as the Andes and the Central American Plateau. The staple food of most of these countries are cereal grains and legumes. Common bean (*Phaseolus vulgaris* L.) is the most important species in the region, but its cultivation under humid tropical conditions is limited because of disease problems (Enriquez, 1977). Other legume grains had been introduced to replace common beans. Of the different species of *Vigna* tested, *V. unguiculata* appears to be the best adapted to the area. The winged bean (*Psophocarpus tetragonolobus* (L.) DC.) is also one of the several tropical legumes recently introduced in Latin America with striking potentials as a food crop (Pinchinat, 1976).

Most of the wet American Tropics have been identified as areas of severe protein deficiency (Enriquez, 1977). However, with intelligent research and extension programs the potentials of the winged bean as source of high food nutrient especially protein can be exploited.

The Centro Agronomico Tropical de Investigacion Y Enseñanga (CATIE) is very much concerned about the problems related to the production and consumption of this legume in tropical America, particularly its acceptability and palatability for human and animal consumption.

Because of the extensive use of some species of *Phaseolus* and *Vigna* in this region, the winged bean has to be tested against other legume species to determine their acceptability as grain and vegetable. One way to introduce the winged bean into the market, could be as canned, precooked food, eliminating any of its undesirable flavor.

Among the more important uses of winged bean in tropical America could be in industry, as source of oil. But then this crop has yet to compete efficiently with soybean oil, palm and other oil crops. Immediately however the winged bean can qualify as a small farm crop.

## MATERIALS PLANTED AT CATIE

Seeds were introduced from different sources. One group of seeds was planted at Turrialba in 1975, and four different lines of seeds were harvested from this.

The Genetic Resources Program of CATIE planted some seeds selected from the original material on the basis of their adaptability and high yield performance. Some of the plants were selected and classified according to different characteristics of the flowers, pods, stems and others. The program is also planting winged bean in large experimental areas as green manure crop, because of its high nitrogen fixing activitiy.

The *Rhizobium* of the winged bean is in the same compatibility group with *Vigna* (Elmes, 1976). *Vigna* species are widely cultivated in Latin America, suggesting that minor problems will be expected in the nitrogen fixation of winged bean by the use of cowpea group strains or some other *Vigna* species.

## MATERIALS PLANTED AT GUAPILES

Four varieties: Chimbu, UPS 31, 799.2 B and Coll. 993, were planted in Guapiles in rows at 1.3 m apart and 1 m within the row. Some of the seeds did not germinate so they were replanted.

[1] Agronomist in the Cropping Systems Project at CATIE, Turrialba, Costa Rica.

At the beginning, the seedlings were growing very slow due to a dry spell after planting. Consequently, the first planting was also damaged by rabbits. Table 1 contains some information on the varieties planted at Guapiles.

**Table 1. Mean length of pod and number of seeds of the 4 varieties planted in Los Diamantes.[a]**

| Variety | Mean length (cm) | Mean number of seeds (per pod) | Number of pods (per plant) |
|---|---|---|---|
| 1 799 2 B | 22 89 | 13 22 | 22 |
| 2 Coll 993 | 12 90 | 8 50 | 16 |
| 3 Chimbu | 19 88 | 8 33 | 24 |
| 4 UPS 31 | 17 | 5 42 | 12 |

[a]Guapiles, 1975.

The first flowers of the UPS 31 variety appeared on March 7, 1976. The first three pods that gave 20 seeds were harvested on April 16. This was the earliest variety of the group.

Chimbu, produced pink pods, the first of which was harvested on April 18, producing only 5 seeds. The pod was 9 cm. long and 7 cm. of external circumference.

On May 12, 5 more pods of the UPS 31 variety were harvested, which gave 39 seeds and had a mean length of 11 5 cm and the circumference of 7 cm. The basic pod color was green while its wing color was pink. Seven days later 1 small pod containing 4 seeds was harvested.

Two pods that yielded 25 seeds were harvested on May 21 from variety Chimbu. One of the pods measured 29 cm long and 8 cm of circumference containing 19 seeds. The other one was 14 5 cm long and 9 cm of circumference containing 6 seeds.

The other varieties began to produce pods beginning in the 4th of June.

The mean of length and the number of seeds of the four varieties are presented in Table 1.

Varieties numbers 1 and 3 had very long pods. One of the pods of variety number 3 was 33 cm long, with 20 seeds, and was harvested at the end of the season.

Varieties numbers 2 and 4 were not very well adapted and had a lot of problems.

All the seeds of this harvest were stored, only the roots of variety number 4 were harvested on July 9, 1976, and presented two short white roots.

In the Boliche Experimental Station, Ecuador, the Bean Program planted a few seeds received from CIAT, Colombia in 1974 and harvested some seeds that were classified in four groups according to color. In 1975 the four lines were planted separately, unfortunately most of the plants were attacked by virus and only a few seeds were harvested. No more planting was made from this material.

CATIE has plans to introduce winged beans in the cropping systems research of regions where common bean or other legumes are difficult to cultivate. We are looking for the best adapted variety and the best way to use it. The farmers of this region will need a convincing evidence of the food palatability and cash values to use a new crop in their systems, because of their agricultural tradition with common beans.

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# Observations and Experience with Winged Beans in Puerto Rico

*Franklin W. Martin*[1]

## INTRODUCTION

The winged bean is not known as a crop in Puerto Rico. Cognizant of its immense potentials however the Mayaguez Institute of Tropical Agriculture (MITA) conducted exploratory studies on this species as early as 1974.

Several varieties were collected in Indonesia in 1975, and fair collections were later obtained from Kahn, in Papua New Guinea, and Rachie, in Nigeria. A few accessions were obtained from the Caribbean, and most recently from introduced stocks at Experiment, Georgia. These, in turn, are from Papua New Guinea. Thus, 59 accessions were collected, but were separated into 100 or more lines of contrasting differences.

Substantial results were obtained from experiments conducted to make some judgment about this plant possible. Majority of the conclusions however, are not backed by repheated, measured experiments. This paper therefore shall carefully distinguish between observations and experimentally verified results.

Winged bean were grown on some of the most sterile clay sub soils of Puerto Rico, on a variety of acid clay and loam soils, and on carefully prepared soils enriched with organic matter. The winged bean, can grow and produce very well on even fairly sterile soils without inoculation and is adaptable to very good soils high in organic material. However, it has not yet been adequately proven that winged bean is a good crop for marginal lands.

## FLOWERING

All varieties fruit and flower best during the season of short days. When the winged bean is planted at this period some vines begin to flower when only 30 cm long. During the long summer days, strong differences in photoperiodic response are seen. A few varieties have been identified to continue flowering but at a reduced rate during the summer months. While other varieties have been found to flower sparsely, and then only during the shortest days. These set only enough seed to preserve the variety. They are called forage types. On the basis of year long production, or for other traits, 13 varieties were selected.

## FIELD PERFORMANCE

The absence of tuberous roots was one of the unexpected and frustrating experience. Mature plants were sampled for tuberous roots. In heavy clay soil and subsoil little or no tuberous root formation was seen. The few tubers found were small and fibrous. Based on this experience, the ability of winged bean plants to produce worthwhile tubers became questionable. Subsequent experience has shown that winged bean is an excellent vegetable for the hot, humid tropics during the season of short days when soil moisture is sufficient.

In several ocassions, winged bean was compared to several cowpea accessions, their nearest rivals during the rainy seasons. Under excellent conditions including protective spraying, excellent yields of these beans have been obtained. The cowpea varieties tend to produce very high yields over a short period. The best winged beans were capable of the same high yields, but extended over a relatively long period. The cowpeas, in contrast to the winged beans, were very susceptible to insect pests.

There are reports that the winged bean is a better yielder under conditions of poor fertility and neglect that any other bean that the Institute has worked with. As a commercial crop however under optimum conditions, cowpeas can produce as well or better than winged beans as available local data show.

[1]Horticulturist and Director, Mayaguez Institute of Tropical Agriculture, Mayaguez, Puerto Rico.

## NUTRITION

The protein content of the green pods at various stages of growth were determined. At all stages, the bulk of the dried weight were in the pods, not in the seeds. As the green pod matures, it continues to contain much more protein than the beans themselves, for the overall contribution of the seed protein to the combined seed and pod protein is small. Thus, green pods appear to be good food items with about 15 per cent protein, dry weight basis. Pods can be eaten best when they are large, but with the fibers still tender. If the pods are permitted to mature further, the immature but somewhat bitter seeds are still good food, and contain about 24 percent protein on a dried weight basis. Nevertheless, the total protein obtained from seeds is always much less than that obtained from the seed and the pod, when harvested at the optimum stage. It has been recommended locally that the winged bean be grown for its green pods.

Winged bean seeds are exceptionally hard. When soaked overnight in water, some seeds imbibe water and swell normally. Some seeds hardly imbibe water at all and do not swell. Many seeds fall between these extremes. The ability of seed to imbibe water varies with time. Young seeds imbibe better than old seeds. Well formed, mature seeds imbibe better than seeds damaged by fungi or by early harvest. There is also a strong varietal influence on winged bean seed imbibition. Seeds of some varieties imbibe water much more freely than others.

The capacity to imbibe water is closely related to the capacity of seeds to soften when cooked. Winged bean seeds need prolonged cooking, it took 3 or 4 hours in the laboratory. Seeds that have imbibed water freely, soften rapidly on cooking.

A simple, effective technique has been found to prepare winged bean seeds for eating as follows: Rinse the beans and add 5 volumes of water. Add 1 percent sodium bicarbonate (soda or baking soda) to the water. Bring the beans to boiling and allow to simmer for 3 minutes. Remove from heat, and let the beans soak overnight in the solution. The following day discard the soaking water, rinse twice with fresh water, and boil the beans in about double their volume of water for 20 to 25 minutes.

A careful evaluation of 19 varieties of winged bean showed that all winged bean varieties react to this treatment. Nevertheless, most hard seeds, or intermediate seeds do not soften sufficiently for pleasurable eating. Hard seeds can be separated from the larger soft seeds by a screen of appropriate size. Small, hard seeds that fall through and can be discarded. On the other hand, all of the seeds of some varieties are softened sufficiently, and harshness of flavor is reduced by this treatment. These cooked dry bean seeds can then be prepared for eating by any other technique, and are highly acceptable. It may be noted that even one hard seed among 100 makes eating winged bean a difficult experience.

Winged bean accessions and their sources are given in Table 1. While the present sample of varieties is fairly cosmopolitan, it does not include varieties from Burma or Thailand. It is probably a biased sample.

