AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION

A. PRIMARY: Agriculture

B. SECONDARY: Legume Crops

2. TITLE AND SUBTITLE

The Winged Bean A High-Prote-n Crop for the Tropics

3. AUTHOR(S)

Ad Hoc Panel

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1975	49p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

National Academy of Sciences
2101 Constitution Avenue
Washington,D.C. 20418

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*

9. ABSTRACT

Edible legumes are excellent sources od dietary protein and oils. Many nutritionists expect them to play an increasing role in meeting food needs in this time of food shortages and widespread malnutrition. In addition to the major cultivated edible legumes-soybeans, peanuts (groundnuts), peas, and beans-there are more than 50 minor tropical legumes that have received little scientific attention (mainly because researchers have concentrated on more conventional crop species, especially cereals). This report focuses on the exceptional promise offered by one of these: the winged bean, Psophocarpus tetragonolobus (L.) DC.

Having considered all available information, the panel is persuaded that with research the winged bean can become a significant food crop in the humid tropics. It recommends that a major development effort be undertaken to test it in new areas and to expand the knowledge base that will make possible its most efficient exploitation.

Little research has been done on the winged bean; information, therefore, is limited. Today it is grown only as a backyard crop in Papua New Guinea and Southeast Asia. But these regions are typical of the humid tropical zone that encompasses large belts of Central and South America, the Caribbean, Africa, Oceania, and West Asia, where protein deficiency is high and the plant is still unknown. That an edible crop with high protein content will grow in this region is uncommon. The winged bean appears to have great potential for easing the problem of protein malnutrition throughout the humid tropics.

10. CONTROL NUMBER	11. PRICE OF DOCUMENT
PN-AAB-319	

12. DESCRIPTORS

Protein, Oil, Food Crops, Malnutrition, New Guinea, Southeast Asia, Research, Tropics, Legume, Vitamins, Roots

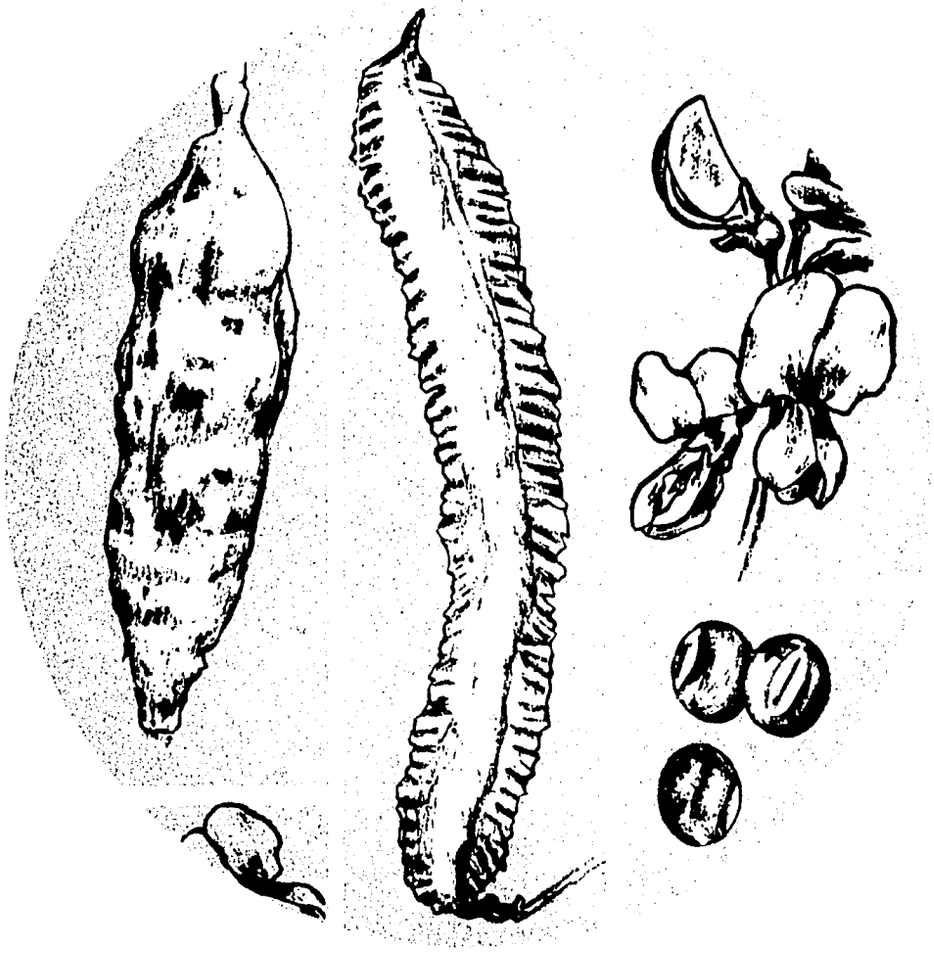
13. PROJECT NUMBER: 931-11-995-029

14. CONTRACT NUMBER: AID/CSD-2584

15. TYPE OF DOCUMENT: Panel report

The Winged Bean
A HIGH-PROTEIN CROP FOR THE TROPICS

NATIONAL ACADEMY OF SCIENCES



The Winged Bean
A HIGH-PROTEIN CROP FOR THE TROPICS

Report of an Ad Hoc Panel of the
Advisory Committee on Technology Innovation
Board on Science and Technology for
International Development
Commission on International Relations

Avec résumé en français
Con resumen en español

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1975

This report has been prepared by an ad hoc advisory panel of the Board on Science and Technology for International Development, Commission on International Relations, National Research Council, for the Office of Agriculture and the Office of Science and Technology, Bureau for Technical Assistance, Agency for International Development, Washington, D.C., under Contract No. AID/csd-2584.

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Board's judgment that the project is of international importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the committee selected to undertake this project and prepare this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. Responsibility for the detailed aspects of this report rests with that committee.

Each report issuing from a study committee of the National Research Council is reviewed by an independent group of qualified individuals according to procedures established and monitored by the Report Review Committee of the National Academy of Sciences. Distribution of the report is approved, by the President of the Academy, upon satisfactory completion of the review process.

Panel on the Winged Bean

RICHARD EVANS SCHULTES, Mangelsdorf Professor of Natural Sciences; Director, Botanical Museum of Harvard University, Cambridge, Massachusetts, *Chairman*

JAMES L. BREWBAKER, Department of Horticulture, University of Hawaii, Honolulu, Hawaii

STERLING B. HENDRICKS, Mineral Nutrition Laboratory, Argicultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland (Retired)

THEODORE HYMOWITZ, Department of Agronomy, University of Illinois, Urbana, Illinois

SAMUEL K. KARIKARI, University of Ghana, Agricultural Research Station, Kade, Ghana

TANVEER N. KHAN, Department of Agriculture, University of Papua New Guinea, Port Moresby, Papua New Guinea

IRVIN E. LIENER, Department of Biochemistry, College of Biological Sciences, University of Minnesota, St. Paul, Minnesota

GEOFFREY B. MASEFIELD, Department of Agricultural Science, Oxford University, Oxford, England

KENNETH O. RACHIE, International Institute of Tropical Agriculture, Ibadan, Nigeria

NOEL D. VIETMEYER, Board on Science and Technology for International Development, Commission on International Relations, National Academy of Sciences, *Staff Study Director*

* * *

JULIEN ENGEL, Board on Science and Technology for International Development, Commission on International Relations, National Academy of Sciences, *Head, Special Studies*

Contributors

ARTHUR CHARLES, Chief Agronomist, Department of Agriculture, Stock and Fisheries, Konedobu, Papua New Guinea

WILLIAM J. CLAUSNER, The Asia Foundation, Bangkok, Thailand

ALAN CLAYDON, Department of Chemistry, University of Papua New Guinea, Port Moresby, Papua New Guinea

RALPH ELMES, Department of Agriculture, Stock and Fisheries, Konedobu, Papua New Guinea

M. S. KISMADI, The Asia Foundation, Jakarta, Indonesia

KENNETH KOPF, Agency for International Development, Washington, D.C. (Retired)

ROLF KORTE, Department of Public Health, Konedobu, Papua New Guinea

KENNETH P. LAMB, Department of Biology, University of Papua New Guinea, Port Moresby, Papua New Guinea

WILLIAM S. McCREA, The Asia Foundation, Manila, Philippines

WILLIAM McDOUGAL, The Asia Foundation, Vientiane, Laos

DOROTHY E. SHAW, Department of Agriculture, Stock and Fisheries, Konedobu, Papua New Guinea

DOUGLAS F. SMITH, The Asia Foundation, Kuala Lumpur, Malaysia

ANDREW STRATHERN, Department of Anthropology and Sociology, University of Papua New Guinea, Port Moresby, Papua New Guinea

Observers

SAMUEL C. LITZENBERGER, Office of Agriculture, Agency for International Development, Washington, D.C.

DONALD L. PLUCKNETT, Office of Agriculture, Agency for International Development, Washington, D.C.

Preface

The winged bean, *Psophocarpus tetragonolobus*, a little-known tropical legume, is grown almost exclusively in Papua New Guinea and Southeast Asia. The plant came to the attention of the National Academy of Sciences during an extensive survey of underexploited tropical plants conducted by an Academy panel in 1974. The report of this survey examines 36 species that show promise as crop plants for the future.* The seemingly exceptional merits of the winged bean, however, suggested that a separate, in-depth examination of its characteristics and prospects be undertaken promptly and the results brought to the notice of the international development community.

The existing literature on the plant is meager, much of it scattered through 60-year-old journals, mimeographed papers, and annual reports from experiment stations. To evaluate the available information and assess the potential of this plant, an international panel was convened at Airlie, Virginia, in October 1974. The panel was composed of specialists with experience in winged bean cultivation, in tropical agriculture, and in nutrition.

Although the panel was not expected to produce a comprehensive report on the winged bean, it was asked to consider such matters as

- The state of knowledge concerning the plant;
- The bean's promise as a crop plant;
- Significant data gaps and research needs; and
- A strategy for international research and testing to assess the crop's future.

This report is intended for the attention of agencies engaged in development assistance and food relief, officials and institutions concerned with agriculture in tropical countries, and scientific establishments with relevant interests.

The panel is indebted to the contributors and to Mary Jane Koob, who acted as administrative secretary for the meeting and for production of the report. The manuscript was edited and prepared for publication by F. R. Ruskin.

*For ordering information, see "Underexploited Tropical Plants with Promising Economic Value," p. 41.

Comments on this report (especially if it has stimulated further work on the winged bean) should be communicated to the staff officer, Dr. Noel Vietmeyer, National Academy of Sciences, 2101 Constitution Avenue N.W., JH215, Washington, D.C. 20418, U.S.A.

Contents

Chapter 1	Summary	1
Chapter 2	Agronomy	5
Chapter 3	Composition and Nutritive Value	17
Chapter 4	Recommendations	22
Appendix A	Researchers Working with Winged Bean	27
Appendix B	Selected References	29
Resumen en Español		32
Résumé en Français		36

Chapter 1

Summary

Edible legumes are excellent sources of dietary protein and oils. Many nutritionists expect them to play an increasing role in meeting food needs in this time of food shortages and widespread malnutrition. In addition to the major cultivated edible legumes–soybeans, peanuts (groundnuts), peas, and beans–there are more than 50 minor tropical legumes[1] that have received little scientific attention (mainly because researchers have concentrated on more conventional crop species, especially cereals). This report focuses on the exceptional promise offered by one of these: the winged bean, *Psophocarpus tetragonolobus* (L.) DC.