**Table 1. Winged bean varieties evaluated in Puerto Rico.**

| Our number | Source to US | Other identification | Our number | Source to US | Other identification |
|---|---|---|---|---|---|
| WB 1 | Trinidad | WB 27 | WB 33 | Papua New Guinea | UPS 33 |
| 2 | Indonesia | 503, WB 29, Bogor | WB 34 | Papua New Guinea | 34 |
| 3 | Indonesia | 502, WB 28 | 35 | Papua New Guinea | 45 |
| 4 | Papua New Guinea | Chimbu | 36 | Papua New Guinea | 46 |
| 5 | Papua New Guinea | UPS 31 | 37 | Papua New Guinea | 47 |
| 6 | Papua New Guinea | 48 | 38 | Papua New Guinea | 51 |
| 7 | Papua New Guinea | 58 | 39 | Papua New Guinea | 59 |
| 8 | Papua New Guinea | 76 | 40 | Papua New Guinea | 60 |
| 9 | Papua New Guinea | 58 | 41 | Papua New Guinea | 61 |
| 10 | IITA, Nigeria | Tpt 11 | 42 | Papua New Guinea | 62 |
| 11 | IITA, Nigeria | 22 | 43 | Papua New Guinea | 67 |
| 12 | IITA, Nigeria | 33 | 44 | Papua New Guinea | 71 |
| 13 | IITA, Nigeria | 66 | 45 | Papua New Guinea | 78 |
| 14 | IITA, Nigeria | 77 | 46 | Papua New Guinea | 81 |
| 15 | IITA, Nigeria | 88 | | | |

**Table 1. continued. . .**

| Our number | Source to US | Other identification | Our number | Source to US | Other identification |
|---|---|---|---|---|---|
| 16 | IITA, Nigeria | Tpt 99 | 47 | Papua New Guinea | UPS 81 |
| 17 | IITA, Nigeria | 10 | 48 | Papua New Guinea | 89 |
| 18 | IITA, Nigeria | 11 | 49 | Papua New Guinea | 99 |
| 19 | IITA, Nigeria | 12 | 50 | Papua New Guinea | 102 |
| 20 | IITA, Nigeria | 10.1 | 51 | Papua New Guinea | 105 |
| 21 | IITA, Nigeria | 10.2 | 52 | Papua New Guinea | 111 |
| 22 | Costa Rica | PI 338610 | 53 | Papua New Guinea | 113 |
| 23 | Indonesia | 785 | 54 | Papua New Guinea | 115 |
| 24 | Indonesia | 7992B | 55 | Papua New Guinea | 121 |
| 25 | Indonesia | 933 | 56 | Unknown | 867A |
| 26 | Indonesia | 1102d | 57 | Unknown | 908 |
| 30 | Papua New Guinea | UPS 38 | 58 | Unknown | 909 |
| 31 | Papua New Guinea | UPS 31 | 59 | Papua New Guinea | 18 |
| 32 | Papua New Guinea | 32 | 60 | Papua New Guinea | 19 |
| | | | 61 | Papua New Guinea | 65 |
| | | | 62 | Papua New Guinea | 76 |

In Table 2, the winged bean selections available from the Mayaguez Institute of Tropical Agriculture are presented. The list will be revised and an effort will be made to find the correspondence between these and other selected varieties. Seeds of these are available in small quantities to any investigator who cares to ask.

Table 2. Winged bean (*Psophocarpus tetragonolobus*) selections for distribution from the Mayaguez Institute of Tropical Agriculture, Mayaguez, Puerto Rico, 00708.

| No. | Name | Source to US | Interesting characteristics | Period of flowering |
|---|---|---|---|---|
| WB 2 | Bogor | Indonesia | Smooth pod, reduced wing, excellent yields | Reduced |
| WB 4 | Chimbu | Papua New Guinea | Large, purple pods | Winter only |
| WB 10 8 | Mariposa | Nigeria, TPt 1 | Large, square, speckled pods | Winter only |
| WB 11 2 | Ribbon | Nigeria, TPt 2 | Square, rather smooth wings | Reduced |
| WB 12 11 | Siempre | Nigeria, TPt 3 | Long, straight pods | Year round |
| WB 15 | Lunita | Nigeria, TPt 8 | Short, often curved pods | Winter only |
| WB 18 1 | Dual | Nigeria, TPt 11 | Green, curved pods | Winter only |
| WB 19 9 | Toaño | Nigeria, TPt 12 | Slightly flattened pods | Year round |
| WB 21 8 | Tinge | Nigeria, TPt 10 2 | Short, flattened pods | Year round |
| WB 22 | Alipasto | Costa Rica | Forage type | Winter only |
| WB 35 | Garden pod | Papua New Guinea, UPS 31 | Medium, square, straight pods | Year round |
| WB 41 | Garden pod | Papua New Guinea, UPS 61 | Short, flattened green pods prolific | Year round |
| WB 44 | Purwing | Papua New Guinea, UPS 71 | Long, straight flattish pod with purple wings, early | Year round |

In Table 3, data are summarized from the study of oil and protein contents. These data are typical of those now reported by other investigators. Protein contents of up to 40 percent are found.

**Table 3. Data on total, protein, and oil yields from 167 winged bean stocks.**

| | Mean | Range |
|---|---|---|
| Yield of seed per plant, g | 156 | 43 — 328 |
| Protein content of seed, % | 34.25 | 29.2 — 40.9 |
| Protein production per acre, kg | 479 | 136 — 1062 |
| Oil content of seed, % | 16.8 | 14.3 — 19.1 |
| Production of seed protein per day per plant, mg | 311 | 113 — 697 |

In Table 4, some data on yields of green pods winged bean, as compared to yields of cowpea varieties, are presented. These data show that cowpea varieties sometimes yielded more than winged bean and over a shorter period of time. We think winged bean is more useful than the asparagus bean type of cowpea in the home garden, but is probably inferior under most commercial conditions.

**Table 4. Winged bean yields as compared to those of cowpeas (asparagus bean) grown under similar conditions.**

| Species and variety | Year | Ton hectare | Weeks of production |
|---|---|---|---|
| Asparagus bean, 503 | 1975 | 40.1 | 10 |
| Asparagus bean, 504 | 1975 | 33.8 | 16 |
| Winged bean, 3 | 1975 | 9.9 | 16 |
| Winged bean, 2 | 1975 | 34.7 | 21 |
| Asparagus bean, extra long, red seeded | 1976 | 12.3 | 5 |
| Asparagus bean, extra long, black seeded | 1976 | 15.7 | 7 |
| Asparagus bean, 503 | 1976 | 17.6 | 7 |
| Winged bean, 10.3 | 1976 | 11.1 | 18 |
| Winged bean, 11.4 | 1976 | 6.8 | 18 |
| Winged bean, 12.2 | 1976 | 7.2 | 16 |
| Winged bean, 16.1 | 1976 | 10.9 | 18 |
| Winged bean, 19.9 | 1976 | 10.5 | 18 |
| Winged bean, 2 | 1976 | 10.5 | 17 |

In Table 5 the data are presented showing that in green pods, there is much more protein available in the pod than in the seed, even though the percent protein content of the seed is higher than that of the pod.

**Table 5. Changes of protein content of winged bean pods during growth.**

| Stage of pod | Length of pod (cm) | Dry weights g 100g fresh | | Protein content (%) | | Total protein content g 100g fresh weight | | |
|---|---|---|---|---|---|---|---|---|
| | | Pods | Seeds | Pods | Seeds | Pods | Seeds | Total |
| Immature | 10.1 | 13.8 | 0.6 | 16.4 | 23.6 | 2.26 | 14 | 2.4 |
| Mature | 13.8 | 12.0 | 0.8 | 15.6 | 22.4 | 1.87 | 18 | 2.05 |
| Mature but stringy | 15.6 | 17.4 | 1.3 | 14.2 | 24.2 | 2.47 | 32 | 2.79 |
| Overmature | 19.4 | 17.0 | 1.7 | 14.0 | 24.6 | 2.38 | 48 | 2.85 |

Finally, in Table 6, data on the cooking qualities of winged bean seed, using the sodium bicarbonate technique, are presented. An outstanding variety with respect to use of the seeds is number 20, from Nigeria. Some plants of this variety are produced throughout the year in Puerto Rico.

**Table 6. Percentage of hard seed and intermediate seeds in winged bean varieties after sodium bicarbonate treatment and cooking.**

| Number of accession | Varietal name if available | Percentage of Hard seed | Percentage of Intermediate seed | Rating for suitability for cooking* |
|---|---|---|---|---|
| 5·6 | | 0 | 65 | Poor |
| 6·2 | | 1 | 6 | Good |
| 7 | | 0 | 2 | Very good |
| 10 | Mariposa | 4 | 9 | Good |
| 11 | Ribbon | 15 | 20 | Poor |
| 12 | | 17 | 13 | Poor |
| 12·1 | | 64 | 23 | Very poor |
| 13 | | 2 | 12 | Poor |
| 15 | Lunita | 15 | 11 | Poor |
| 16 | | 3 | 0 | Fair |
| 17 | | 2 | 12 | Poor |
| 18 | Dual | 12 | 4 | Poor |
| 19 | Toaño | 33 | 19 | Very poor |
| 20 | | 0 | 0 | Excellent |
| 21 | | 0 | 0 | Excellent |
| 21·8 | Tinge | 5 | 6 | Good |
| 26 | | 12 | 24 | Very poor |
| 27 | | 15 | 16 | Poor |
| 28 | | 8 | 18 | Poor |

*A summary rating based principally on measurements of hard and intermediate seed, and also on color, flavor, and bitterness.

## FUTURE WORK

With respect to future studies with the winged bean, a list of important manuscript on the winged bean in Puerto Rico is shown below. The institute expects to foment interest in winged bean for its green pods. This will be done through its newsletter, "Vegetables for the Hot, Humid Tropics," and through its garden circular where the winged bean will be featured regularly. The institute shall also serve as a storehouse for requests for seed in the area.

**Manuscripts from the winged bean program in Puerto Rico.**


1. **Harding, J. A., F. W. Martin,** and **R. Kleiman.** Seed protein and oil yields of the winged bean, *Psophocarpus tetragonolobus*, in Puerto Rico. (Submitted for publication to Tropical Agriculture, Trinidad.)
2. **Martin, F. W.,** and **H. Delpin.** Vegetables for the Hot, Humid Tropics. I. The winged bean, *Psophocarpus tetragonolobus*. (To be published in early 1978 as a bulletin by U.S. Department of Agriculture, Southern Region.)
3. **Ruberté, R.M.,** and **F. W. Martin.** Cooking of winged bean see. (Submitted for publication to Journal of Agriculture, University of Puerto Rico.)
4. **Martin, F.W.,** and **R.A. Ruberté.** A simple technique to make winged bean seeds edible. (A short unpublished report to be distributed at the Workshop Seminar on Development of the Potential of the Winged Bean, Manila, January, 1978.)
5. **Mayaguez Institute of Tropical Agriculture.** 1976. Winged Bean Fact Sheet. (Unpublished, distributed on receipt of request for information.)
6. **Mayaguez Institute of Tropical Agriculture.** Winged bean (*Psophocarpus tetragonolobus*) selections for distribution. (Unpublished lists of varieties of winged bean distributed by MITA. To be revised in 1978.)


Finally, the institute serves as the best place for the U.S. Department of Agriculture to multiply and evaluate its introductions of the winged bean. The institute is also particularly interested in obtaining winged beans of the following types: (1) Day neutral types that bear pods year round, (2) Varieties that could be used chiefly for tubers, and (3) Varieties with seed that are easy to cook. Correspondence, requests for seeds, and seed samples can be sent to: Franklin W. Martin, Mayaguez Institute of Tropical Agriculture, Mayaguez, Puerto Rico 00708 U.S.A.

# The Status and Uses of The Winged Bean in Ghana

*S. K. Karikari*[1]

## THE STATUS OF THE WINGED BEAN IN GHANA

Protein malnutrition is a serious problem in the developing countries of Africa, Asia and Latin America. The supply of true animal proteins (meat, eggs, and milk) is greatly inadequate and much is being done to improve the situation. Such efforts are being supplemented by the production of plant proteins whose production costs are about one tenth those for animal proteins. In these same areas, animal products and fish provide less than one third of total dietary protein whereas the plant proteins which are cheaper account for 50 to 70% of the total protein needs. The conventionally known grain legumes in Africa (groundnut, cowpeas, bambarra groundnut and lima beans) constitute the greater part of these plant proteins. In addition to these legumes, there are many other legumes which grow wild or semi wild and are very much unexploited. One such legume is the winged bean (*Psophocarpus spp.*) which has recently received wide publicity and much research attention (NAS 1976).

In Ghana as a result of extensive education, the crop is also catching up with the other known legumes. In agricultural shows and public meetings, the importance of the bean as a potential source of protein has always been emphasized. Feedback information by extension officers reveal that the cultivation of the crop and its small scale utilization as green vegetable, are on going. According to the survey conducted in the Kade/Akwatia area, 100 farmers are now growing the crop on about 348 acres of land with plot sizes ranging from a few plants to about 5 acres. The crop is planted either as intercrop or sole crop and farmers prefer to grow the crop for seeds which they sell. One hundred and twenty farmers claim that they eat the green pod as vegetable, although they are skeptical in doing so because they lose in terms of the quantity of dry seed that would be left for sale. Comparatively, the winged bean is more versatile than the local legumes. Almost all other legumes do not constitute either important cash crops or food crops apart from their edible grains, they apparently do not excell in any secondary utility as the winged bean. Current yields of grain legumes are generally low throughout the tropics including Ghana. However, the winged bean shows definite superiority over the soyabean, groundnut, cowpeas and lima beans in seed yield. Soyabeans are now being cultivated on a wider scale in Ghana, but its yield is still low, at about 700 kg/ha as compared with the seed yield of winged bean which varies from 850 to 1380 kg/ha.

When both crops are adapted to the peasant system, the winged bean shows better response to low technology. It adapts to poor seedbed and cultural methods and is not prone to pest and disease problems in the fields. Perhaps the only agronomic superiority of the soyabean over the winged bean is the absence of staking which makes possible its mechanical cultivation. However, at Kade, some varieties of winged bean have been developed which seed well without staking. The dry seeds of both legumes are difficult to cook for domestic consumption, but the immature pods of winged bean are easily utilized in peasant homes as green vegetables in stew and soups. Generally, mechanization is poorly developed in Ghana and anytime the winged bean opens a reliable market, the direction is likely to change in its favour. (Anon 1973).

The value of legumes is further enhanced because of their ability to improve the nitrogen status of the soil. Many acidic soils of the wetter tropics as well as the more alkaline soils of the arid tropics are often deficient in nitrogen. It is envisaged that legumes, when properly utilized, can correct this deficiency to a large extent. However, a good degree of interspecific variability exists among legumes in their ability to fix nitrogen. The nodulation of some of these grain legumes are compared in Table 1.

[1]University of Ghana, Agricultural Research Station, Kade.

**Table 1. Nodulation of some tropical legumes.**

| | *Psophocarpus tetragonolobus* | *Arachis hypogaea* | *Glycine max* | *Pachyrizus erosus* |
|---|---|---|---|---|
| Mean fresh weight of nodules (gms) | 3.46 | 1.02 | 0.22 | 0.023 |
| Mean no. of nodules per plant | 66.00 | 396.0 | 19.3 | 1.0 |
| Mean plant weight | 98.1 | 132.9 | 123.2 | 42.6 |

The winged bean nodulation is unique, excelling all other annual leguminous crops and is associated with remarkable nitrification. The tendency is to have a more permanent system of farming where the long bush fallow of maintaining soil fertility is abandoned in favour of rotations and the use of artificial fertilizers. The winged bean appears to be the most suitable legume as rotation or long fallow restorative crop. It can provide good ground cover, check erosion and provide extra income from the sale of fresh pods and dry seeds (Doku; Personal communication)

## THE USES OF THE WINGED BEAN IN GHANA

The possible uses of the winged bean in Ghana form the basis of the current research programme carried by the Winged Bean Collaborative Research Team. The Home Science Department of the University of Ghana and the Food Research Institute of the Council for Scientific and Industrial Research are working on dietary uses of the crop, while the University of Ghana, the Agricultural Research Station at Kade, and the Oil Palm Research Centre are working on the functional uses of the crop (Anon. 1974)

The green pods are commonly picked fresh at brittle stage and prepared as green vegetable.

For domestic preparations the dry seeds demand soaking overnight to facilitate cooking and the most popular preparations involve boiling seeds, depulping and stewing with palm oil. When combined with cereals in the form of flour for porridge, it gives a satisfying meal. Sometimes, school boys roast the grains whole and eat it as groundnut.

The Food Research Institute has tried the dry seeds in baby weaning formulations. The concentrated form has also been used successfully to recover babies suffering from kwashiorkor.

Farmers in Kade-Akwatia area who adopted the crop early in its introduction have found other uses for it. Some substitute the milled grains as protein source in poultry feed. Personal communication with some of the poultry farmers show that, it is cheaper and the precocity of egg laying is also encouraging.

In tree plantations, the use of legumes as cover crop is widely practiced. When the performance of the winged bean was tested with the more conventional cover crops, it was found that, in its competition with weeds, the plant initially appears insufficient in tenacity and vigour, but with time, it grows vigorously to form dense foliage. It has been successfully tried on cocoyams, oil palm and citrus. However, the tendency for the winged bean to climb the tree crops is undesirable.

One of the major uses of leguminous cover crops in tree plantation has been the utilization of the foliage for livestock grazing. Where leguminous cover crops like *Centrosema pubescens* or *Pueraria phaseoloides* are available, sheep have preferred them. It is expected that sheep would benefit greatly from winged bean whose foliage protein exceeds 4.5%. Behavioural studies on sheep and cattle in old winged bean farms have shown divergent results. While sheep readily accept and prefer the winged bean foliage, the cattle however, still preferred giant star grass to legumes in general. Research work in this area is not complete but such integration is still possible and beneficial when the winged bean is used as cover crop.

The utilization of the winged bean tuber has not been widely reported in Ghana. As Doku (1969) points out, these crops are consumed for their caloric value but not as source of protein. Incidentally, the successful tuber crops have been the bulk yielders. In Ghana, tuber yields of about 46.1 grams per plant have been obtained which does not compare favourably with the yields of tubers like yams or cassava (Table 2), and farmers who planted the tuberous varieties like Kade 10.6 do not appear to show interest.

**Table 2. Comparison of yields and protein level in roots and tubers.**

| Crop | Tuber Yields tonnes/ha | Protein Content % |
|---|---|---|
| Winged bean | 2.25** | 17-20 |
| Cassava | 71.1*** | 1.2 |
| Sweet Potato | 65.2* | 2 |
| Yam | 93.3* | 2.4 |
| Colocasia | 47.0* | 1.9 |

***Figures derived from cassava in Ghana —E.V. Doku
**Derived from Anon's publications
*Derived from "Root Crops and Their Potential as Food on the Tropics" by Coursey and Hayne 1970

In the North, during the famine, tubers of winged bean and the African yam bean (*Sphenostylis sternocarpus*) are reportedly eaten. The African yam bean is an indigenous legume which produces small under ground tubers as the winged bean. It is believed that with proper education, these leguminous roots can be a source of supplementary protein to improve the starchy diets of the area. The Home Science Department of the University of Ghana is working seriously to develop more acceptable food preparation from the tubers.

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# Progress on Winged Bean Research in Thailand

*Narong Chomchalow*[1]

**The winged bean has been known in Thailand for so long. In fact, most people consider the winged bean as a native crop. The Thai people use the young pod as vegetable in several native dishes such as green or boiled vegetable to be dipped in 'nam prik', as the main constituent in 'yum' and 'kaeng som', as a mixture in 'tod mun', etc. In some regions such as in ratchaburi province, the tuber has been used as food as well as for medicinal remedy.**

**After the world-wide interest in the winged bean in 1973, followed by a campaign to promote research on winged bean by the U.S. National Academy of Sciences, the author has taken great interest in pursuing research in the winged bean since it has a great potential as a new economic crop for the oil and protein industries of Thailand.**

## GOVERNMENT AGENCIES INVOLVED IN WINGED BEAN RESEARCH

Other than the Applied Scientific Research Corporation of Thailand (ASRCT) which plays an active role in winged bean research at present, three other agencies which are also interested in winged bean research are

**Department of Agriculture**

Although no project has been launched, two of its staff are working closely with the author in winged bean research. One is Dr. Tongchai Tong-Uthaisri of the Vegetable Branch, Horticulture Division. The other is Mr. Belgium Chareonpanich of the Horticulture Division. Both are interested in germplasm collection and cultivation practices.

**Kasetsart University**

At present, no one is really engaged in winged bean research. Dean Bunjird Khitikarn of the Graduate School was listed as one who has great interest in the winged bean. The Institute of Food Research and Product Development has lately taken interest in the nutritive aspect of the winged bean. Its Director, Prof. Amara Bhumiratana and his Deputy, Dr. Prateap Rachapaetayakom are both responsible for the project. Dr. Sumin Smutakupt of the Radiation Biology Laboratory is also interested in mutation breeding of the winged bean.

**Chiang Mai University**

Dr. A. Andrews, Research Agronomist, Highlands Agronomy Project, Faculty of Agriculture is interested in the agronomic evaluation of the winged bean for high altitudes. Dr. W. Stern, Leverhulme Fellow, Multiple Cropping Project, Faculty of Agriculture is interested in exploitation and germplasm collection. Dr. Benjawan Rockasem of the Plant Pathology Department is about to start a project on nitrogen fixation.

## PROGRESS OF WINGED BEAN RESEARCH AT ASRCT

With a limited budget and personnel and the lack of support from the National Budget Bureau, research on the winged bean moved slowly at first. Fortunately enough, a private company has offerred financial assistance to continue our research on this crop.

**Collection**

Requests for seeds were sent to various institutes abroad. Altogether, 175 lines were obtained and are at present being investigated. A few strains have been selected on the basis of yield potentials. Within Thailand, requests for seeds were sent out twice to the changwad (provincial) and amphoe (district) agricultural officers

[1]**Deputy Governor, Research 1, Applied Scientific Research Corporation of Thailand.**

throughout the country. Altogether 167 lines coming from 26 changwads, representing 4 parts were obtained. Several lines have been selected for multiplication (see details in another paper, "Genetic diversity of winged bean in Thailand"– A preliminary report). After the study has been completed a pure line selection and a germplasm collection will be made.

**Varietal Selection and Trial**

Among the 167 lines locally obtained, 12 best lines were selected. These lines are early maturing, produce large numbers of large pods which do not shatter upon drying on the plant, and produce good tubers yields. They are now under varietal trials.

**Production of Rhizobium Inoculum**

Isolation of the native strains of *Rhizobium* bacteria specific for local varieties of the winged bean was made. A total of six strains were isolated. They are now ready for field testing. Requests for foreign strains were also sent to a few laboratories abroad. Equipped with 300 l fermentor, ASRC I is now ready to produce on a commercial scale inoculum for winged bean as well as for other grain legumes. This has already been put on market trial in Thailand, the response of which is favorable.