Having considered all available information, the panel is persuaded that *with research the winged bean can become a significant food crop in the humid tropics. It recommends that a major development effort be undertaken to test it in new areas and to expand the knowledge base that will make possible its most efficient exploitation.*

Little research has been done on the winged bean; information, therefore, is limited. Today it is grown only as a backyard crop in Papua New Guinea and Southeast Asia. But these regions are typical of the humid tropical zone that encompasses large belts of Central and South America, the Caribbean, Africa, Oceania, and West Asia, where protein deficiency is high and the plant is still unknown. That an edible crop with such high protein content will grow in this region is uncommon. The winged bean appears to have great potential for easing the problem of protein malnutrition throughout the humid tropics.

The possibilities of the plant for improving the human diet have not been recognized. It is an exceptional legume; the green pods, leaves, and seeds are rich in protein and vitamins, and the tuberous roots are–among root crops–uniquely rich in protein. In addition, the seeds are a source of edible oil.

Winged bean plants grow vigorously and have extensive root systems. Nitrogen from the atmosphere is "fixed" by bacteria in nodules on the roots and becomes incorporated into the plant, principally as protein. Compared with other edible legumes, the winged bean plants appear to have more (and larger) nodules on their roots. This superior nodulation may account for the plant's exceptional protein content.

[1] See for example the list in Aykroyd and Doughty, 1964. Selected References.

Immature pods can be eaten raw. They are highly palatable, taste like green beans, and seem to be readily accepted, even by those who have not previously eaten them. Winged bean seeds are similar to soybeans in composition. They average about 34 percent protein (on a dry weight basis) and 17 percent oil. Individual seeds with as much as 37 percent protein or 20 percent oil have been found. The protein's nutritional quality appears comparable to that of soybeans in its digestibility and composition (it has as much lysine, methionine, and cystine). The oil has a favorable proportion of polyunsaturated essential fatty acids. Like soybeans, the seeds of the winged bean contain compounds that interfere with protein digestion—trypsin inhibitors and hemagglutinins—but these can be destroyed satisfactorily with cooking.

The slightly sweet tuberous roots contain 20 percent protein (dry weight). This is much higher than the protein content in other edible roots and tubers such as cassava (1 percent), potatoes (2 percent), sweet potatoes (2 percent), or yams (2 percent). The plant grows in regions where people now depend on these low-protein root crops. No adverse effects have been reported from the use of winged bean tubers in foods.

Although the winged bean is indigenous to the humid tropics, it responds favorably to irrigation and, consequently, can be grown in drier regions. The winged bean tolerates a wide range of altitudes, an unusual characteristic in cultivated tropical plants. It grows from sea level to a height of 2,000 m (7,000 ft.) in Papua New Guinea. It is clear from independent small-plot-trials in Papua New Guinea, Ghana, and Nigeria[2] that the winged bean can produce seed yields comparable to those of other legumes. Seed yields of 2,000 kg per hectare (2,000 lb. per acre) are possible.[3] It seems likely that yields could be further increased by additional research; no genetic selection has yet been undertaken, and there has been little investigation of the best methods of cultivation.

Tropical soils are often poor in nitrogen, but the winged bean can grow in poor soil, reflecting, perhaps, its ability to fix nitrogen from the air. The winged bean normally does not need inoculation with nitrogen-fixing bacteria to grow vigorously. Its seeds can be planted directly even into newly cleared soil—a major advantage over many tropical legumes that have to be inoculated when their bacterial strains are deficient in the soil.

The winged bean could be a good restorative crop, which might meet the requirements of small-scale farmers in the tropics. It grows quickly and enriches the soil with nitrogen, especially if ploughed under.

Almost nothing is known of winged bean varieties, which have yet to be collected and established in nurseries for the proper development of the

[2]The experiments at the University of Ghana and at the International Institute of Tropical Agriculture in Nigeria both used seed originally imported from New Guinea.
[3]K.O. Rachie—personal communication to the panel.

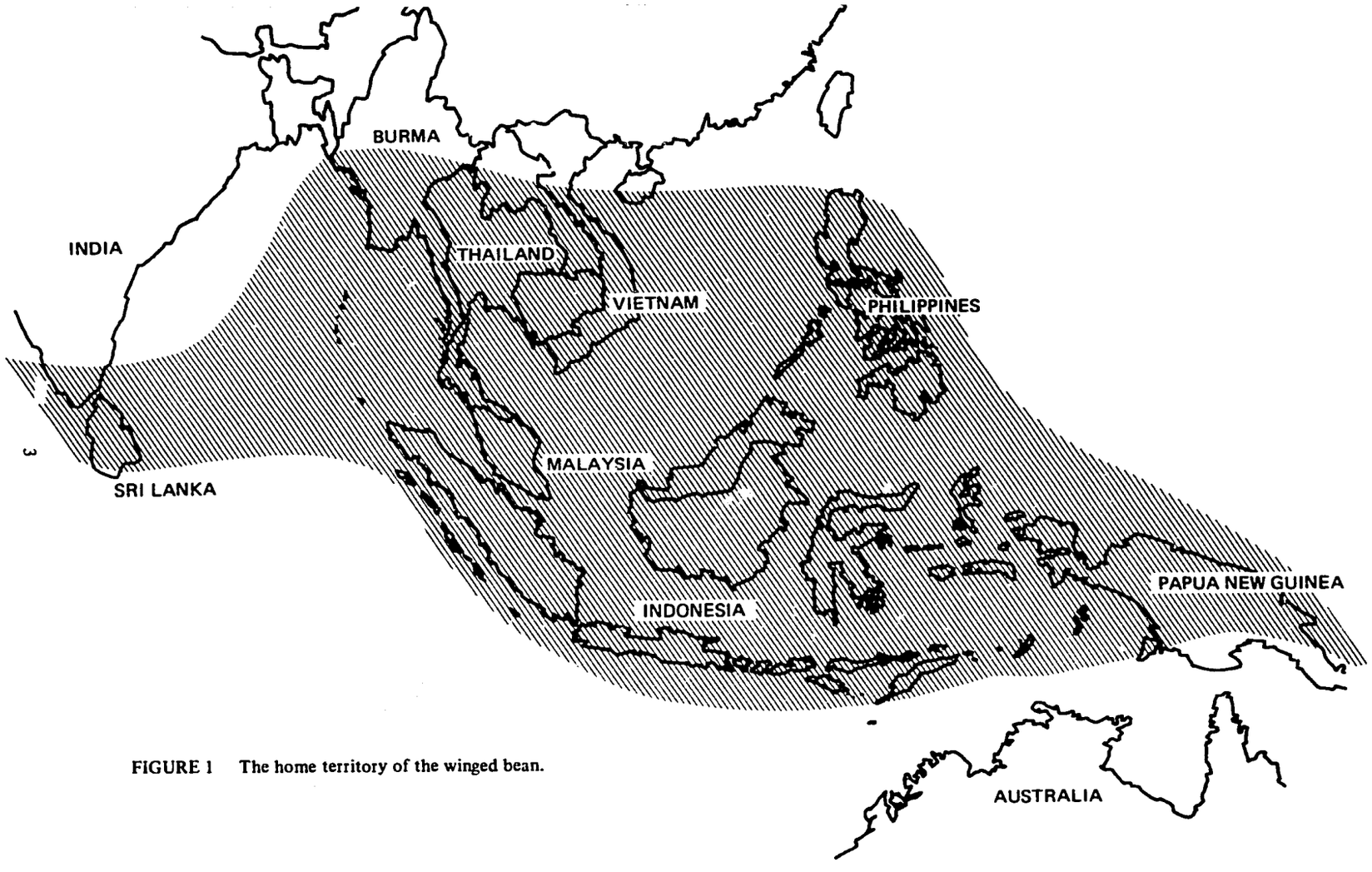


FIGURE 1 The home territory of the winged bean.

plant. The few varieties now cultivated require staking to produce high yields of pods and seeds. Because this method of agriculture is impractical and uneconomical for mass cropping, and because not all winged bean pods mature at the same time, the plant is not likely to rival the soybean as a large-scale commercial product in the near future. Its potential is as a subsistence crop or as a cash crop for small markets. For these purposes, the fact that it produces food during many months is an advantage, and staking is not a serious handicap.

Most wild legumes have climbing growth habits similar to those of the winged bean; even wild soybeans and wild lima beans grow this way. The specific varieties now cultivated have been bred for the self-supporting growth necessary for large-scale farming. There is a pressing need to find and develop similar self-supporting varieties of winged bean.

What is known today about the winged bean is roughly tantamount to what was known about the soybean 60 years ago, shortly after its commercial introduction to the United States. Many advances in the genetic improvement of the soybean could be applied to the winged bean. It is possible that the winged bean may be as significant for world agriculture in the future.

The techniques for producing soybean flour and protein concentrates for use in foods could be applied to winged bean processing. The winged bean has several nutritional advantages over the soybean. All parts of the plant can be eaten—tubers, seeds, leaves, flowers, and shoots—whereas only seeds of the soybean are used. The bitter, beany flavor of many soybean products appears to be absent in the winged bean, which should encourage its widespread introduction into the human diet.

Because of the exceptional qualities of winged beans the panel believes that the plant deserves intensive investigation and testing in experiment stations in diverse regions of the tropics. To do this piecemeal will not be as effective as mounting a coordinated effort to distribute seeds and to collect, collate, and compare results.

Much of the testing can be carried out by local stations, but the coordinating function cannot. For this, some sort of international mechanism is required. A few likely possibilities are suggested in chapter 4, as is a program detailing research strategies to promote better understanding of the winged bean. This is intended to be a guide for agronomists, botanists, and nutritionists as well as for foundations and agencies that finance economic-development activities.

Chapter 2

Agronomy

Psophocarpus is a genus with four or five species;[4] details of its taxonomy remain to be clarified. Two species, *P. tetragonolobus* and *P. palustris*, have long been a source of food. The other species are wild African plants that have never been cultivated. Although eventually they may prove useful, these wild species seem less important for the immediate future than *P. tetragonolobus*. Of the two best-known species, *P. tetragonolobus* appears more vigorous, productive, and useful than *P. palustris*. It is already a crop plant in Asia, whereas *P. palustris* is a semi-wild plant used mainly in times of food shortages in Ghana and neighboring nations. The origin of *P. tetragonolobus* is probably Papua New Guinea and Southeast Asia; *P. palustris* is native to West Africa.

This report deals exclusively with *P. tetragonolobus* because of its apparent advantages over the other species. (Further research to determine the relative merits of each of the species is needed.)

In Papua New Guinea, the winged bean is an important backyard and market crop in the Central Highlands and in the Sepik District. Almost all parts of the plant are eaten, although preferences vary from area to area. The number of varieties and their use in some tribal rites suggest that the winged bean has been cultivated in Papua New Guinea for centuries. The tribesmen differentiate seed varieties that produce high tuber yield from those that produce high pod yield. Cultivation practices include pruning and removal of flowers to increase the tuber yield. In some areas winged bean tubers are a food staple, but in most areas they are seasonal and are consumed during only a few weeks of the year.

In Burma, the crop is important in the south and central regions. Planted in rich river-bank soils as flood waters recede, the plants are given no care if tubers are desired. But the plants grown for pods are staked on bamboo poles. The tubers are boiled and eaten like potatoes—mainly by children. The pods, dipped briefly in boiling water, are commonly eaten as a snack in the early afternoon.