**Cultural Practices**

Due to the lack of seeds of selected varieties, experiments on cultural practices have to wait until enough seeds have been multiplied. A few experiments which have already been started are:

1. **Effect of planting date.** It was observed that the winged bean is a short day plant. An experiment was started since November 1977 to determine the effect of planting date (daylength effect) on five selected lines. Planting will be done every month for 12 months.
2. **Effect of rhizobium inoculum.** Three locally selected strains of *Rhizobium* were used with five selected lines of winged bean. The experiment was started in November 1977.
3. **Observations.** Observations were made on the response of the winged bean to photoperiod. It was concluded that most lines are short day plants which start to bloom in October, having the critical value of about 12½ hrs. Tuber formation was also affected by photoperiod since it was observed that no tuber was formed during the long day condition. These observations will have to be confirmed by future experiments. Several insect species were found to attack the winged bean plant. Aphids were the most common. The young leaves which were attacked by mites did not expand but folded towards the lower surface. Cut worms were also found to attack the leaves. In general however, insects do not cause serious problems and can be controlled by common insecticides. No serious disease was found even during the rainy season. Flower drops as the result of disease was commonly seen, but the amount was not much.

   Germination of the winged bean seeds was quite a serious problem since the seed coat is rather impermeable to water and gets harder during long storage. To overcome poor germination, the following practices were made at ASRC I: (1) Drying the seeds properly, packing in sealed container, and storing in cool, dry place. (2) Using new seeds for planting. (3) Soaking the seeds overnight before planting. (4) Injuring the uninibibed seeds with a razor blade and then soak again for six hours. (5) Dipping the seeds in warm water (about 65°C) for 5 minutes.

   Symptoms of mineral deficiency were observed in some plots, particularly in the newly filled areas. Pale yellow leaves with green midribs and veins were frequently observed. Too acidic or alkaline soils were found to inhibit the growth of the winged bean.

**Utilization**

Winged bean milk was prepared by an aqueous extract of the seeds. The milk had a good appearance with none of the beany taste of soybean milk. The samples, however, had a "green smell" but this was not much of a problem, especially when other flavors were added.

Winged bean tubers are excellent raw material for snack and desert. Fried chips and long square threads were found to be very delicious. When cut into thin pieces and boiled in syrup, they can be served as nutritive dessert, but the texture gets harder after a few days.

Full fat flour and protein from the tuber have also been prepared (14% starch and 34% protein).

Ground haulm was found to be a good source of cattle feed. The same is true with the dry pods after the seeds have been removed. Both ground haulm and dry pods were also tried as mushroom medium. The results were very encouraging.

# Evaluation of Agronomical Behavior of Winged Bean in El Salvador

*Ricardo Yohalmo Leon Esperanza*[1]

**Winged bean was first sown in El Salvador, Central America on July 20, 1977, as part of the first experiment which started with four varieties (UPS-122, UPS-31, Chimbu, Mixed). Germination was conducted in pots filled with 6,000 gm of soil. The seedlings were staked upon reaching a height of 0.20 m with poles 1.3 in. high. When the varieties grew up, a fence was used as trellis, but did not prove so good. The varieties were blooming between 58 and 80 days from planting. UPS-122 was the early maturing variety and Mixed was the late one. Chimbu was the most productive and UPS-31 has the longest pods (a mean length of 16.1 cm) and the greatest number of seeds per pod (an average of 12.1 seeds). The second experiment was performed at the Agricultural Experimental Station of the Faculty of Agricultural Sciences. Eight varieties (Alipasto, Tpt-1, Tpt-, Tpt-3, Tpt-8, Tpt-11, Tpt-12 and Tpt-10-2) were sown in a friable fertile alluvial soil. The germination was very good in Tpt-1, Tpt-3 and Tpt-11. However, in the other varieties, germination was below 50 percent. All varieties grew very well, with the exception of Alipasto and Tpt-2, which grew weakly and had only a few flowers. When the seedlings reached the height of 0.30 m they were staked with a pole 2.5 m high. When some of the plants became leafy, two steel wires were used to hang the vines from pole to pole but it did not work as expected. Some vines did climb up the wire though. The days to blooming were between 46 to 92 (Tpt-3 and Alipasto, respectively). Alipasto and Tpt-2 did not set pods (110 days old). Pod was longest in Tpt-3 (18.3 cms long); it also produced the greatest number of seeds per pod (13.1 seeds as the mean). Tpt-3 and Tpt-10-2 seem to be the most productive varieties. All varieties were infected by some pests from cotton crops around the site where the winged bean was planted.**

## EXPERIMENTATION AND OBSERVATIONS

The first experiment was done on July 20, 1977, in a greenhouse of the Faculty of Agricultural Sciences (640 m above sea level). Four cultivars (UPS 122, UPS-31, Chimbu and Mixed) were sown in pots 40 cm high and 25 cm wide, filled with 6000 gms of soil to which 10 gms of 1-2-2 fertilizer was added. Fifty gm soil from a cowpea plantation was added to each of the pots in order to help nodulation. Some 15 to 20 seeds were sown per variety. The data, which appear in Table 1 were taken according to the following criteria:

1 — Emergence time: Taken when 50% of the plants have emerged.
2 — Percentage of germination: The ratio of emerged plants over the sown seeds multiplied by 100.
3 — Days from sowing to bloom: Taken when half of the population are flowering.
4 — Length of pods: At physiological maturity.
5 — Seed size: weight of 100 seeds (14% moisture).
6 — Seeds per pod: The seed from 20 randomized pods were counted.

Table 1. Performance of four varieties of winged bean.

| Varieties | Emergence time (days) | Germination (%) | No. of days to bloom | Pod length (cms) | No. of seeds per pod | Seed size (g) | Height (m) after 66 days |
|---|---|---|---|---|---|---|---|
| UPS 122 | 5 | 33 | 58 | 10.7 | 8.1 | 24.2 | 1.80 |
| UPS 31 | 6 | 46 | 71 | 16.1 | 12.0 | 27.5 | 1.68 |
| CHIMBU | 16 | 4 | 66 | 9.0 | 7.2 | 25.0 | 1.43 |
| MIXED | 7 | 30 | 80 | 11.0 | 9.0 | 24.8 | 1.30 |

[1]Professor of Plant Sciences Department Faculty of Agricultural Sciences, University of El Salvador.

When the winged bean cultivars were 60 days old, they were placed out of the green house. Using fence as the trellis (1.3m high), they proved to be good climbers. Frequent watering was done to prevent injury to the plants through strong evapo-transpirtation. The Florida cultivar or mixed was the most drought resistant.

UPS 122 and UPS 31 are early maturing varieties while Chimbu and Mixed are the late ones. The pods were green with purple in UPS 31 and Chimbu, and green in Mixed.

The number of pods per plant was not computed, but Chimbu seems to be the most productive variety. All varieties are still bearing pods (150 days old). Water was provided manually because the rainy season was usually short.

A scratcher insect (*Corythucha gossypii* Tingidae) was found in the back leaf of some varieties. Some flowers which rot and dried at the tip of the pods with remains of dry flower rot, and spores of *Cunvularia* sp, *Alternaria* sp and *Fusarium* sp were isolated.

The second experiment was performed at the Agricultural Experiment Station of the Faculty of Agricultural Sciences (50 m above sea level). Eight varieties were planted on September 6, 1977, spacing was 1.2 between rows and 1.0 m between plants. The soil was friable and alluvial. No fertilizer was added. The prior crop was *Vigna sinensis*. When the seedlings were 0.30 m high, they were staked with a pole 2.5 m high. The following diagram shows the arrangement of the varieties on the field.

| | |
|---|---|
| Tpt — 11 | Tpt — 12 |
| Tpt — 2 | Tpt — 10.2 |
| Tpt — 3 | Tpt — 8 |
| Alipasto | Tpt 1 |

The same data as in the previous experiment were collected (Table 2). In addition, the mean number of pods per plant (107 days old) was also taken.

**Table 2. Performance of 8 varieties of winged bean in the second experiment.**

| Variety | Emergence time | Germination (%) | No. of days to bloom | Length of pods (cm) | No. of pods plant | No. of seeds pod | Seed size (cm) |
|---|---|---|---|---|---|---|---|
| Alipasto | 13 | 20 | 92 | No pods | — | — | — |
| Tpt 1 | 10 | 65 | 52 | 15.7 | 27 | 12.2 | 29.0 |
| Tpt 2 | 11 | 8 | 95 | No pods | — | — | — |
| Tpt 3 | 6 | 90 | 46 | 18.3 | 30 | 13.1 | 39.2 |
| Tpt 8 | 11 | 8 | 54 | 14.0 | 25 | 11.2 | 31.7 |
| Tpt 11 | 8 | 50 | 82 | 14.7 | 14 | 11.0 | 26.0 |
| Tpt 12 | 8 | 80 | 56 | 15.2 | 12 | 11.7 | 30.4 |
| Tpt 10.2 | 8 | 90 | 53 | 14.5 | 27 | 11.7 | 23.7 |

The following are some characteristic of the varieties:

(1) Alipasto is slow growing and weak. When 115 days old, it has no pods, just a few flowers. It is very susceptible to drought. In October when wind is strong, the tendrils dry up. Some flowers were eaten by *Stigmene ocreae* (shaggy worm) and the foliage was attacked by *Spodoptera exigua* (soldier worm).

(2) Tpt 1 is a well adapted variety with good foliage. It has an average of 27 pods per plant (117 days old). It is still bearing pods and flowers. Some plants grow faster than others. It was attacked by *Prodenia* sp., *Spodoptera exigua* (attacked the leaves) and *Stigmene ocreae* (attacked pods and immature seeds).

(3) Tpt 3 seems to be a productive variety with good seed size, an average 30 pods per plant (107 days old) and the largest pods (Table 2). It was also attacked by pests. Its flowers are purple and leaf alike.

(4) Tpt 8 has a good growth and productive with 10-54 pods per plant (25 as average). Some plants have green pod with purple wings. It has the largest seed size.

(5) Tpt 2 is slow growing and weak. Heights were unequal: two plants were 0.15 m high while another was 1.0 m high (110 days old). Some flowers dropped with the cold winds of mid December.

(6) Tpt 10.2 is a well adapted variety with profuse flowering and produces 20 to 50 pods per plant (110 days old). It survives in semi waterlogged soil. Its pods must be pulled out before they dry out to prevent shattering.

(7) Tpt-11 has a good growth although late (Table 2). Its height ranges from 0.15 m to 2.3 m. It has abundant leaves. It was also attacked by pests.

(8) Tpt 12 produced with 15-22 pods per plant (110 days old). Only a few pods dried up. Two plants have smaller leaves than the others.

All varieties were infected by pests such as *Prodenia* sp. which eats the whole leaves, *Spodoptera exigua* (soldier worm) which burrows through the leaves and *Stigmene ocreae* (shaggy worm) which eats both leaves and pods.

The pests were prevalent because cotton was also grown in the experimental area. In late November and December, when cotton started to dry up, the pests transferred to the growing winged bean plant.

Almost all varieties showed phenotypical differences in growth, color, and shape of flowers and pods. Tpt 1, Tpt 3 and Tpt 8 are early varieties, Tpt 12 and Tpt 10-2 are intermediate, and Alipasto, Tpt 2 and Tpt 11 are late varieties.