[4]These should not be confused with the winged beans of the genus *Lotus* that grow in temperate regions, particularly around the Mediterranean.

In Thailand, Malaysia, the Philippines, Vietnam, and other countries of Southeast Asia, winged bean pods are eaten as a cooked vegetable. The beans are cultivated by home gardeners for family consumption as well as by vegetable farmers for sale in local markets. The tubers are not eaten.

In parts of Indonesia, winged bean pods and leaves are eaten as a vegetable. Like soybeans, the dry seeds are often made into a fermented cheese-like food.

Botany

The winged bean, a climbing, herbaceous perennial (FIGURE 2), can reach heights of 3-4 m (9-12 ft.) if supported. The blue, white, or purple flowers are self-pollinating. The pods are four sided, with characteristic wings, vary in length from 6-36 cm (2-14 in.), and contain from 5-20 seeds each. The globular-shaped, shiny seeds may be white, yellow, brown, black, or mottled and vary in weight from 0.06-0.40 g.

The pods develop in two stages. In the first, which takes about 20 days, the pod grows to its ultimate size. In the second, which takes about 44 days, the seeds mature and the pod surrounding them shrivels and dries out.

The winged bean develops an unusual amount of nodulation. Plants in Malaya carry up to 440 nodules each, and these nodules are unusually large. A single nodule may have a fresh weight of 0.6 g with a diameter up to 1.2 cm (0.5 in.).[5] Excellent nodulation without any need for inoculation appears to take place everywhere the crop has been grown. The bacterium involved is probably the common *Rhizobium* that nodulates many wild legumes and is sometimes spoken of as belonging to the cowpea group.[6]

Environmental Requirements

The winged bean is cultivated from sea level up to 2,000 m (7,000 ft.) and between 20°N and 10°S latitude in the Asian tropics. Its climatic requirements have not been studied in detail, but it appears to require a short day for normal flower induction. When grown outside the tropics, winged beans rarely flower. This seems to be caused by day-length differences (photoperiodic inhibition) and not by temperature. While the crop fares best in the humid tropics, under irrigation it can be grown with equal success in dry tropics. Despite its perennial nature and extensive root system, it does not survive prolonged drought.

[5]Masefield, 1971. See Selected References.
[6]Information supplied by R. Elmes, Department of Agriculture, Stock, and Fisheries, Konedobu, Papua New Guinea.

FIGURE 2 The plant. (S. K. Karikari)

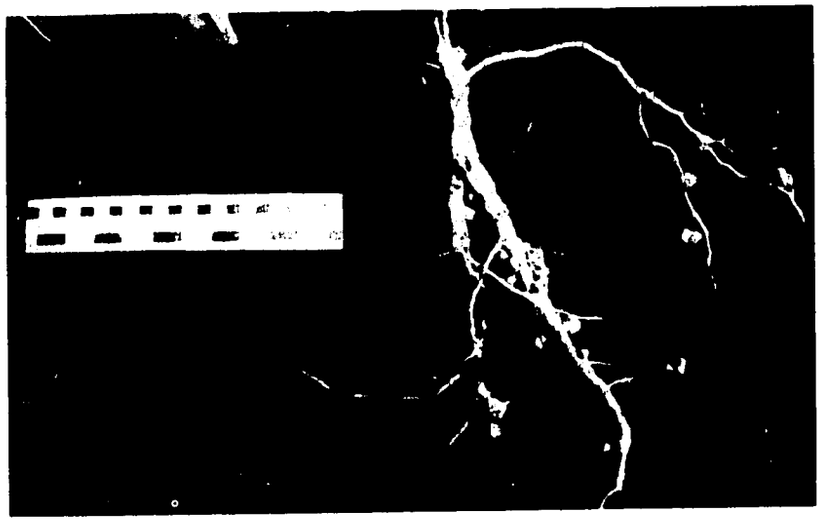


FIGURE 3 Nodules of the winged bean. (S. K. Karikari)

The winged bean does not appear to be demanding in its soil requirements. Although it will not survive waterlogged soil, it can adapt to a wide range of soils. Little is known, however, of its requirements for lime, phosphate, and other nutrients often lacking in tropical soils. It can grow in nitrogen-poor soils, reflecting its ability to obtain fixed nitrogen via its root nodules (FIGURE 3). Under irrigation, it has been grown successfully during the extended dry seasons in the Port Moresby area of Papua New Guinea.

The use of raised beds or mounds for winged bean production, a practice that improves drainage and stimulates tuber growth, is common in Papua New Guinea.

Biological Variation

At present, only a few varieties are available to investigators, and the observations on growth and management of winged beans are often based on single, or at most a few, cultivars. Studies of Papua New Guinean collections (over 100 varieties) reveal extensive genetic variability in the plant's ability to form tubers and produce seeds and pods. Varieties have been observed having

FIGURE 4 A pod three weeks after fertilization. (N. D. Vietmeyer)

FIGURE 5 (Inset) Seeds of the winged bean. (S. K. Karikari)

FIGURE 6 The tuberous root of the winged bean. (N. D. Vietmeyer)

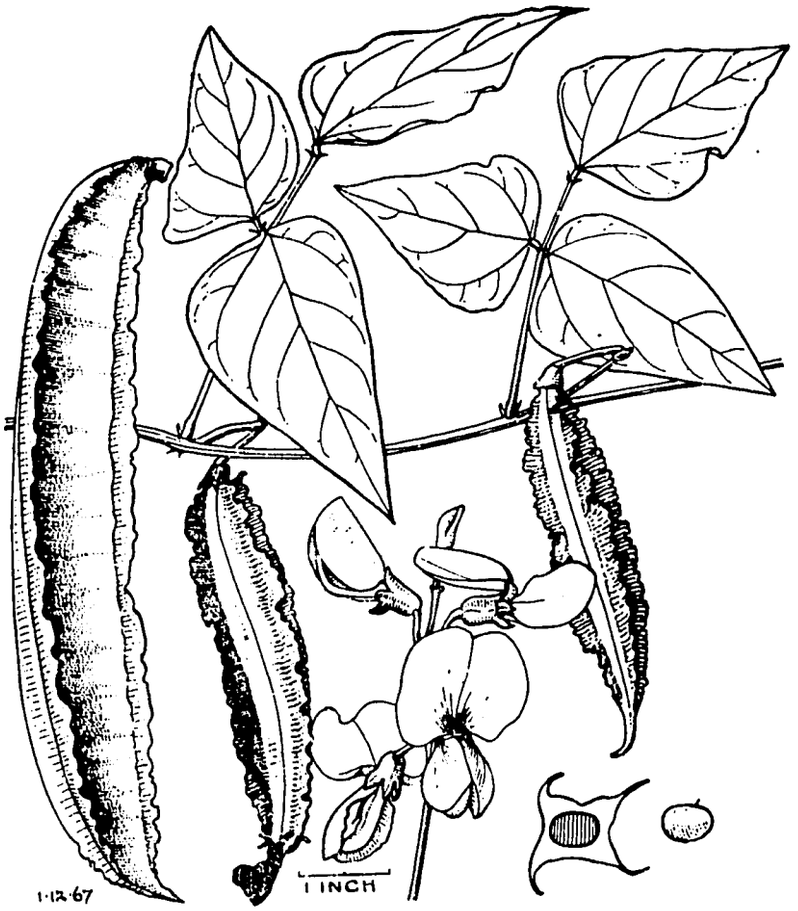


FIGURE 7 *Psophocarpus tetragonolobus*: winged bean. Leaves, inflorescence with pale blue flowers and buds and young and mature pods. The insets on the right are of a cross section of an old pod and seed. (Based on a drawing by G. A. C. Herklots)

different shapes, sizes, and colors of the pods, seeds, and flowers (FIGURE 8). Certain varieties are unable to form tubers, while others produce both tubers and seeds[7] (FIGURE 9).

	Range	Average
Seed yield in gm per plant	0.6 to 72.0	15.7
Length of pods in cm	5.8 to 26.4	15.2
Seed weight in mg	62 to 417	224
Tuber yield in gm per plant	1.3 to 50.3	15.9

FIGURE 8 Biological variation in winged bean. The data is based on measurements of 500 plants in Papua New Guinea. (After Kahn, 1974)

Cultivation

Winged bean seed is sown at the beginning of the rainy season. The plant is grown as a single crop with poles or trellises and begins to flower as early as 50 days in the lowland tropics or as late as 3-4 months at higher elevations. Although the plant grows vigorously once established, seedlings germinate and grow slowly during the first 3-5 weeks after planting.

If weeds become established among the young plants, they become entwined and are very difficult to remove.

Rotations and Intercrops

Like many legumes cultivated in the tropics, the winged bean can be grown as an intercrop. For example, in Papua New Guinea it is interplanted with sweet potatoes, sugar cane, taro, bananas, green vegetables, or other grain legumes. It is planted in a similar fashion in Indonesia, where it is also grown on the borders of rice paddies.

[7]Information on a dual-purpose variety was supplied by Dr. Setijati Sastraprada, Bogor, Indonesia.

FIGURE 9 A dual-purpose variety of winged bean that yields both pods and tubers, grown at Lembaga Biology National, Bogor, Indonesia. (K. O. Rachie)

Staking

It is customary to support winged bean plants on poles (bamboo is often used) arranged either singly or in tripods (FIGURE 10). But on poles the plants sometimes grow so tall that some pods cannot be picked without using ladders; therefore, it is often more convenient to use a trellis or wire fence 1.20 m (4 ft.) high.[8] However, where the crop is grown for its tubers, as in Burma, no supports are needed. The vines ramble over the ground, forming a vegetation cover about 30 cm (1 ft.) deep.

In experiments carried out at the International Institute of Tropical Agriculture in Nigeria in 1971 and 1972, seed and pod yields of plants supported on trellises or poles were more than double the yield of unsupported plants (K. O. Rachie).

Pests and Diseases

As currently grown in mixed garden culture or shifting agriculture, the winged bean is unusually free of serious pests and diseases. However, biologists and agronomists have noted that sometimes young flowers and pods are attacked by caterpillars, and the leaves can be damaged by leaf miners, grasshoppers, and spider mites. There is one record of a root-knot nematode on winged bean plants in Papua New Guinea. Crown rot, false rust, and leaf spot fungi have also been observed. When the bean is more widely grown in monoculture it will probably be increasingly subject to disease and insect pests.

Harvesting

Green pods and dry seeds. The first green pods are ready for picking about 10 weeks after sowing. About 2 weeks after pollination the succulent pod reaches its full length and can be used as a green vegetable. After 3 weeks the pod becomes fibrous and less palatable. After 6 weeks the seeds are mature and can be harvested. The plant may continue to bear pods indefinitely, but the experience of cultivators suggests that the rate of production declines after several months. There is no definitive information on how long it is economically profitable to keep the crop in the ground. Farmers now treat the winged bean as an annual crop.

Tubers. To grow large tubers the plants are spaced 10-20 cm (0.5-1.0 ft.) apart and are allowed to trail. The tubers are harvested 4-8 months after sowing, when they reach 2-4 cm (1-2 in.) in diameter and 8-12 cm (3-5 in.) in length.

[8] Pospisil *et al*, 1971. See Selected References.

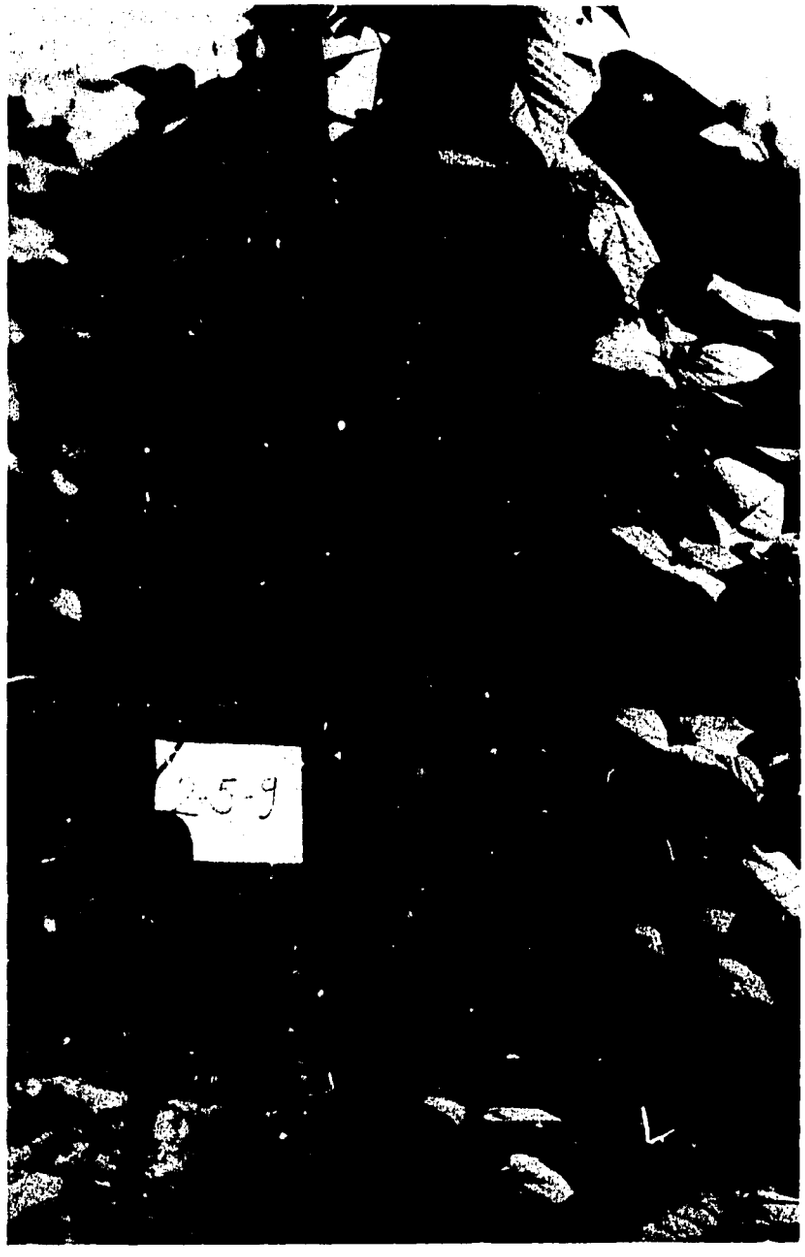


FIGURE 10 Pole staking of the winged bean. (S. K. Karikari)

Productivity

Little documented information is available on winged bean yields. Green pods mature and are harvested as long as the climate remains favorable. The harvest ends usually with the onset of the cold season. Small-plot-yields up to 1.9 tons of seed per ha (0.8 tons per acre) have been realized in Papua New Guinea; in Ghana and Nigeria, during several years of experiments using a *P. tetragonolobus* variety from Papua New Guinea, seed yields of 1.2-1.4 tons per ha (0.5-0.6 tons per acre) have been routinely obtained. Up to 2.4 tons per ha (1 ton per acre) have been recorded in agronomic trials at the International Institute of Tropical Agriculture (1974) in Ibadan, Nigeria.[9]

Tuber yields have not been reliably measured in large plantings. In small plots in Ibadan, from 600-1,300 kg of fresh tubers per ha (600-1,300 lbs. per acre) were obtained; in addition, multiple harvests produced 2.2 tons and 1.8 tons per ha (0.9 and 0.7 tons per acre) of dry seeds (FIGURE 11).

Species	Seed Yield Potential	Reference
Winged bean	720 - 1,946	
Soybean	2,730	Sumbak (1974)*
Peanut	2,184	Vance (1974)*
Mung Bean	1,482	Khan (unpublished)
Pigeon pea	1,112	Khan (unpublished)
Rice bean	954	Khan (unpublished)
Cowpea	1,800	Erskine & Khan (unpublished)
Bean	699	Khan (unpublished)

*See *Science in New Guinea* Vol. 2, No. 1 (1974) [Reprints available from Biology Department, University of Papua New Guinea, P.O. Box 4820, University, Papua New Guinea.]

FIGURE 11 Estimated yield potential of various legumes (expressed as kg per ha) in Papua New Guinea compared with winged bean.

Fresh tuber yields exceeding 4.0 tons per ha (1.6 tons per acre) have been reported from Burma.[10] It seems likely that tribesmen in the highlands of Papua New Guinea realize higher yields by using cultivation practices (e.g., plucking off the flowers) that enhance tuber growth.

[9]Rachie, 1974. See Selected References.
[10]Burkhill, 1906. See Selected References.

Chapter 3

Composition and Nutritive Value

Pods

The young, green pods make a tender, crunchy vegetable that is eaten raw or is added to cooked vegetable dishes. Other than proximate composition (FIGURE 12) and some data on mineral and vitamin content (FIGURE 13),

	Immature pods	Seeds	Tubers	Leaves	Flowers
Water	76.0-92.0	6.7-24.6	54.9-65.2	64.2-77.7	84.2
Protein	1.9- 2.9	29.8-37.4	12.2-15.0	5.7-15.0	5.6
Fat	0.2- 0.3	15.0-20.4	0.5- 1.1	0.7- 1.1	0.9
Carbohydrate	3.1- 3.8	31.6-28.0	27.2		
Fiber	1.2- 2.6	5.0-12.5	17.0		
Ash	0.4- 1.9	3.6- 4.0	0.9		
S/N ratio		2.7- 3.4			

FIGURE 12 The proximate composition of different parts of the winged bean. Values recorded here (expressed as mg per 100 gm fresh weight) show the ranges reported by Bailey, 1968; Brown, 1954; Claydon, 1974; Kapsiotis, 1968; Pospisil *et al*, 1971; Purseglove, 1968; Rachie, 1974; Watson, 1971.

Component	Immature Pod	Seed	Tuber
Minerals			
Calcium	63 - 330	204 - 370	40
Magnesium		120 - 204	
Potassium		110 - 120	
Sodium		20 - 56	
Phosphorus	60	320 - 276	64
Iron	1.3 - 1.7	9.6 - 11.8	3.0
Vitamins			
β-Carotene	0.54		
Tocopherols		126	
Thiamin	0.06	1.4	
Riboflavin	0.12	0.2	
Niacin	0.5		
Ascorbic acid	22 - 37		

FIGURE 13 The content of minerals and vitamins in different parts of the winged bean. The values are expressed as mg per 100 gm fresh weight. (Data are taken from literature cited in the footnote to FIGURE 12.)

little information is available on the nutritional value of the immature pod. Amino acid composition data, for example, are lacking, and no studies on animal growth have been reported. No adverse effects have been reported despite the widespread consumption of the pods (raw and cooked) and seeds in Southeast Asia.

Seeds

Mature seeds are not eaten raw. They require cooking for 2-3 hours. Sometimes they are roasted and eaten like peanuts; in Java the seeds are frequently parched before eating.

The nutritive quality of the cooked bean, as assessed by the Protein Efficiency Ratio (PER) and Net Protein Utilization (NPU) values, compares well with that of soybean.[11] These conclusions are based on the data presented in FIGURE 14.

Although the diet containing only winged bean seeds (at a level providing 10 percent protein) does not show a nutritive value as high as skim milk, combining the winged bean with maize (corn) does. Nutritionally, the winged bean is superior to the peanut. Of special significance is the report that a flour made from the winged bean was suitable as a milk substitute in the treatment of children suffering from kwashiorkor.[12]

	10% protein		16% protein
Protein component of diet	PER	NPU	PER
Winged bean*	2.14	55.0	2.00
Peanut*	1.53	46.2	
Skim Milk*	3.04	73.2	2.37
Winged bean plus corn*	2.70	65.7	2.20
Peanut plus corn*	1.92	54.7	1.82
Soybean**	2.10	56.0	

FIGURE 14 The nutritive value of the winged bean as measured in rats. (*Data from Cerny *et al*, 1971; **data from Liener, 1972)

These results indicate that the nutritive value of winged bean seed-protein is similar to that of the soybean. The amino acid composition (FIGURE 15) is also similar. Like the soybean, the winged bean is somewhat deficient in the sulfur-containing amino acids. Since the winged bean is rich in lysine it could supplement cereal diets that are lysine deficient.

[11] Cerny *et al*, 1971. See Selected References.
[12] Cerny and Adndy, 1973. See Selected References.

Amino Acid	Winged Bean	Soybean
Cystine	1.6 - 2.6	1.2
Lysine	7.4 - 8.0	6.6
Histidine	2.7	2.5
Arginine	6.5 - 6.6	7.0
Aspartic acid	11.5 - 12.5	8.3
Threonine	4.3 - 4.5	3.9
Serine	4.9 - 5.2	5.6
Glutamic acid	15.3 - 15.8	18.5
Proline	6.9 - 7.6	5.4
Glycine	4.3	3.8
Alanine	4.3	4.5
Valine	4.9 - 5.7	5.2
Methionine	1.2	1.1
Isoleucine	4.9 - 5.1	5.8
Leucine	8.6 - 9.2	7.6
Tyrosine	3.2	3.2
Phenylalanine	4.8 - 5.8	4.8
Tryptophan	1.0	1.2

FIGURE 15 Animo acid composition of protein of winged bean as compared to soybean. Expressed as gm per 100 gm of protein. (Data from Cerny *et al*, 1971, and Kapsiotis, 1968.)

Like soybeans and most other legume seeds, the winged bean seed contains a trypsin inhibitor. This reduces the dietary effectiveness of the protein, but the inhibitor can be inactivated by moist-heat treatment (autoclaving for 10 minutes at 130° or by boiling for 30 minutes after soaking in water for 10 hours[13]).

The winged bean also contains a phytohemagglutinin,[14] but its nutritional significance is unknown. In many other beans, particularly those of the genus *Phaseolus*, phytohemagglutinins are definitely toxic and must be destroyed by heat if the beans are to be eaten without adverse effects. If the winged bean is similar, the phytohemagglutinins are apparently destroyed by cooking (Cerny *et al*).

Like soybeans, winged bean seeds are rich in oil (15-20 percent; see FIGURE 16). Of the fatty acids in the oil, 71 percent are unsaturated. If extracting the oil becomes commercially feasible, the residual meal should be an excellent protein source analogous to soybean meal.

The seeds are also rich in tocopherol—an antioxidant—that improves the utilization of vitamin A in the human body. This is important since vitamin A deficiency is common in many tropical countries.

[13]Sohonic *et al*, 1954. See Selected References.
[14]Renkonen, 1948. See Selected References.