All varieties except Alipasto and Tpt 2 are still bearing pods and their yields cannot be determined yet.

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# The Winged Bean in the Philippines: Its Current Status and Potentials

*Jose M. Soriano* and *Ponciano A. Batugal*[1]

The winged bean (*Psophocarpus tetragonolobus*) is a common minor vegetable in the country. It is known by such common names as, "calamismis", "sigarilyas," "kabey", and many others depending on the region of the country where it is grown. The plant can grow in almost all places in the country but it is grown mostly in small scale in the backyard mostly along fences or on small trellises in the corners of the yard. In many cases this vegetable is considered a perennial plant because even without replanting, new plants come out every start of the rainy season.

Its use is limited to the yound pods which are cooked with other vegetables. The pods are also made into pickles. In some places they are cooked in coconut milk. The pods are seldom eaten fresh. The use of mature seeds and the tubers are virtually unknown in this country.

The limited culture of winged bean can be attributed to the following:

a) Only the green pods are used for food. The nutritive value of the leaves, seeds and tubers are not yet known in this country. In addition, available information on the methods of preparation for food and other uses are not well disseminated.
b) The locally available cultivars exhibit photoperiodism so that the pods are only available for a limited period of at most three months of the year in November, December and January.
c) The use of trellis as plant support makes it difficult to grow this crop in wider areas due to the need for additional labor and materials.
d) There are no known ways of preserving the pods to extend their availability for a longer period.

## RESEARCH WORK

There are virtually no published reports on studies on the winged bean in the country. This is attributed to the fact that winged bean has been considered a minor vegetable and has been relegated to a low priority in the national research system. The new information on its nutritional value and the multiplicity of uses of almost all parts of the plant has aroused interest on the crop.

## STUDIES IN PROGRESS

### Germplasm Evaluation and Breeding

Realizing the nutritional potential of winged bean, the Philippine Council for Agriculture and Resources Research (PCARR) has funded the following projects starting January 1978:

1. **Plant exploration and collection of indigenous and exotic varieties of winged bean in Negros Occidental** — Bureau of Plant Industry.
2. **Regional trials of improved varieties of winged bean** — Bureau of Plant Industry.
3. **Development of winged bean as a tropical substitute for soybean thru irradiation/mutant induction** — Philippine Atomic Research Center.
4. **Variety trials.** Preliminary trials in at least four locations to evaluate varieties introduced from Papua New Guinea, IITA (Nigeria) and AVRDC (Taiwan). Local varieties are also included in these trials — Bureau of Plant Industry.

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**Culture and Management**

Several undergraduate student theses are currently being conducted at the Palawan National Agricultural College at Aborlan, Palawan. The areas of these works and a brief description of the treatments are shown below:

1. **Time of planting** — Plantings were made in August, September and October to determine possible photoperiodic effects and other information.
2. **Types of trellises** — The following types are being tested: A-type, T-type, Fan type, Fence type against no trellis.
3. **Effect of number of plants per hill** — The study will evaluate the performance of the winged bean when planted at 1, 2, 3, 4 and 5 plants per hill.
4. **Lime application** — Rates of lime application at 0, 250, 500, 750 and 1000 kg/ha are being evaluated.
5. **Phosphorus application** — This involves the testing of 0, 28, 56, 84 and 112 kg $P_2O_5$ per hectare.
6. **Nitrogen application** — Application rates being tried are 0, 30, 60 and 90 kg N/hectare.
7. **NPK combinations** — Combination of the 3 elements at three rates, 30, 60 and 90 kg/hectare.
8. **Animal manures application with NPK** — Chicken, swine, and cattle manures in combination with a complete fertilizer (14-14-14) are being evaluated.

**Pests and Diseases**

Preliminary surveys on pests and diseases are being undertaken using the current plantings for the variety trials.

## RESEARCH PROPOSALS SUBMITTED FOR FUNDING

A Philippine national winged bean research and development program was recently formulated by an inter-agency and interdisciplinary team. The components of the proposal are shown below:

1. Germplasm collection and maintenance.
2. Varietal evaluation and seed multiplication for pods, seeds and tubers.
3. Formulation, testing and dissemination of packages of winged bean technology in backyards and farmers' fields.
4. Processing and utilization — The study intends to concentrate on the utilization and processing of the seeds, pods and tubers including packaging and storing of products.
5. Physiology, handling and storage of winged bean — A proposal to study changes in the green pod from pod setting up to post harvest period, including studies on storage of the pods and methods of harvesting and packing.
6. Survey of pests and diseases — A more comprehensive study of the important pests and diseases of the crop during its growing season and in several places in the country.
7. Determination of chemical composition and nutritive value of different cultivars — This study attempts to compare the nutritive values of the different cultivars. The different parts of the plant will be analyzed.
8. Studies on the nitrogen fixing systems — This study has three components: a) Collection of *Rhizobium* strains from the bean, b) Evaluation of the nitrogen-fixing efficiency of the *Rhizobium* strains, c) Environmental factors affecting the rhizobial activity.
9. Variety by population studies — These will take into account green pod, seed and tuber yields.
10. Time of planting of promising varieties to evaluate seasonal effects.
11. Fertilizer application — Kinds and rates of application will be evaluated in a more comprehensive manner to include varieties, season as well as location.

## PROPOSED PROGRAM FOR THE COUNTRY

The growing awareness on the importance of nutrition is indicated by the Green Revolution Program of the government. The planting of nutritious vegetables including the winged bean is one of the important components of the program. The proposed national winged bean program, therefore, will be geared towards

backstopping the nutrition program. However, efforts will also be directed towards the development of this vegetable as an important economic crop for food, feed and industrial uses.

**The Initial Program**

This is an initial project to promote the increased consumption of winged bean: its green pods, leaves, mature seeds, and tubers. This will be approached in two directions:

1. The dissemination of information on the nutritive values of the different parts of the vegetable as well as on the methods of preparation of the products for food. On the food preparation aspect, emphasis will also be given to the parts not yet commonly used as food, such as, the seeds and the tubers.
2. The distribution of mini seed kits. These kits will contain the seeds of recommended cultivars from the trials currently being conducted in different government stations. These kits will contain updated instructions for growing, processing and utilization as well as the seeds, fertilizer and chemicals needed. It will also contain a data sheet to be filled up and returned to the project leader. These kits will be distributed to about 3,000 Home Economics teachers and technicians all over the country.

**Commercial Development of the Crop**

The proposed national research and development program on the winged bean proposes to develop a technology that is suitable to each region of the country.

To attain the most benefits within a short time, information from studies done in other countries will be availed of whenever feasible to avoid unnecessary duplications. This applies specifically to the acquisition of new varieties and to purely basic studies.

# Winged Bean Culture in Korea

*Kim Ki-jun*[1]

## INTRODUCTION

It is interesting to note that for the first time winged bean was planted in Korea on a trial basis in 1977. In these trials some desirable and fundamental information have been found which demonstrate that the winged bean is worth planting in the country

## MATERIALS AND METHODS

Twelve varieties UPS-47, UPS-63, UPS-66, UPS-67, UPS-90, UPS-91, UPS-99, UPS-102, UPS-121, UPS-ICA, Chimbu and Tpt-2, were used. The seeds were planted at different dates: May 5, 1977, May 12, 1977 and June 18, 1977 in different locations in Seoul (the parallel of 37°37' north and the meridian of 127°4' east). The seeds were disinfected by soaking in 0.001% mercuron solution for 1 hour. The seed coats were slightly cut on the opposite tip of the embryo with a sharp knife to facilitate germination.

## RESULTS

Germination was 9% within 10 to 14 days. Flower buds were formed on August 10, 1977. On August 27, 1977, flowering began and from that time on, the pods continued to form. After the first frost in October 12, 1977, there was difficulty in growing the winged bean except under polyethylene house conditions. Varieties UPS-63 and UPS-90 bloomed under natural conditions. Their vines grew to an average length of 3 to 4m. Tuberous roots were formed.

The other varieties showed extreme shrunken leaves like those afflicted with virus and failed to come into flowers.

Because of extreme dryness in 1977, it became necessary to water the winged beans. Some withered up, however they were artificially given water near the roots. Owing to the phenomenon, artificial watering was discontinued.

## FUTURE PLANS

This year, more extensive experiments will be carried out in the districts of Seoul, Cheju (33°30', north latitude and 126°31', east longitude), Chinju (35°11', north latitude and 128°5', east longitude), and Sunchun (34°56', north latitude and 127°29', east longitude). These experiments on the ecology of the winged beans will be under the financial support of the Asia Foundation.

Our estimate is that seed production is possible in the southern parts such as in Cheju Island. As a soil restorative and soil conserving crop however the winged bean is suited in almost all parts of Korea.

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# BANGLADESH COUNTRY REPORT ON WINGED BEAN

*Dr. M. A. Mannan*[1]

The winged bean (*Psophocarpus tetragonolobus*) is known as "Kamranga Sim" in Bangladesh. It is cultivated as a backyard crop. No attempt in the past was made for its improvement and propagation either through research or extension. Cultivation of the winged bean is still confined to certain pockets of the country, particularly in the districts of Chittagong (22 to 23°N), Chittagong Hill Tracts (22 to 24°N), Sylhet (25°N) and Mymensingh (25°N). It is believed that winged bean seeds were brought in Bangladesh from the neighbouring countries of Burma and India. In the absence of any survey there exists no data on the acreage, per acre production, or food value of this crop in the country.

The method of cultivation followed by farmers like that of the country bean (*Dolichos lablab*). Winged bean seeds (2 to 3 seeds) are sown per hill during hot months of the season (June to August). Small bushy plants, trees, and bamboo platforms are used as supports of the winged bean plant. No special care is taken by the farmers to grow them in their homesteads. Most of the farmers apply ash around the plants as mature. According to the farmers, the incidence of disease and insect pests is comparatively less in winged bean than those in other legume crops. Only the green pods are eaten as vegetables. The flowers, stems and tubers are generally not eaten. These are sometimes used as fodder.

In Bangladesh winged bean is not yet grown as green manure crop, intercrop or fodder crop. Cultivation of this crop is limited to very small areas, so much so that most of the people have not even seen how a winged bean looks like. People are not aware either of the nutritional value of the crop or its nitrogen fixing ability. It is not known to the growers that different parts of the plant such as leaves, flowers, and tubers can be eaten, and no atempt was made in the past to popularize the crop.

The future of large scale winged bean cultivation in Bangladesh appear to be bright. Realizing the prevalence of chronic malnutrition in the country, it is strongly felt that a protein rich crop like the winged bean should be studied scientifically for its improvement and widespread cultivation. The Bangladesh Agricultural Research Council (BARC) has, therefore, undertaken a 5 year coordinated research project on the winged bean with the assistance and cooperation of the Asia Foundation.

The main objectives of the project are: to survey the extent of winged bean cultivation in the country, to conduct experiments on different varieties under different agroclimatic conditions, to multiply and distribute seeds among farmers, to establish a germplasm bank, to analyze the nutritional quality of foliage, tubers, seeds and pods, and to improve winged bean through breeding.