Fatty acid	Winged bean	Soybean
	% by weight	
14:0 Myristic	0.06	–
16:0 Palmitic	8.9 - 9.7	11.0
16:1 Palmitoleic	0.83	–
18:0 Stearic	5.7 - 5.9	4.0
18:1 Oleic	32.3 - 39.0	25.0
18:2 Linoleic	27.2 - 27.8	50.0
18:3 Linolenic	1.1 - 2.0	–
18:4 Parinaric	2.5	–
20:0 Arachidic	2.0	0.4
22:0 Behenic	13.4 - 15.5	0.3

FIGURE 16 Fatty acid composition* of seed of winged bean and soybean. (Data from Cerny *et al*, 1971.)

Tuberous Roots

The winged bean's tuberous roots are rich in protein (12-15 percent wet weight, more than 20 percent on a dry weight basis; see FIGURE 12). An edible tropical root crop with such a high protein content could be of great value in helping to reduce protein malnutrition. This is especially important since the natural environment of the winged bean is the humid tropics, where inhabitants already live on root crops low in protein such as cassava, potatoes, yams, taro, and sweet potatoes, whose exclusive consumption leads to protein deficiency and kwashiorkor.

The winged bean tubers are eaten like potatoes–sometimes raw, but more frequently cooked. In Papua New Guinea, they are wrapped in banana leaves or in bamboo and cooked in a large earth-oven or in a fire. In Burma, the tubers are boiled until soft, then are peeled and eaten as a snack with a sauce made from vegetable oil and salt.

Despite the fact that they are eaten in several Asian countries, there is a scarcity of data regarding the nutritive properties of the tuber.

Leaves and Flowers

The leaves and flowers may be eaten either raw or cooked; the flowers are added to salads. In Burma, salads are made from leaves that have been boiled briefly; the leaves are also added to fish and prawn soups. In the highlands of Papua New Guinea, the flowers are fried in oil and have a taste suggestive of mushrooms.

Like all other parts of the plant, the foliage has a high protein content (5-15 percent; see FIGURE 12). The protein percentage of dry matter for the whole above-ground part of the plant is 25.6 percent (as against a figure, in the same experiments, of only 11.7 for *P. palustris*, which forms far fewer and smaller root nodules).[15] If this figure is confirmed as being a fair average, the leaves of the winged bean would have one of the highest protein contents of tropical forage legumes.

After harvesting the crop of pods, seeds, or tubers, the haulm can be fed to animals, who find it palatable (Burkhill).

[15] Masefield, 1961. See Selected References.

Chapter 4

Recommendations

The following recommendations outline a program for research and action that should help to determine conclusively the importance of the winged bean and the role it could play in combating malnutrition in the tropics. The recommendations provide scientific challenge to researchers in many fields of agriculture and food science in various parts of the world. They also provide challenge to the philanthropic institutions and international development agencies concerned with the growing problems of world food shortage and malnutrition.

Germ Plasm Collection

The panel recommends that a concerted effort be undertaken immediately to systematically collect, store, and replicate elite winged bean varieties available in Southeast Asia. A germ plasm collection is the first and most crucial need for rational and efficient agronomic development of the winged bean. Major emphasis should be given to strains found in Papua New Guinea, Indonesia, the Philippines, Malaysia, Thailand, and Burma. The collecting should be done by experienced agronomists; herbarium specimens should be prepared.

The collected seed should be stored in an institution such as the International Institute of Tropical Agriculture (IITA) in Nigeria, International Rice Research Institute (IRRI) in the Philippines, International Center for Tropical Agriculture (CIAT) in Colombia, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India, Asian Vegetable Research and Development Center (AVRDC) in Taiwan, Commonwealth Scientific and Industrial Research Organization in Austrailia, the U.S. Department of Agriculture, or other organizations equipped for safe, long-term seed storage.

The institution maintaining the seed bank should be prepared to grow promising varieties and to distribute seed to agronomists.

This project is commended to the attention of the United Nations Food and Agriculture Organization, the U.S. Agency for International Development, the International Development Research Centre of Canada, and those foundations that have supported tropical agronomic research.

Varietal Selection and Improvement

The panel recommends that four or five institutions, in various tropical localities (such as the University of Papua New Guinea, the International Center for Tropical Agriculture, the International Institute of Tropical Agriculture, and the Asian Vegetable Research and Development Center), maintain living collections and begin small-plot-trials and plant-improvement programs.

Researchers at these institutions should be given ready access to the germ plasm collection (see above) and should first develop tests to distinguish and select elite varieties. The selection and breeding programs in the several localities should focus on

- Increasing the yield of various parts of the plant, including pods, seeds, and tubers;
- Increasing the combined yield of both tubers and pods on the same plant;
- Increasing possibilities for large-scale commercial cultivation of dwarf and erect plants; and
- Increasing the resistance to diseases and pests.

For operational simplicity it would appear desirable that one or two research institutions assume leadership for the varietal selection and improvement, taking responsibility for stimulating initiatives, enlisting cooperation from other research institutions, and disbursing support funds.

Taxonomic Survey

The panel recommends that a monograph be prepared on the genus *Psophocarpus*. Taxonomists should collect and study specimens of *P. tetragonolobus* in Papua New Guinea and Southeast Asia, *P. palustris* in West Africa, and the other wild *Psophocarpus* species in West and East Africa.

It is basic to all plant improvement programs to know exactly the genetic materials involved and their interrelationships. The classification of species of *Psophocarpus* is still in a preliminary state, due primarily to lack of collection and study of specimens of wild and cultivated populations. Furthermore, relationships between *Psophocarpus* and other genera have not been evaluated. Morphological and cytological variation, pollen studies, and chemotaxonomical and anatomical data all need study. The results will provide a clear understanding of the limits of the genus, its species, subspecies, and varieties. These

studies are fundamental to experimental improvement programs because researchers would then have a common basis for identifying their genetic material. It also would lay the foundation for more academic determinations, such as center of origin of the winged bean and its area of maximum diversity.

Agronomic Research Needs

The panel recommends that agronomic research be initiated in the following areas where present lack of knowledge constitutes a serious barrier to the rational development of the winged bean:

- Nitrogen fixation (inoculation, organisms, amount of nitrogen fixed per acre, environmental factors, etc.).
- Nutritional quality of foliage, new shoots, tubers, seeds, and pods. Screening for desirable varieties.
- Oil content and composition of different varieties. Utilization of residual meal after oil extraction.
- Water requirements (irrigation, drought tolerance, etc.). Screening for desirable varieties.
- Photoperiodic pecularities. Extending its use to higher latitudes.
- Vegetative reproduction (including tissue culture).
- Tuber development. Screening for high-yielding, nutritious varieties.
- Diseases and pests. Screening for resistant varieties.
- Storage and loss of viability during storage.
- Cultivation methods.
- Testing its value as a green-fertilizer, forage, or as a cover-crop.

Moreover, investigations should be launched to compare the agronomic and nutritional characteristics of the winged bean with those of the other species in the genus *Psophocarpus*.

Nutritional Research Needs

The panel recommends that research be undertaken on the nutritional aspects of the winged bean.

More work on the nutritive effectiveness of the protein (PER and NPU) must be conducted on the mature beans, immature pods, and tubers. The winged bean is accepted as food where available, and there is no evidence of deleterious effects from its consumption. However, research is needed to determine levels of trypsin inhibitors and hemegglutinins and methods to

detoxify them. This is particularly important where the pods and tubers are eaten raw.

It is not yet known whether, like soybeans, winged beans cause flatulence. Research to determine this is needed.

Research should also be directed to identification of the amino acid compositions of leaves, pods, and tubers and to determination of amino acid composition differences between winged bean varieties for each portion of the plant. It is important as well to establish the ranges of lipid content of the seeds in different winged bean varieties.

Research is particularly needed on the extraction of oil and the use of the residual protein-rich seed meal in food. The preparation of a winged bean milk, curd, or gruel (particularly for the feeding of infants) should be examined (the seeds appear to be suitable for processing like soybeans, which can be used as a guide). Possibilities of fermenting winged bean seeds to products equivalent to the soybean-derived miso and tempeh should be investigated.

Sociological studies are required in those areas where winged beans are to be introduced. Social mores (particularly important in the feeding of weanling children) are as important as the availability of suitable products in determining dietary practices.

Cooking methods and the home economics of the winged bean (especially at the village level) call for investigation.

The panel wishes to draw the attention of the Protein-Calorie Advisory Group of the United Nations System, the League for International Food Education (Washington, D.C.), and other organizations to the nutritional aspects of the plant so that information can be disseminated to the research community.

Newsletter

The panel recommends that a research center actively engaged in winged bean research undertake to publish an informal newsletter that will provide the interested research community with continuous information.

Future research on the winged bean may well be conducted in a variety of research stations and laboratories around the world. It will involve subjects as diverse as biochemistry, plant selection, soil science, and agricultural engineering and extension. The rapid exchange and dissemination of information and research results, necessary for the effective development of the plant into a crop, can best be achieved by an informal newsletter.

The newsletter might include

- Information on seeds available for dissemination;

- Short reports of observations (of the type insufficient for formal publication);
- Preliminary experimental data;
- Reprints or abstracts of newly published papers; and
- Opinion letters.

A Grower's Handbook

A step-by-step practical guide would be valuable to introduce the winged bean to uninitiated researchers in the new areas. It would save much wasted effort and prevent false conclusions brought on by ignorance of cultural methods. The panel recommends that an institution experienced in winged bean cultivation undertake to produce a brief pamphlet providing guidance on planting, culturing, harvesting, and processing winged beans for distribution to researchers obtaining seeds from the germ plasm bank.

Appendix A

Researchers Working with the Winged Bean

The following researchers are working with the winged bean (some in just a minor way) and they may be able to supply readers with seeds and advice.

J. BOHN, Department of Agriculture, Stock and Fisheries, Mt. Hagen, W.H.D., Papua New Guinea (Agronomy)

H.H. BRYAN, Agricultural Research and Education Center, University of Florida, 18905 S.W. 280th Street, Homestead, Florida 33030, U.S.A. (Horticulture)

BUNJIRD KHATIKARN, Dean, Graduate School, Kasetsart University, Bangkok, Thailand (Horticulture)

K. CERNY, Postgraduate Medical School, Ruská 85, Prague 10, Czechoslovakia (Nutritive value)

A. CHARLES, Department of Agriculture, Stock and Fisheries, Konedobu, Papua New Guinea (Agronomy)

Y. H. CHEONG, Head, Division of Nutrition, Institute of Medical Research, Kuala Lumpur, Malaysia (Composition)

A. CLAYDON, Department of Chemistry, University of Papua New Guinea, Port Moresby, Papua New Guinea (Composition)

R. ELMES, Department of Agriculture, Stock and Fisheries, Konedobu, Papua New Guinea (Soil microbiology)

T. HYMOWITZ, Department of Agronomy, University of Illinois, Urbana, Illinois 61801, USA (Agronomy)

W. G. JAFFE, Instituto Nacional de Nutrición, Carmen a Ptc Arauca, Caracas, Venezuela (Nutritive value)

S. K. KARIKARI, Agricultural Research Station, University of Ghana, Kade, Ghana (Agronomy)

T. N. KHAN, Department of Agriculture, University of Papua New Guinea, Port Moresby, Papua New Guinea (Agronomy and genetics)

R. KORTE, Department of Public Health, Konedobu, Papua New Guinea (Nutritive value)

G. B. MASEFIELD, Department of Agricultural Science, Oxford University, Oxford OXI 3PF, England (Agronomy)

J. POWELL, Department of Ethnobotany, University of Papua New Guinea, Port Moresby, Papua New Guinea (Ethnobotany)

K. O. RACHIE, International Institute of Tropical Agriculture, P.M.B. 5320, Ibadan, Nigeria (Agronomy)

S. SASTRAPRADA, Director, Lembaga Biology National, Bogor, Indonesia (Agronomy)

D. E. SHAW, Department of Agriculture, Stock and Fisheries, Konedobu, Papua New Guinea (Pest control)

A. STRATHERN, Department of Anthropology and Sociology, University of Papua New Guinea, Port Moresby, Papua New Guinea (Ethnobotany)

WONG KAI CHOO, Agriculture Faculty, University of Malaysia, Kuala Lumpur, Malaysia (Genetics)

Appendix B

Selected References

Anonymous. 1961. Edible African legumes. *Field Crop Abstracts*. 14:161.

Agcaolili, F. 1929. Seguidillas bean. *Philippine Journal of Science*. 40(4):513-4.

Aykroyd, W. R., and J. Doughty. 1964. Legumes in human nutrition. *FAO Nutritional Studies No. 19*. FAO, Rome.

Bailey, K. V. 1968. Composition of New Guinea highland foods. *Tropical Geography Medicine*. 20(2):141-6.

Barrau, J. 1958. *A Reconnaissance Survey in the Field of Economic Botany in Western Melanesia*. South Pacific Commission, Noumea, New Caledonia.

Brown, W. H. 1954. Useful plants of the Philippines. Vol. 2, *Technical Bulletin No. 10*. Bureau of Prints, Manila, Philippines.

Burkill, I. H. 1906. Goa beans in India. *Agricultural Ledger*. 4:51.

Cerny, K., and H. A. Adndy. 1973. The winged bean (*Psophocarpus palustris* Desv.) in the treatment of kwashiorkor. *British Journal of Nutrition*. 29:105-7.

Cerny, K., M. Kordylas, F. Pospisil, O. Svabensky, and B. Zajic. 1971. Nutritive value of the winged bean (*Psophocarpus palustris* Desv.). *British Journal of Nutrition*. 26:293-9. [Although entitled *P. palustris*, the authors have pointed out in a later paper that the species tested was in fact *P. tetragonolobus*.]

Claydon, A. 1974. Personal communication to the panel.

Crevost, C., and C. Lemarié. 1921. Catalogue des produits de l'Indochine. *Bulletin economique de l'Indonchine*. 23:121.

FAO. 1959. Tabulated information on tropical and subtropical grain legumes. Rome.

Gibberd, A. V., and V. L. Gibberd. 1953. *A Gardening Note Book for the Tropics*. Longmans, Green and Co, Ltd., London.

Herklots, G. A. C. 1972. *Vegetables in South East Asia*. George Allen and Unwin Ltd., London.

Hipsley, E. H., and F. W. Clements. 1947. *Report of the New Guinea Nutrition Survey Expedition, 1947*. Department Exterior Territory, Canberra, Australia.

IITA. 1971-74. *Grain Legume Improvement:* 1971, 1972, and 1973 reports. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Jaffe, W. G. 1969. Hemagglutinins. In *Toxic Constituents of Plant Foodstuffs*, ed. I. E. Liener. Academic Press, New York. pp. 69-94.

Kapoor, V. P., R. N. Raina, Saminddin, R. S. Tripathi, P. S. H. Khan, and M. I. Farooqi. 1972. Chemical analysis of seeds from sixty leguminous species. *Science and Culture*. 37:349.

Kapsiotis, G. D. 1968. *Chemical Analysis on Winged Beans*. FAO, Rome.

Karikari, S. K. 1969. Winged bean (*Psophocarpus tetragonolobus*) as a fallow crop in cocoyams. *Annual Report, University of Ghana*. Agriculture Research Station, Kade, Ghana.

Karikari, S. K. 1972. Pollination requirements of winged beans (*Psophocarpus* spp. Neck) in Ghana. *Ghana Journal of Agriculture Science.* 5(3):235-9.

Khan, T. N. 1973. A preliminary report of a trip to Mt. Hagen and Goroka to collect wing bean samples. Unpublished report of the Faculty of Agriculture, University of Papua New Guinea.

Khan, T. N. 1974. Problems and progress in improvement of wing beans in Papua New Guinea. Unpublished report on the winged bean.

Khan, T. N., W. Erskine, P. J. Keane, and K. P. Lamb. 1974. Improvement of beans, cowpeas, and wing beans. *Science in New Guinea.* 2:90-6.

Liener, I. E., ed. 1969. *Toxic Constituents of Plant Foodstuffs.* Academic Press, New York.

Liener, I. E. 1972. Nutritional value of food protein products. In *Soybeans: Chemistry and Technology*. eds. A. K. Smith and S. J. Circle. Avi Publishing Co., Westport, Connecticut. pp. 203-77.

MacMillan, H. F. 1948. *Tropical Planting and Gardening.* 5th ed. Macmillan, London.

Masefield, G. B. 1952. The nodulation of annual legumes in England and Nigeria: Preliminary observations. *Empire Journal of Experimental Agriculture.* 20:175.

Masefield, G. B. 1957. The nodulation of annual legumes in Malaya. *Empire Journal of Experimental Agriculture.* 25:139.

Masefield, G. B. 1961. Root nodulation and agricultural potential of the leguminous genus *Psophocarpus. Tropical Agriculture, Trinidad.* 38:225.

Masefield, G. B. 1973. *Psophocarpus tetragonolobus*, a crop with a future? *Field Crop Abstracts.* 26(4):157-60.

Milsum, J. N., and D. H. Grist. 1941. *Vegetable Gardening in Malaya.* Agriculture Department of the Strait Settlements and Federated Malay States, Kuala Lumpur.

Paul, W. R. C. 1953. Notes on legumes 3. *Tropical Agriculturist.* 109:27.

Pellegrin, R. 1949. *The Leguminosae of Gabon.* Mem. No. 1 de l'Institut d'Études Centrafricaines, Librarie Larousse. Paris.

Platt, B. S. 1962. *Tables of Representative Values of Foods Commonly Used in Tropical Countries.* Her Majesty's Stationery Office, London.

Platt, B. S. 1971. Tables of representative values of foods commonly used in tropical countries. *Medical Research Council, Sp. Rep. Series No. 302.* Her Majesty's Stationery Office, London.

Pospisil, F., S. K. Karikari, and E. Boamah-Mensah. 1971. Investigations of winged bean in Ghana. *World Crops.* 23(5):260-4.

Purseglove, J. W. 1968. *Tropical Crops: Dicotyledons I.* John Wiley and Sons, Inc., New York.

Rachie, K. O. 1974. Observations on winged bean at the International Institute of Tropical Agriculture. Unpublished notes.

Ramirez, D. A. 1960. Cytology of Philippine plants. V. *Psophocarpus tetragonolobus* (Linn.) D. C. *Philippine Agriculturist.* 43:533.

Renkonen, D. O. 1948. Studies on hemagglutinins present in seeds of some representatives of the family of Legunimoseae. *Annales Medicinae Experimentalis et Biologiae Fenniae.* 26:66-72.

Sohonie, K., and A. P. Bhandarkar. 1954. Trypsin inhibitors in Indian foodstuffs. II Inhibitors in vegetables. *Journal of Scientific and Industrial Research (India).* 13B:500-3.

Thomas, A. 1965. *Gardening in Hot Countries.* Faber and Faber, London.

Thompstone, E., and A. M. Sawyer. 1914. The peas and beans of Burma. *Agricultural Department of Burma Bulletin No. 12.*

Tindall, H. D. 1968. *Commercial Vegetable Growing.* Oxford University Press, London.

Watson, J. D. 1971. Nutritive value of some Ghanian root crops. *Ghana Journal of Agricultural Science.* 4:95-111.

Yepes, S., F. M. Alfonso, and F. Funes. 1971. An introduction to the study of the seedlings of legumes. *Ingenieria Agronomica.* 1 (b). Ciencias Agropecuarias Universidad de la Habana.

Resumen

Las legumbres comestibles constituyen una fuente excelente de proteínas y aceites de la dieta. Muchos expertos en nutrición esperan que estos desempeñen un papel cada vez más importante para satisfacer las necesidades de la alimentación en esta época de escasez de alimentos y malnutrición generalizada. Además de las principales legumbres comestibles que se cultivan—frijol de soya, maní (cacahuete), guisantes y habas—existen más de cincuenta legumbres[1] tropicales que han recibido menos atención en el campo científico (principalmente debido a que los investigadores han concentrado su atención en las cosechas de especies más convencionales, en especial los cereales). Este informe está enfocado en la promesa excepcional que uno de estos ofrece: el frijol alado (también llamado frisol de Goa), *Psophocarpus tetragonolobus* (L.) DC.

Después de considerar toda la información disponible, el grupo de expertos está convencido de que si se hicieran las investigaciones del caso, el frijol alado podrá constituirse en un producto alimenticio de importancia en la región tropical húmeda y recomienda que se inicie un desarrollo en gran escala para probarlo en nuevas áreas y ampliar el conocimiento ya obtenido que permitirá que se le cultive de manera más eficiente.

Pocos son los estudios que se han realizado sobre el frijol alado y de ahí que la información sea tan limitada. En Papua Nueva Guinea y en el Sudeste de Asia se cultiva en la actualidad solo para el consumo de la familia. Pero estas regiones son típicas de la zona tropical húmeda que abarca grandes zonas en Centroamérica, Sudamérica, el Caribe, Africa, Oceanía y Asia Occidental, donde la deficiencia proteínica es alta y aún no se conoce la planta. No es muy conocido que un producto comestible con tan alto contenido de proteína puede cultivarse en esta región y parece tener muy buenas posibilidades de reducir el problema de la malnutrición proteica en toda la región tropical húmeda.

Aún no se han reconocido las posibilidades que tiene el frijol alado como complemento de la dieta humana. Esta es una legumbre excepcional; las vainas verdes, hojas y semillas son ricas en aceite, proteína y vitaminas, y las raíces tuberosas—entre los tubérculos—son extremadamente ricas en proteína.

[1] Para ejemplos véase la lista de Aykroyd y Doughty. Véase asimismo las referencias escogidas.

La planta del frijol alado crece vigorosamente, parece tener más nódulos para la fijación del nitrógeno por planta que otras legumbres comestibles y su extenso sistema de raíces contiene nódulos excepcionalmente grandes. El nitrógeno de la atmósfera se fija por bacteria en el nódulo y luego pasa a formar parte de la planta principalmente como proteína. Por cuanto el nitrógeno es un elemento clave en la síntesis de la proteína el crecido número de nódulos podrá ser la razón de que el frijol alado tenga tan alto contenido de proteína.

Las vainas inmaduras pueden comerse crudas. Su gusto es sumamente aceptable al paladar, saben a habichuelas y al parecer son aceptadas con facilidad, aun por aquellas personas que nunca antes la hayan comido. Las semillas del frijol alado son parecidas a las del frijol de soya en cuanto a composición. Su promedio de contenido proteínico es alrededor de 34% (basado en peso seco) y 17% de aceite. Se han encontrado semillas individuales hasta con un 33% de contenido proteínico y 20% de aceite. La calidad nutritiva de la proteína parece compararse con la del frijol de soya en su facilidad de ser digerida y su composición (contiene igual cantidad de lisina, metionina y cistina). El aceite tiene un contenido relativamente alto de ácidos grasos no saturados y una proporción favorable de ácidos grasos esenciales no polisaturados. Las semillas del frijol alado, así como las del frijol de soya, contienen compuestos que interfieren con la digestión de las proteínas–inhibidores de la tripsina y la hemaglutinina–pero durante la cocción estos pueden destruirse satisfactoriamente.