A germplasm bank comprising of thirty four exotic and two local varieties of winged bean has been established. Seeds were collected from Thailand, Nigeria (International Institute of Tropical Agriculture), and Indonesia. Attempts are being made to collect seeds from other countries. A country wide survey of winged bean has been started to collect data on various aspects of winged bean. The survey is expected to be completed by the end of February, 1978. The Executive Vice-Chairman of the Bangladesh Agricultural Research Council visited Bogor, Indonesia and one of the Senior Scientific Officers of the project visited Thailand to gather information on the work being done on winged bean in those countries. The Senior Scientific Officer met Dr. Narong Chomchalow, Deputy Governor, Applied Crop Research and Cooperation, Thailand and exchanged views on winged bean cultivation.

Under the coordinated winged bean research, projects experiments have been laid down on May 31, 1977 in each of the five regional stations. These stations are located at Dacca (24 to 25°N), Comilla (24°N), Mysemensing (25°N), rajshahi (25°N), and Jessore (24°N). The main purpose of the study is to determine the performance of the different varieties of winged bean grown in different agro ecological zones of Bangladesh. In the study, six exotic and one local variety have been included. The experiments are still in progress. Pro-

[1]Member - Director, Bangladesh Agricultural Research Council.

fuse bearing has been noticed on the exotic varieties but they were late in flowering compared to the local variety. The pods were allowed to mature for collection of seeds.

The plants were planted 4' x 4' square. Manures and fertilizers were applied at the following rate: Cow dung at 8000 lbs/acre, Urea at 40 lbs/acre, T.S.P. at 120 lbs/acre and M.P. at 30 lbs/acre.

Insects like aphids and leaf miners and stem rot disease were noted in the field. Aphids and leaf miners were controlled by spraying malathion and stemrot disease was controlled by application of Bordeaux mixture.

Data collected so far on the performance of different varieties of winged bean grown in Dacca centre are summarized in Table 1.

**Table 1. Germination, growth and yield of selected varieties of winged bean grown in Dacca.**

| Variety | Germination percentage (pods) | Plant height (in) | No. of Pods per plant | Pod length (in) | No. of seeds per pod | Days to flower | Days to harvesting (Green pods) | (Seeds) | Wt. of green pods (10 pods) (oz.) |
|---|---|---|---|---|---|---|---|---|---|
| Ipt 1 | 85 | 20' | 60 | 12 | 16 | 110 | 140 | 165 | 10 |
| Ipt 2 | 85 | 17' | 80 | 7 | 11 | 110 | 140 | 165 | 6 |
| IP - 1 | 80 | 18' | 70 | 8 | 11 | 100 | 130 | 160 | 6 |
| IP - 2 | 82 | 17.5' | 65 | 11 | 14 | 105 | 135 | 165 | 8 |
| IP - 6 | 85 | 16' | 75 | 17 | 12 | 110 | 140 | 165 | 5 |
| Local variety (Sylhet) | 90 | 10' | 85 | 8 | 10 | 100 | 130 | 160 | 4.5 |

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It will appear from the table that the percentage of germination is higher in the case of the local variety than the exotic ones. The local plants are shorter in size than the exotic plants. The number of seeds per pod and the weight of pods are less in the case of the local variety.

The experiment is still in progress. However, the observations noted in the field and the data collected so far clearly indicate that winged bean can be grown throughout Bangladesh. Further studies have been planned for the next season.

# Observations on Winged Bean at CIAT: 1976-1977

*K. O. Rachie* and *G. Giraldo*

## PRELIMINARY OBSERVATIONS

Some winged bean genetic stocks from IITA (Ibadan, Nigeria) were grown at CIAT in 1976 to review germinability and obtain sufficient seeds (a few 100 grams for long term storage). This also provided an excellent opportunity to carry out some preliminary observations on adaptation and certain agronomic characters under CIAT conditions. Unfortunately, several lines were apparently subjected to excessively high temperatures in shipment and failed to germinate on arrival in Colombia. However, a few lines — notably the narrow leaved Tpt 15 — were viable and succeeded brilliantly. The major problem observed was the occurrence of "problem X" at certain stages of growth, but which the plants eventually "grew out of." This problem was later defined as a soil toxicity factor resulting when residues or degradation products of certain widely used herbicides (like Atrazine) become bound on the heavy, clayey (montmorillonite) soils of the CIAT Station. The first 65 genetic stocks of a total PNG collection of 120 accessions were planted on August 31, 1976 and harvested four to five months later at CIAT's Palmira Station. Plots were intensively managed to assure success in increasing seeds.

### Trellis Design

This also provided an opportunity to design special plant support systems for large numbers of genetic stocks in small plots. The available options were single stakes, tripods (2 to 5 stakes tied together at the top) or conventional trellises. The problem with single vertical stakes was the amount of material required and few plants (1 or 2) accommodated per stake, while conventional trellises allowed intermingling of adjacent plots or rows and considerable effort was required to keep them separated. The best support system for small plots were tripods, but to reduce cost of materials, single, light posts 2.5 m high and spaced 2 m apart in both directions were used. Six nylon strings were fastened to the top of the post (representing a single plot or cultigen) and connected to six 60 cm stakes imbedded in the ground in two rows on each stake for a total of 12 plants per plot. This system proved to be highly successful in reducing stake requirements, maximizing plants per plot and separating adjacent genotypes.

### Observations

Several agronomic characters were recorded for each collection (Table 1). These observations demonstrate the broad range of genetic variability available in the Papua New Guinea collection although representing only about half the total collections available. The remaining 50 lines are presently being increased and evaluated in the field at CIAT — Palmira from a November 1977 planting. Successful increases of seeds ranging from 75 to 765 grams were obtained from each of the 65 plots. However, 63 out of 65 PNG lines produced more than 150 grams of dry seeds. Eight elite/diverse lines were also selected for more intensive study and seed increase in March 1977.

## LARGE PLOT INCREASES

Eight selected lines representing a measure of the broad range of genetic variability available in the PNG genetic stocks as well as "eliteness" within type were planted in larger plots — 3 m × 13 m having 2 rows 100 cm apart and supported by one trellis wire 2 m high and replicated twice on March 28, 1977 where more detailed observations and yield estimates were taken, as shown in Tables 2 and 3. Seeds were treated with Arasan — T; granular Furadan was applied to the seed furrow; and zinc and boron (both deficient in CIAT Palmira soils) were applied along with urea (to compensate for presumed inadequate nodulation) as foliar sprays prior to and during flowering.

**Table 1. Botanical characters of winged bean lines from Papua New Guinea observed at CIAT-Palmira, Columbia (August, 1976).**