Las raíces tuberosas que son levemente dulces contienen un 20% de proteínas (peso seco). Esto es mucho más elevado que el contenido proteínico de otras raíces y tubérculos comestibles tales como la manioca (casabe), papas, camote o papa dulce. La planta crece en regiones donde los habitantes dependen del cultivo de estos productos de bajo contenido proteínico. Aún no se ha informado acerca de efectos adversos producidos por la raíz del frijol alado en los alimentos.

Si bien el frijol alado es oriundo de la zona tropical húmeda, este responde favorablemente a la irrigación y, por lo tanto, se puede cultivar en regiones más secas. El frijol alado puede tolerar un amplio rango de alturas, lo que es una característica no común de las plantas tropicales que se cultivan. Este se puede cultivar desde el nivel del mar hasta una altura de 2,000 metros (7,000 pies) en Papua Nueva Guinea. A juzgar por experimentos independientes en pequeña escala en Papua Nueva Guinea, Ghana y Nigeria[2] es evidente que el frijol alado produce tantas semillas como las de otras legumbres. Los experimentos realizados revelan que es posible obtener 2,000 kilogramos de semilla por hectárea.[3] Al parecer existe la posibilidad de poder incrementar la pro-

[2] En los experimentos llevados a cabo en la Universidad de Ghana, y en el Instituto Internacional de Agricultura Tropical en Nigeria, se usaron semillas originalmente importadas de Nueva Guinea.

[3] K.O. Rachie. Comunicación personal al grupo.

ducción de la semilla mediante investigación adicional; aún no se ha hecho ninguna selección genética y poco se ha realizado en cuanto a los mejores métodos de cultivo.

A menudo los suelos tropicales son de bajo contenido de nitrógeno, pero el frijol alado puede crecer en suelos pobres y por ende reflejar, tal vez, la capacidad de fijar nitrógeno del aire. Normalmente el frijol alado no necesita ser inyectado con bacteria fijadora de nitrógeno para crecer vigorosamente. Las semillas pueden sembrarse aun en terreno recién talado lo que representa una gran ventaja sobre muchas legumbres tropicales que necesitan inoculación cuando las cepas bacterianas no se hallan en el suelo.

El frijol alado podría ser un buen producto restaurador, que podría llenar los requisitos del agricultor minorista de los trópicos. Este es un producto constante, de crecimiento rápido que enriquece el suelo con nitrógeno, en especial si se mezcla con la tierra para usarlo como fertilizante.

En cuanto a las variedades del frijol alado se sabe muy poco. Todavía hay que recolectar información para establecerlas en viveros para el debido crecimiento de la planta.

Es menester apoyar con estacas las variedades conocidas del frijol alado si se espera que estas den un alto rendimiento de vainas y semillas. Por cuanto este sistema agrícola no se presta para la producción en masa, y debido a que no todas las vainas del frijol alado maduran a la vez, no parece que esta planta se convertirá en un rival del frijol de soya en un futuro cercano como producto comercial en gran escala. Sus posibilidades estriban como producto de subsistencia, o solvente, en los mercados pequeños. Cuando se cultive en escala limitada no es necesario apoyarlo en estacas y el hecho de que las vainas comestibles están disponibles durante muchos meses es una ventaja decidida.

La mayoría de las legumbres silvestres (como son el frijol de soya, habas) tienen hábitos de crecimiento parecidos a los del frijol alado, pero se han escogido variedades con características propicias para el cultivo en gran escala. Existe una necesidad apremiante de hallar y desarrollar variedades parecidas entre el frijol alado.

Lo que se sabe hoy acerca del frijol alado es aproximadamente igual a lo que se sabía en cuanto al frijol de soya hace 60 años, poco después de su introducción en los Estados Unidos. Es posible que en el futuro el frijol alado llegue a cobrar tanta importancia en el mundo agrícola.

Al frijol alado se le pueden aplicar muchas de las mejoras genéticas del frijol de soya. Asimismo las técnicas para producir harina de frijol del soya para hornear se pueden aplicar al frijol alado, y los concentrados de proteínas y aislados para uso en alimentos se podrían aplicar a la elaboración del frijol alado.

El frijol alado ofrece varias ventajas nutricionales sobre el frijol de soya. Todas las partes de la planta son comestibles: raíces, semillas, hojas, flores y retoños. En el caso del frijol de soya se usa solo la semilla. Al parecer, el sabor

amargo y a frijol de muchos productos del frijol de soya no se encuentran en el frijol alado, lo cual deberá promover su introducción generalizada en la dieta humana.

Debido a las cualidades excepcionales del frijol alado, el grupo de expertos opina que la planta debe investigarse en forma intensiva y probada en estaciones de experimentación en distintas regiones de los trópicos. Pero, llevar esto a cabo en forma fragmentada no surtirá el mismo efecto como si se hiciera un esfuerzo coordinado para distribuir las semillas y luego recolectar, compaginar y comparar los resultados.

Los gobiernos locales podrán realizar una buena parte de dichos estudios, pero no así con la coordinación. Para que esto se efectúe será necesario contar con un mecanismo internacional. En el Capítulo 4 se ofrecen algunas posibilidades así como un programa donde se detallan estrategias de investigación para promover la mejor comprensión del frijol alado. Esto se ha hecho con la intención de que se constituya en una guía para los agrónomos, botánicos y nutriólogos así como para fundaciones y organismos que financian actividades de desarrollo económico.

Résumé

Les légumineuses comestibles sont d'excellentes sources de protéines et d'huiles alimentaires. De nombreux diététiciens pensent qu'elles auront à jouer un rôle de plus en plus important dans le combat mené pour satisfaire les besoins alimentaires en ce temps de pénurie et de malnutrition à l'échelle mondiale. Outre les principales légumineuses comestibles cultivées : soja, arachides, pois et haricots, il existe plus de cinquante légumineuses tropicales[1] de moindre importance qui n'ont fait l'objet que d'une recherche scientifique limitée–surtout parce que les chercheurs ont consacré leurs efforts aux espèces cultivées plus classiques, en particulier les céréales. Ce rapport met l'accent sur l'une de ces légumineuses : le haricot ailé (aussi connue comme pois carré ou haricot de la forêt), *Psophocarpus tetragonolobus* (L.) D.C., que est particulièrement prometteuse.

Après avoir étudié tous les renseignements disponibles, le groupe de travail est persuadé *qu'au prix d'une certaine recherche le haricot ailé pourrait représenter une culture vivrière importante dans les zones tropicales humides et il recommande qu'un gros effort soit fait pour le mettre à l'essai dans de nouvelles régions et qu'on élargisse les connaissances fondamentales qui permettraient son exploitation optimale.*

On ne dispose que de peu de renseignements sur le haricot ailé puisqu'il n'a fait l'objet que d'études limitées. Actuellement, il n'est cultivé que dans les jardins potagers familiaux de Papua Nouvelle Guinée et dans le Sud-Est asiatique. Ces régions sont typiques de la zone tropicale humide que l'on retrouve en Amérique centrale, en Amérique du Sud, aux Antilles, en Afrique, en Océanie et en Asie occidentale où le manque de protéines est élevé et où cette légumineuse est encore inconnue. Qu'une culture vivrière possédant une si haute teneur en protéines puisse réussir dans cette région est inhabituel et il semble qu'elle présente de grandes possibilités pour la solution du problème des carences protéiques dans l'ensemble des régions tropicales humides.

Les possibilités du haricot ailé comme apport au régime alimentaire humain n'ont pas encore été reconnues. C'est, cependant, une légumineuse exceptionnelle : les gousses vertes, les feuilles et les graines sont riches en huile,

[1] Cf. liste d'Aykroyd and Doughty. Voir les références choisies.

en protéines et en vitamines. De leur côté les tubercules, par rapport à tous ceux qui sont cultivés, sont particulièrement riches en protéines.

Le haricot ailé pousse vigoureusement et semble avoir plus de nodosités fixant l'azote qu'aucune autre légumineuse. Son système radiculaire étendu porte des nodosités exceptionnellement grandes. L'azote de l'air, fixé par un microbe dans les nodosités, se trouve incorporé à la plante principalement sous forme de protéines. Puisque l'azote est un élément clé de la synthèse des protéines, la formation nodulaire supérieure du haricot ailé peut en expliquer la teneur exceptionnelle.

Les gousses qui ne sont pas encore mûres peuvent être mangées crues. Elles sont très appétissantes, ont le même goût que les haricots verts et sont tout de suite acceptées, même par ceux qui n'en ont jamais mangé. Les graines ont une composition similaire à celle du soja. Leur teneur moyenne en protéines est de 34 pour cent (poids sec) et celle en huile est de 17 pour cent. On a trouvé des graines dont les teneurs en protéines et en huile étaient respectivement de 37 et 20 pour cent. La qualité nutritive des protéines semble comparable à celle du soja, de même que la digestibilité et la composition–même proportion de lysine, de méthionine et de cystine. L'huile a une teneur relativement élevée en acides gras non saturés et une proportion satisfaisante de polyacides gras essentiels non saturés. Comme pour le soja, les graines du haricot ailé contiennent des composés qui entravent la digestion des protéines–inhibiteurs de la trypsine et agglutinines des hématies–toutefois, ils peuvent être détruits de façon satisfaisante par la cuisson.

Les racines tubéreuses, légèrement sucrées, contiennent 20 pour cent de protéines (poids sec). Cette teneur est beaucoup plus élevée que celle des autres tubercules comestibles comme le manioc, la pomme de terre, la patate douce ou l'igname. Cette plante pousse dans des régions où l'alimentation des habitants dépend actuellement de ces récoltes de tubercules à faible teneur en protéines. On n'a signalé aucune contre indication à l'emploi de tubercules du haricot ailé dans l'alimentation.

Quoique le haricot ailé soit natif des zones tropicales humides, il répond favorablement à l'irrigation et peut être ainsi cultivé dans des régions plus sèches. Il présente la possibilité de croître à des altitudes variées, caractéristique inhabituelle pour les végétaux tropicaux cultivés. En Papua Nouvelle Guinée, son aire de dispersion s'étend du niveau de la mer jusqu'à 2.000 mètres. Des essais individuels à petite échelle faits dans ce pays de même qu'au Ghana et au Nigéria[2] ont mis en évidence le fait que le haricot ailé peut donner des récoltes de graines comparables à celles des autres légumineuses. Des essais expérimentaux donnent à penser que des récoltes de deux tonnes à

[2]Ce sont des graines importées à l'origine de Nouvelle Guinée qui ont servi aux expériences conduites à l'Université du Ghana et à l'Institut International pour l'Agriculture Tropicale au Nigéria (IITA).

l'hectare sont dans le domaine des possibilités.[3] Il paraît vraisemblable qu'un rendement plus important pourrait être obtenu grâce à une recherche supplémentaire. Jusqu'à présent aucune sélection génétique n'a été effectuée et on n'a entrepris que peu de recherches sur les méthodes de cultures les plus appropriées.