| PEDIGREE | DAYS TO | | | LEAVES | | | PODS | | | PODS SEEDS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flowering | First Pod | Flower Color[1] | Color[2] | Length (cm) | Width (cm) | Color[3] | Length (cm) | Width (cm) | Seed per pod | Wt. of 10 pods (gms) | Wt. of seed in 10 pods (gms) | Wt. 100 seeds (gms) | Seeds Produced |
| UPS 4 | 62 | 67 | R | LG | 10.9 | 8.7 | G + P | 11.8 | 3.2 | 10 | 64.9 | 28.6 | 29.6 | 118 |
| UPS 5 | 62 | 67 | LV | LG | 8.7 | 6.6 | G | 17.6 | 2.5 | 9 | 41.8 | 21.4 | 23.9 | 246 |
| UPS 7 | 56 | 62 | R | LG | 9.6 | 6.9 | G + P | 10.5 | 2.3 | 10 | 40.7 | 22.0 | 22.0 | 316 |
| UPS 8 | 62 | 68 | R | LG | 11.8 | 8.7 | G + P | 19.1 | 2.4 | 10 | 98.2 | 43.0 | 41.2 | 244 |
| UPS 10 | 62 | 67 | LV | DG | 11.3 | 8.3 | G | 13.5 | 2.6 | 14 | 89.9 | 43.2 | 20.2 | 365 |
| UPS 11 | 61 | 67 | V | DG | 8.2 | 6.1 | G + P | 8.7 | 2.5 | 12 | 26.4 | 38.6 | 32.2 | 75 |
| UPS 12 | 61 | 67 | LV | DG | 11.1 | 7.7 | G | 7.7 | 2.9 | 10 | 47.5 | 24.6 | 25.6 | 165 |
| UPS 13 | 56 | 67 | LV | DG | 9.4 | 6.9 | G | 6.9 | 2.5 | 14 | 65.2 | 30.0 | 20.4 | 265 |
| UPS 14 | 56 | 62 | LV | DG | 10.5 | 7.4 | G | 14.5 | 2.6 | 14 | 62.3 | 30.3 | 21.6 | 382 |
| UPS 16 | 57 | 66 | V | DG | 9.6 | 7.0 | G + P | 15.6 | 1.9 | 12 | 56.4 | 27.7 | 26.6 | 174 |
| UPS 17 | 56 | 63 | LV | LG | 10.5 | 8.0 | G | 15.3 | 3.0 | 14 | 81.2 | 33.4 | 26.3 | 370 |
| UPS 18 | 62 | 67 | DV | LG | 9.9 | 7.4 | G + P | 16.1 | 2.3 | 12 | 70.0 | 32.2 | 27.4 | 395 |
| UPS 19 | 56 | 62 | V | LG | 9.5 | 7.1 | G + P | 17.1 | 2.8 | 11 | 72.8 | 31.5 | 32.7 | 282 |
| UPS 20 | 56 | 62 | V | LG | 10.1 | 6.8 | G + P | 15.3 | 2.4 | 10 | 67.7 | 30.3 | 29.4 | 368 |
| UPS 25 | 55 | 66 | V | DG | 10.8 | 8.8 | G | 15.7 | 2.7 | 13 | 84.9 | 44.6 | 33.6 | 418 |
| UPS 26 | 55 | 62 | V | DG | 13.3 | 11.2 | G | 18.4 | 2.7 | 11 | 90.0 | 41.4 | 38.0 | 406 |
| UPS 27 | 62 | 67 | LV | LG | 8.7 | 8.2 | G | 12.1 | 2.1 | 11 | 79.4 | 37.1 | 32.3 | 382 |
| UPS 28 | 62 | 67 | LV | LG | 9.2 | 6.7 | G | 20.5 | 1.9 | 11 | 48.6 | 25.3 | 22.1 | 320 |
| UPS 29 | 62 | 67 | LV | LG | 10.8 | 8.6 | G | 11.4 | 2.5 | 10 | 70.6 | 30.2 | 31.0 | 244 |
| UPS 31 | 57 | 62 | DG | 6.5 | 5.6 | G + P | 22.1 | 1.9 | 9 | 45.4 | 24.2 | 27.2 | 345 | |
| UPS 35 | 56 | 62 | V | DG | 12 | 8.6 | G + P | 25.5 | 2.6 | 15 | 86.2 | 40.6 | 26.1 | 381 |
| UPS 36 | 56 | 65 | R | LG | 10.8 | 8.4 | G + P | 14.9 | 2.9 | 11 | 86.4 | 29.7 | 28.8 | 216 |
| UPS 37 | 56 | 62 | LV | LG | 10.2 | 7.3 | G | 22.1 | 2.7 | 12 | 64.7 | 34.8 | 28.9 | 428 |
| UPS 39 | 56 | 62 | R | LG | 10.7 | 7.6 | G + P | 10.7 | 2.5 | 14 | 93.0 | 45.9 | 33.8 | 224 |
| UPS 42 | 57 | 62 | DV | DG | 7.2 | 5.1 | P | 13.5 | 1.9 | 10 | 32.0 | 16.6 | 17.0 | 382 |
| UPS 46 | 57 | 65 | R | LG | 7.6 | 6.1 | G + P | 13.6 | 2.1 | 7 | 26.2 | 12.3 | 22.4 | 345 |
| UPS 47 | 56 | 61 | R | LG | 7.7 | 6.6 | G + P | 12.2 | 2.0 | 11 | 49.5 | 26.1 | 23.6 | 267 |
| UPS 48 | 56 | 62 | LV | LG | 9.3 | 6.9 | G | 17.6 | 1.9 | 11 | 45.4 | 26.2 | 24.0 | 393 |
| UPS 49 | 58 | 64 | | LG | 11.4 | 7.5 | P | 13.4 | 2.2 | 11 | 70.6 | 33.1 | 29.4 | 451 |
| UPS 54 | 62 | 67 | R | LG | 9.8 | 7.0 | G + P | 12.6 | 2.3 | 11 | 49.5 | 25.6 | 25.0 | 437 |
| UPS 56 | 62 | 67 | R | LG | 8.9 | 6.4 | G + P | 8.5 | 2.9 | 12 | 51.5 | 25.8 | 21.7 | 245 |
| UPS 57 | 56 | 62 | R | LG | 9.0 | 7.4 | G + P | 9.9 | 2.5 | 11 | 34.2 | 17.2 | 15.9 | 380 |
| UPS 58 | 62 | 68 | R | LG | 9.8 | 6.8 | G + P | 12.3 | 2.2 | 10 | 46.4 | 25.8 | 26.2 | 409 |
| UPS 61 | 62 | 67 | LV | LG | 10.0 | 7.1 | G | 13.6 | 2.0 | 8 | 39.2 | 19.0 | 28.0 | 598 |
| UPS 63 | 61 | 67 | R | LG | 9.2 | 7.5 | G | 18.6 | 2.0 | 11 | 44.7 | 23.3 | 21.1 | 488 |
| UPS 64 | 61 | 67 | R | LG | 10.4 | 6.6 | G + P | 17.3 | 2.3 | 10 | 59.0 | 28.6 | 27.8 | 370 |
| UPS 65 | 56 | 67 | DV | LG | 9.0 | 6.8 | G + P | 17.0 | 2.3 | 12 | 59.5 | 27.7 | 24.1 | 310 |
| UPS 66 | 56 | 62 | R | LG | 8.6 | 7.4 | G + P | 18.2 | 2.3 | 10 | 39.3 | 22.9 | 21.9 | 176 |
| UPS 67 | 57 | 66 | LV | LG | 9.7 | 7.1 | G | 18.9 | 2.6 | 11 | 64.7 | 29.9 | 29.9 | 401 |
| UPS 68 | 56 | 63 | LV | LG | 10.7 | 8.5 | G | 16.2 | 2.9 | 14 | 76.2 | 32.8 | 22.6 | 372 |
| UPS 70 | 62 | 67 | R | LG | 9.6 | 7.5 | G + P | 10.9 | 2.4 | 12 | 60.3 | 30.0 | 23.5 | 369 |
| UPS 71 | 56 | 62 | DV | LG | 6.0 | 5.4 | G + P | 12.7 | 2.1 | 9 | 39.5 | 21.6 | 23.1 | 423 |
| UPS 85 | 56 | 62 | DV | LG | 9.5 | 7.2 | G + P | 14.8 | 3.1 | 12 | 59.3 | 31.8 | 26.3 | 316 |
| UPS 87 | 55 | 66 | V | DG | 9.2 | 4.9 | R | 9.7 | 2.4 | | | | | 147 |
| UPS 88 | 55 | 62 | VD | DG | 6.1 | 5.3 | G | 10.1 | 1.6 | 19 | 30.4 | 19.2 | 22.0 | 182 |
| UPS 90 | 62 | 67 | R | DG | 8.6 | 6.7 | G + P | 12.4 | 2.1 | 10 | 48.4 | 23.3 | 23.0 | 182 |
| UPS 92 | 67 | 67 | V | DG | 7.1 | 5.3 | G | 14.1 | 2.2 | 10 | 60.7 | 28.6 | 28.6 | 380 |
| UPS 93 | 62 | 67 | DV | LG | 8.8 | 7.6 | G + P | 10.4 | 2.3 | 12 | 56.0 | 29.6 | 24.7 | 407 |
| UPS 95 | 57 | 62 | V | DG | 8.2 | 7.0 | P | 21.8 | 1.9 | 8 | 36.8 | 19.1 | 25.0 | 290 |
| UPS 97 | 56 | 62 | V | LG | 7.2 | 5.5 | G | 5.5 | 2.3 | 9 | 40.0 | 20.8 | 32.1 | 163 |
| UPS 101 | 56 | 65 | V | DG | 7.8 | 5.9 | P | 5.9 | 1.9 | G | 35.1 | 19.2 | 24.0 | 221 |

**Table 1. continued...**

| PEDIGREE | DAYS TO Flower (sg) | DAYS TO First Pod | DAYS TO Flower Color | LEAVES Color[2] | LEAVES Length (cm) | LEAVES Width (cm) | PODS Color[3] | PODS Length (cm) | PODS Width (cm) | PODS SEEDS Seed per pod | PODS SEEDS Wt. of 10 pods (gms) | PODS SEEDS Wt. of seed in 10 pods (gms) | PODS SEEDS Wt. 100 seeds (gms) | Seeds Per Acre |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UPS 102 | 56 | 62 | V | DG | 5.8 | 5.7 | G + P | 5.7 | 2.2 | 9 | 37.6 | 21.6 | 23.4 | 154 |
| UPS 103 | 56 | 62 | LV | DG | 6.9 | 5.3 | G | 5.0 | 2.3 | 10 | 46.5 | 24.3 | 24.5 | 241 |
| UPS 104 | 57 | 62 | V | LG | 6.9 | 6.4 | G | 11.0 | 2.4 | 10 | 40.8 | 21.6 | 21.9 | 330 |
| UPS 105 | 57 | 65 | DV | DG | 11.3 | 8.7 | P | 24.9 | 3.3 | 15 | 86.7 | 31.1 | 27.7 | 154 |
| UPS 106 | 56 | 61 | V | DG | 11.6 | 8.9 | P | 19.2 | 2.8 | 15 | 77.0 | 45.5 | 34.6 | 290 |
| UPS 107 | 56 | 62 | V | LG | 11.2 | 8.5 | G | 19.3 | 2.9 | 15 | 112.0 | 57.2 | 42.1 | 256 |
| UPS 109 | 58 | 64 | DV | LG | 7.2 | 6.5 | G + P | 11.8 | 2.4 | 10 | 28.6 | 18.2 | 21.0 | 270 |
| UPS 110 | 58 | 64 | LV | LG | 7.0 | 6.3 | G | 14.4 | 2.1 | 8 | 24.2 | 13.0 | 15.8 | 75 |
| UPS 111 | 56 | 62 | V | DG | 8.1 | 6.6 | G + P | 12.1 | 3.0 | 7 | 26.4 | 14.6 | 21.5 | 337 |
| UPS 112 | 56 | 62 | LV | LG | 6.9 | 6.1 | G | 18.8 | 2.3 | 10 | 42.8 | 23.2 | 23.4 | 350 |
| UPS 121 | 62 | 68 | V | LG | 14.0 | 11.0 | G + P | 18.3 | 2.5 | 13 | 50.2 | 26.1 | 21.9 | 750 |
| UPS 122 | 61 | 66 | V | LG | 12.0 | 8.7 | G + P | 8.7 | 2.5 | 12 | 26.4 | 38.6 | 32.2 | 75 |
| UPS ICA | 56 | 62 | V | LG | 13.2 | 10.4 | G + P | 22.0 | 2.4 | 16 | 109.7 | 58.5 | 36.1 | 750 |

[1]Flower petal color: LV-light; V-violet; DV-dark violet
[2]Leaf colors: LG—light green; DG-dark green
[3]Unripe pod color: G-green; G + P-green with purple wings; P-purple; R-red.

**Table 2. Growth characteristics of seven selected Papua New Guinea and ICA winged bean lines grown at CIAT during March to October 1977.**

| PEDIGREE | Flower Color[1] | LEAVES Color[2] | LEAVES Length (cm) | LEAVES Width (cm) | PODS Color[3] | PODS Length (cm) | PODS Width (cm) | PODS SEEDS Seed pod | PODS SEEDS Wt. 10 pods (g) | PODS SEEDS Wt. 100 seeds (g) | PODS SEEDS Color |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UPS 54 | 4 | 1 | 9.8 | 7.0 | 2 | 12.6 | 2.3 | 11 | 49.5 | 25.0 | Lt. brown |
| UPS 61 | 1 | 1 | 10.0 | 7.1 | 1 | 13.6 | 2.0 | 8 | 39.2 | 28.0 | Lt. brown |
| UPS 63 | 4 | 1 | 9.2 | 7.5 | 1 | 18.6 | 2.0 | 11 | 44.7 | 21.1 | Carmel |
| UPS 67 | 1 | 1 | 9.7 | 7.1 | 1 | 18.9 | 2.6 | 11 | 64.7 | 29.9 | Grey |
| UPS 91 | 3 | 1 | 6.0 | 5.4 | 2 | 12.7 | 2.1 | 9 | 39.5 | 32.1 | Black |
| UPS 109 | 3 | 2 | 7.2 | 6.5 | 2 | 11.8 | 2.4 | 10 | 28.6 | 21.0 | Black |
| UPS 121 | 2 | 1 | 14.0 | 11.0 | 2 | 18.3 | 2.5 | 13 | 50.2 | 21.9 | Carmel |
| UPS ICA | 2 | 1 | 13.2 | 10.4 | 2 | 22.0 | 2.4 | 16 | 109.7 | 36.1 | Carmel |
| Mean | — | — | 9.8 | 7.7 | — | 16.0 | 2.3 | 11 | 53.8 | 25.8 | — |

[1]Flower petal color: LV-light; V-violet; DV-dark violet
[2]Leaf colors: LG—light green; DG-dark green
[3]Unripe pod color G-green G + P-green with purple wings; P-purple; R-red

There was considerable variation in all characters observed, but the components of pod and dry seed yields are particularly interesting. Pods averaged 16.0 cm in length and ranged from 11.8 to 22.0 cm long. Mean seeds per pod were 11; but ICA had up to 16 seeds with the weight of 36.1 g/100 seeds. Manual harvesting was continued until the seventh month, although about 63 percent of total yields were already obtained within the first 137 days (figure 1). However, UPS 121 and ICA did not produce their first harvest until 123 days after planting with 87.2 and 89.3 percent, respectively, of their total yields obtained during the first two pickings (123 and 137 days).