On sait que les sols tropicaux sont souvent pauvres en azote, cependant le haricot ailé peut pousser dans un sol pauvre, ce qui reflète peut-être sa capacité à fixer l'azote atmosphérique. Il n'est pas nécessaire en général de lui inoculer le microbe fixateur d'azote pour qu'il pousse vigoureusement. Ses graines peuvent être plantées directement dans un sol qui vient d'être défriché. Ceci représente un avantage considérable par rapport à de nombreuses légumineuses tropicales qui doivent être inoculées quand leurs lignées microbiennes font défaut dans le sol.

Le haricot ailé pourrait constituer une bonne culture améliorante qui permettrait de satisfaire les besoins des petites exploitations agricoles sous les tropiques. C'est une plante vivace à croissance rapide et à bonnes nodosités, qui enrichit le sol en azote, particulièrement s'il est biné.

On ne connaît presque rien de certaines variétés du haricot ailé qui sont encore à recueillir et à acclimater dans des pépinières pour obtenir un développement normal de la plante.

Quant aux variétés connues, elles doivent être ramées pour produire un rendement élevé en gousses et en graines. Parce que cette méthode de culture ne se prête pas à une exploitation à grande échelle et aussi parce que les fruits ne mûrissent pas tous en même temps, il est douteux que cette légumineuse puisse rivaliser dans un proche avenir avec le soja pour une exploitation commerciale de grande envergure. Ses possibilités résident plutôt dans une culture de subsistance, ou culture marchande, pour les petits marchés. Le grand avantage du haricot ailé est qu'il n'est pas nécessaire de le ramer pour une production à moindre échelle et que ses gousses comestibles peuvent être récoltées pendant une période s'étendant sur plusieurs mois.

L'habitus de croissance du haricot ailé est semblable à celui de la plupart des légumineuses sauvages: soja, haricot de Lima, par exemple, dont on a sélectionné des variétés ayant des caractéristiques se prêtant à une culture intensive. Il est urgent de découvrir et d'acclimater des variétés similaires du haricot ailé.

Ce que l'on sait aujourd'hui du haricot ailé est sensiblement l'équivalent de nos connaissances sur le soja peu après son introduction aux Etats-Unis, il y a soixante ans. On pense que le haricot ailé pourrait représenter un atout important pour l'agriculture mondiale dans l'avenir.

Les grands progrès faits dans l'amélioration génétique du soja pourraient être appliqués au haricot ailé; tout autant, les techniques de production de

[3] K.O. Rachie: communication personnelle au groupe de travail.

farine panifiable, d'extraits et de concentrés de protéines pour l'alimentation pourraient servir à son traitement.

Par rapport au soja, le haricot ailé présente plusieurs avantages diététiques. En effet, toutes les parties de la plante sont comestibles: racines, graines, feuilles, fleurs et pousses. Dans le soja on n'utilise que les graines. Le goût de haricot, à saveur amère de nombreux produits tirés du soja, semble absent dans le haricot ailé, ce qui devrait encourager son introduction largement répandue dans l'alimentation humaine.

En raison de ses qualités exceptionnelles, le groupe de travail pense que cette plante mérite d'être étudiée et expérimentée très sérieusement dans des centres agronomiques de diverses régions tropicales. Des efforts dispersés n'auraient pas l'efficacité d'un programme cohérent qui pourrait être établi pour répartir les graines, recueillir, collationner et comparer les résultats.

La majorité des essais peuvent être effectués par les collectivités locales, mais ces dernières ne peuvent pas assumer les fonctions de coordination. A cet effet, il faudrait une espèce de mécanisme international. Quelques possibilités sont énumérées au chapitre 4, de même qu'un programme donnant le détail des démarches nécessaires pour encourager une meilleure connaissance du haricot ailé. Ceci constitue un guide pour les ingénieurs agronomes, les botanistes et les diététiciens tout autant que pour les fondations et les institutions qui financent les activités dans le domaine du développement économique.

Board of Science and Technology for International Development
Commission on International Relations
National Academy of Sciences—National Research Council
2101 Constitution Avenue, Washington, D.C. 20418, USA

Advisory Studies and Special Reports

Published

1. **East Pakistan Land and Water Development as Related to Agriculture.** January 1971. 67 p. (out of print) Reviews World Bank proposed action program in land and water management. NTIS Accession No. PB 203-328. $4.25.
2. **The International Development Institute.** July 1971. 57 p. Endorses concept of new science-based technical assistance agency as successor to AID; examines its character, purposes, and functions.
3. **Solar Energy in Developing Countries: Perspectives and Prospects.** March 1972. 49 p. (out of print) Assesses state of art, identifies promising areas for R & D, and proposes multipurpose regional energy research institute for developing world. NTIS Accession No. PB 208-550. $4.25.
4. **Scientific and Technical Information for Developing Countries.** April 1972. 80 p. (out of print) Examines problem of developing world's access to scientific and technical information sources, provides rationale for assistance in this field, and suggests programs for strengthening information infrastructure and promoting information transfer. NTIS Accession No. PB 210-107. $4.75.
6. **Research Management and Technical Entrepreneurship: A U.S. Role in Improving Skills in Developing Countries.** 1973. 40 p. Recommends initiation of a systematic program and indicates priority elements.
7. **U.S. International Firms and R, D & E in Developing Countries.** 1973. 92 p. Discusses aims and interests of international firms and developing-country hosts and suggests that differences could be mitigated by sustained efforts by the firms to strengthen local R, D & E capabilities.
8. **Ferrocement: Applications in Developing Countries.** 1973. 89 p. Assesses state of the art and cites application of particular interest to developing countries—boat-building, construction, food- and water-storage facilities, etc.
9. **Mosquito Control: Some Perspectives for Developing Countries.** 1973. 63 p. Examines biological-control alternatives to conventional pesticides; evaluates state of knowledge and research potential of several approaches.
10. **Food Science in Developing Countries: A Selection of Unsolved Problems.** 1974. 81 p. Describes 42 unsolved technical problems with background information, possible approaches to a solution, and information sources.
11. **Aquatic Weed Management: Some Perspectives for Guyana.** 1973. 44 p. Report of workshop with the National Science Research Council of Guyana describes new methods of aquatic weed control suitable for tropical developing countries.
12. **Roofing in Developing Countries: Research for New Technologies.** 1974. 74 p. Emphasizes the need for research on low cost roofs, particularly using materials available in developing countries.
13. **Meeting the Challenge of Industrialization: A Feasibility Study for an International Industrialization Institute.** 1973. 133 p. Advances concept of an independent, interdisciplinary research institute to illuminate new policy options confronting all nations.

14. **More Water for Arid Lands: Promising Technologies and Research Opportunities.** 1974. 153 p. Outlines little-known but promising technologies to supply and conserve water in arid areas.
15. **International Development Programs of the Office of the Foreign Secretary,** by Harrison Brown and Theresa Tellez. 1973. 68 p. History and analysis, 1963-1972; lists staff/participants and publications.
16. **Underexploited Tropical Plants with Promising Economic Value.** 1975. Describes 36 little-known tropical plants that, with research, could become important cash and food crops in the future. Includes cereals, roots and tubers, vegetables, fruits, oilseeds, forage plants, etc.
17. **The Winged Bean: A High Protein Crop for the Tropics.** 1975.

In Preparation (Working Titles)

5. The Role of U.S. Engineering Schools in Foreign Assistance Activities.
18. Alternative Energy Sources for Developing Countries.
19. Methane Generation from Human, Animal, and Agricultural Wastes.
20. Systems Analysis and Operations Research: A Tool for Policy and Program Planning.
21. The Control of Aquatic Weeds: Some Lesser-Known Approaches.

Related Publications

Other reports (prepared in cooperation with BOSTID) available from the above address are:

An International Centre for Manatee Research. 1975. 34 p. Describes the use of the manatee, a large, almost extinct, marine mammal, to clear aquatic weeds from canals. Proposes a research laboratory to develop manatee reproduction and husbandry. Published by the National Science Research Council of Guyana.

Products from Jojoba; a Promising New Crop for Arid Lands. 1975. 30p. Describes the chemistry of the oil obtained from the North American desert shrub *Simmondsia chinensis.*

Published reports (unless out of print) are available free on request from the Board on Science and Technology for International Development. BOSTID will fill requests for reports in preparation upon publication. **Out-of-print reports** are available from the National Technical Information Service. To order, send report title, NTIS Accession Number, and amount indicated. Pay by NTIS Deposit Account, check, or money order. U.S. orders without prepayment are billed within 15 days; a 50¢ charge is added. Foreign buyers must enclose payment plus U.S. $2.50 handling charge per item. Send order to

National Technical Information Service
Springfield, Virgina 22161, U.S.A.

ADVISORY COMMITTEE ON TECHNOLOGY INNOVATION

Members

GEORGE BUGLIARELLO, President, Polytechnic Institute of New York, Brooklyn, New York, *Chairman*
E. R. PARISER, Senior Research Scientist, Department of Nutrition and Food Science, Massachusetts Institute of Technology, Cambridge, Massachusetts
LEWIS PERINBAM, Vice President, Canadian International Development Agency, Ottawa, Canada
CHARLES A. ROSEN, Staff Scientist, Stanford Research Institute, Menlo Park, California
VIRGINIA WALBOT, Department of Biology, Washington University, St. Louis, Missouri

BOARD ON SCIENCE AND TECHNOLOGY FOR INTERNATIONAL DEVELOPMENT

Members

CARL DJERASSI, Department of Chemistry, Stanford University, Stanford, California, *Chairman*
GEORGE S. HAMMOND, Foreign Secretary, National Academy of Sciences, *Ex Officio*
RUTH ADAMS, Executive Associate, American Academy of Arts and Sciences, Boston, Massachusetts
JOHN D. BALDESCHWIELER, Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, California
JACK N. BEHRMAN, Professor of International Business, School of Business Administration, University of North Carolina, Chapel Hill, North Carolina
IVAN L. BENNETT, JR., Dean, School of Medicine, New York University Medical Center, New York, New York
LESTER R. BROWN, President, Worldwatch Institute, Washington, D.C.
GEORGE BUGLIARELLO, President, Polytechnic Institute of New York, Brooklyn, New York
CHARLES DENNISON, International Consultant, New York, New York
WILLIAM R. HEWLETT, President and Chief Executive Officer, Hewlett-Packard Company, Palo Alto, California
WILLIAM A. W. KREBS, Vice President, Arthur D. Little, Inc., Cambridge, Massachusetts
FRANKLIN A. LONG, Program on Science, Technology, and Society, Cornell University, Ithaca, New York
JOSEPH PETTIT, President, Georgia Institute of Technology, Atlanta, Georgia
JOSEPH B. PLATT, President, Harvey Mudd College, Claremont, California
HELEN RANNEY, Chairman, Department of Medicine, University Hospital, San Diego, California
ROBERT M. WALKER, McDonnell Professor of Physics, Director, Laboratory of Space Physics, Washington University, St. Louis, Missouri
STERLING WORTMAN, Vice President, Rockefeller Foundation, New York, New York

Staff

VICTOR RABINOWITCH, Director

Order Form

Please indicate on the labels below the names of colleagues, institutions, libraries, etc., that might be interested in receiving a copy of The Winged Bean: A High-Protein Crop for the Tropics.

Please return this form to

Commission on International Relations (JH 215)
National Academy of Sciences
2101 Constitution Avenue N.W.
Washington, D.C. 20418 USA

17	17
17	17
17	