Table 3. Some phenological and harvest data for seven Papua New Guinea and ICA winged bean lines grown at CIAT-Palmira during March to October 1977.

| | Days to Flowering | Phenological Days (Days To Harvest) | | | | | | Dry Seed Harvest Percent Total | | | | | | Yields g m$^{-2}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | 5th | 6th | 1st | 2nd | 3rd | 4th | 5th | 6th | |
| UPS 54 | 58 | 105 | 123 | 137 | 180 | 204 | 47.5 | 18.9 | 2.5 | 5.4 | 13.8 | 11.8 | 21.1 | |
| UPS 61 | 59 | 109 | 123 | 137 | 153 | 180 | 204 | 43.5 | 20.9 | 1.2 | 0.5 | 15.7 | 18.0 | 324. |
| UPS 63 | 59 | 109 | 123 | 137 | 153 | 180 | 204 | 23.6 | 33.2 | 13.0 | 6.9 | 9.9 | 13.3 | 289. |
| UPS 67 | 59 | 109 | 123 | 137 | 153 | 180 | 204 | 46.7 | 18.1 | 1.8 | 0.4 | 14.8 | 18.2 | 268. |
| UPS 91 | 59 | 109 | 123 | 137 | 153 | 180 | 204 | 47.8 | 18.0 | 1.3 | 0.8 | 6.9 | 25.2 | 288. |
| UPS 109 | 63 | 113 | 123 | 137 | 153 | 180 | 204 | 18.4 | 43.2 | 3.7 | 3.0 | 15.7 | 15.8 | 269. |
| UPS 121 | 104 | -- | 123 | 137 | 153 | 180 | 204 | -- | 38.6 | 48.6 | 7.1 | 3.5 | 2.1 | 179. |
| UPS ICA | 104 | -- | 123 | 137 | 153 | 180 | 204 | -- | 8.6 | 80.7 | 1.7 | 5.1 | 3.9 | 180. |
| MEAN | 71 | 109 | 123 | 137 | 153 | 180 | 204 | 28.6 | 24.9 | 19.1 | 3.2 | 10.7 | 13.5 | 151. |

*Based on plot size 3 m × 13 m: two rows 1.5m apart supported on a single trellis wire 2m high.

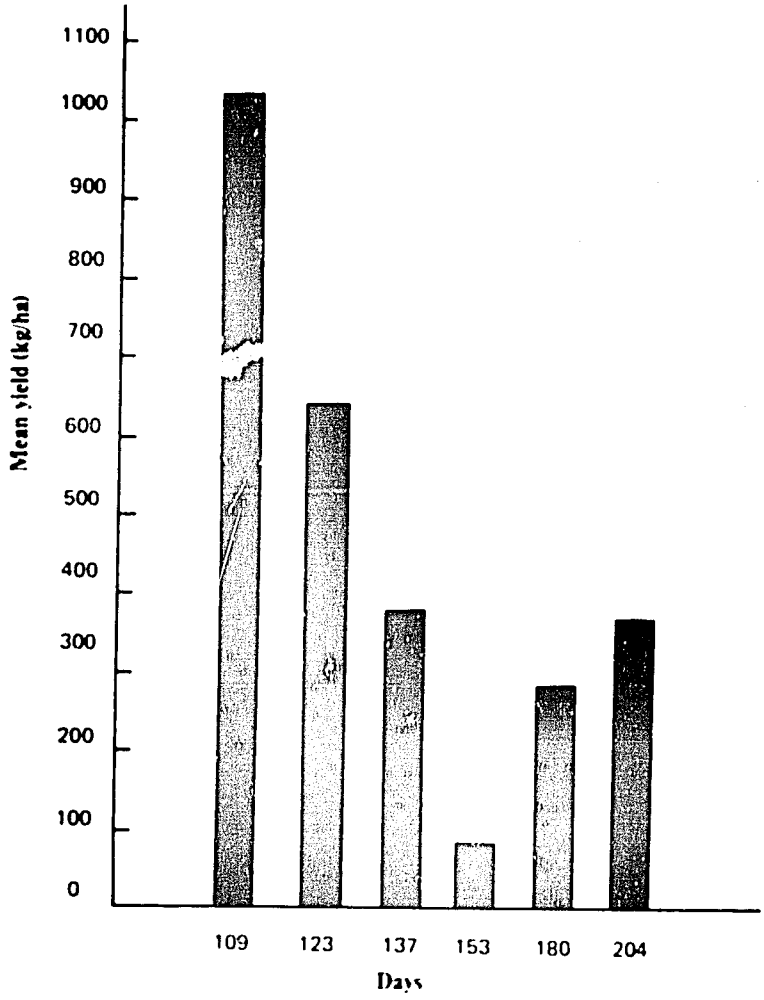


Figure 1. Distribution of mean yields over six harvests among winged bean strains grown at CIAT-Palmira during March to October 1977.

Yields were calculated on the basis of a 39 $m^2$ (3 m × 13 m), area which is a reasonably conservative estimate considering that two rows in double row plots were only one meter apart. Nevertheless, five lines exceeded dry seed yields of 268 g/$m^2$, with UPS 61 producing 325 g/$m^2$. It should also be noted that the two low yielding entries (at 180 g/$m^2$), UPS 121 and ICA which matured late continued producing even after 204 days when the trial was terminated. These two lines should be particularly good for home garden fresh vegetable production.

**Tuber Evaluation**

Two lines, UPS 66 and UPS 92, formed tubers which were collected, dried and analyzed as shown in Tables 4 and 5. Results indicate a considerably higher protein content (27.4%) than previously recorded and also good amounts of iron, calcium ang magnesium. The remainder which is about half the total weight, was presumed to be carbohydrates, which should make the roots a high quality food or feedstuff.

**Table 4. Proximate analysis of winged bean tubers grown at CIAT Palmira in 1976 to 1977.**

| Variety | Moisture % | Nitrogen % | Protein % | Ether extract (%) | Crude fiber (%) | Ash (%) |
|---|---|---|---|---|---|---|
| UPS 92 | 3.68 | 4.03 | 25.50 | 0.86 | 7.92 | 5.68 |
| UPS 66 | 3.27 | 4.68 | 29.50 | 2.75 | 7.37 | 7.90 |
| Mean | 3.47 | 4.38 | 27.4 | 1.80 | 7.6 | 6.79 |
| Irish potato* flour | 7.0 | — | 8.5 | 0.4 | 1.6 | — |
| Cassava meal | 14.0 | — | 1.5 | 0.6 | 1.8 | — |

*Adapted from "Food Composition Table" p. 54, compiled by the Carribbean Food and Nutrition Institute, Kingston 7, Jamaica.

**Table 5. Mineral content of winged bean tubers grown at CIAT-Palmira in 1976 to 1977.**

| Variety | Fe | Mn | Zn | Cu | B | N | P | K | Ca | Mg | Na |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ppm | | | | | % | | | | | ppm |
| UPS 92 | 386 | 53 | 40 | 10.9 | 9.2 | 4.08 | 0.65 | 1.05 | 0.39 | 0.47 | 358 |
| UPS 66 | 410 | 44 | 53 | 14.9 | 7.6 | 4.68 | 0.83 | 1.36 | 0.64 | 0.66 | 500 |
| Mean | 398 | 48.5 | 46.5 | 12.9 | 8.4 | 4.38 | 0.74 | 1.20 | 0.51 | 0.56 | 429 |

## CONCLUSIONS

Preliminary evidence suggests that the winged bean has a vast, unrealized potential for food and feed in the lowland tropics of Latin America. Owing to its many virtues, not the least of which is its comparative freedom from diseases and pests, it could become a highly useful crop. The winged bean has low requirements for externally purchased inputs but is highly responsive to non purchased managerial inputs (like trellising). For those reasons the winged bean should be particularly useful in small farm cropping systems of the Latin American lowland tropics.

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Felix S. Wendt, Apia

Apparently inspired by the discussions on the symposium and a winged bean soup served later during dinner, Dr. Buckminister Fuller, the well known engineer, inventor, humanist and poet and also a conference participant composed the following poem on the winged bean:

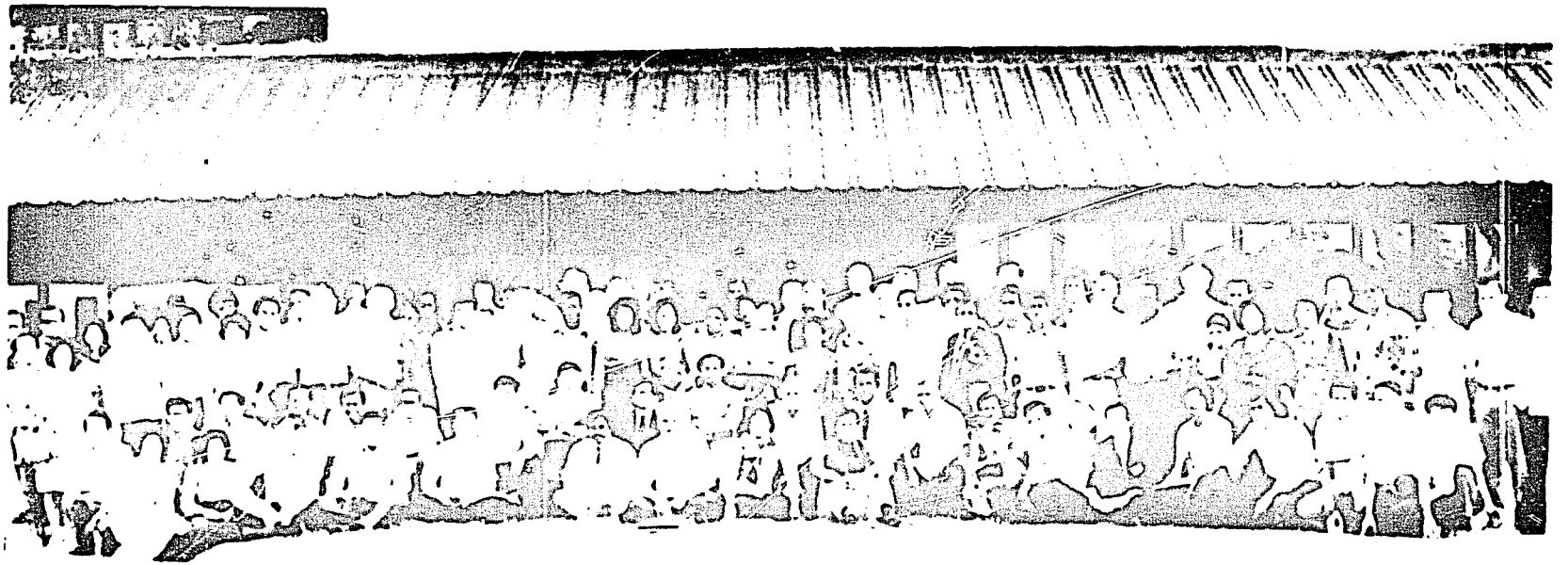
*No politicking hog wash*
*No vote seeking hokus pokus*
*Real nitrogen enfixing*
*Genus psophocarpus*
*tetragonolobus*

*Soup and French cut*
*Formally served*
*Not only did not bloat us*
*But also pleased our palates*
*Long podded Psophocarpus*
*tetragonolobus*

*Purple, yellow, brown and green*
*Sometimes spotted*
*Sometimes clean*
*Grotesquely knotted*
*Roots unseen*
*Why do they call you*
*Winged Bean?*

*Noduled tuber*
*Pole bean tall*
*Flowers, seed pods*
*Edible all*
*Who's the fairest*
*Bean of all*
*Soy or Psophocarpus*
*tetragonolobus?*

Richard Buckminister Fuller
January 1978



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