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9. ABSTRACT

A research report on the Asian Vegetable Research and Development Center's second year of operation. Significant achievements were made in the cultivation of the Center's six crops (soybenas, mungbeans, tomatoes, Chinese cabbages, sweet potatoes, and white potatoes) and are discussed in detail here. This research focused on increased yields, development of superior varieties, and better methods of crop management. This was done by screening cultivars gathered from genetic resources to identify those resistant to insect and disease attack and those with wide adaptability and superior yielding ability. The individual cultivars selected then were utilized as parents in an intensive breeding program seeking to combined in new varieties the best qualities derived from many sources.

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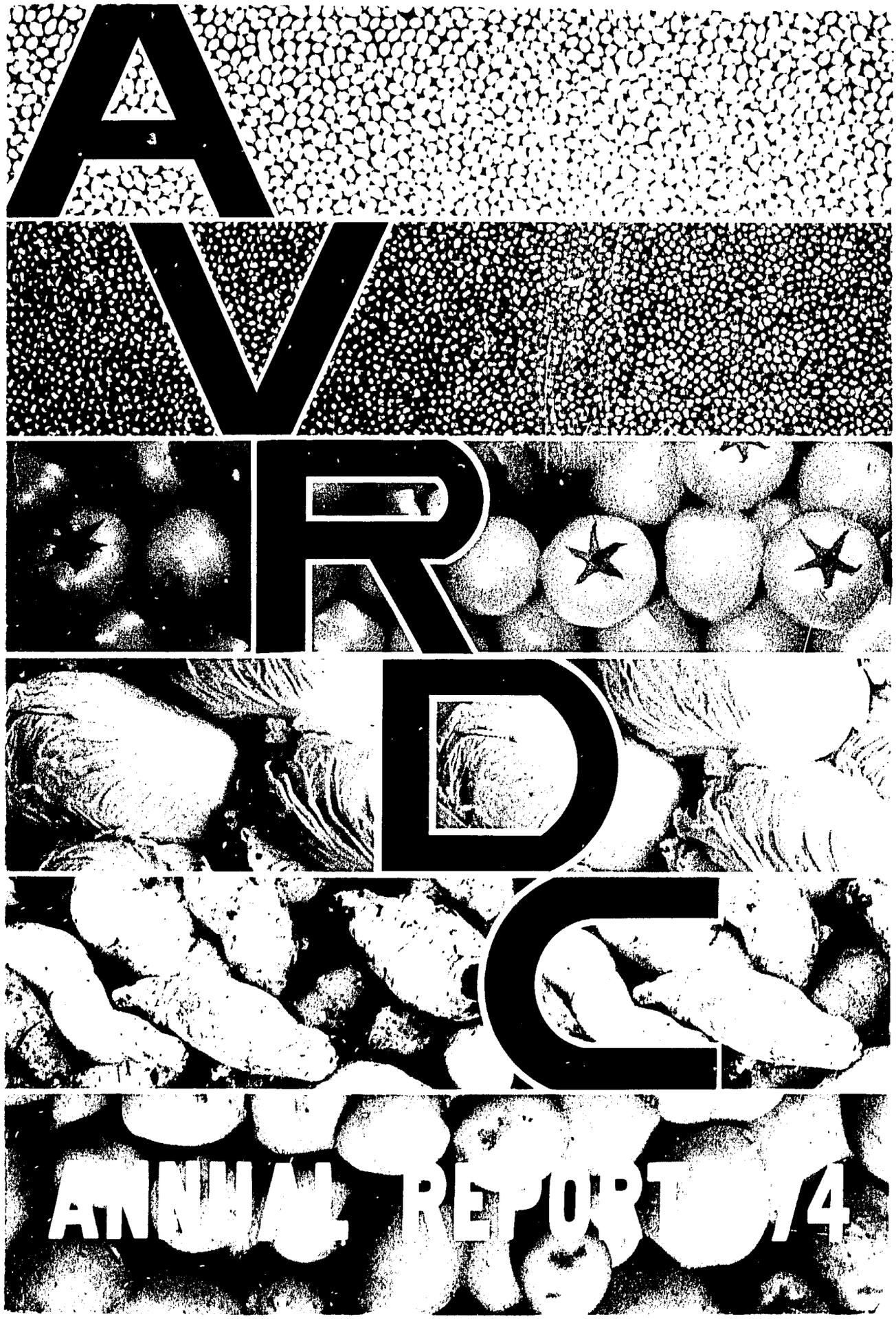

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ERRATA

Page viii: The 3rd line of the 9th paragraph should read "NH_4-N" instead of "NH_4-H".

Page 1: The 5th statement should read:" Seventeen cultivars were identified as resistant to soybean mosaic virus. Eight cultivars were found to be resistant to beanfly (*M. phaseoli*) attack."

Page 5: The 11th line in column1 should read "50 ft-c" instead of "5,000 ft-c".

Page 14: The 2nd line of the 4th paragraph in column 2 should read: "inoculated with uredospores of the two races isolated from one naturally infected leaf of the cultivar 8-3-2 (Acc. 2374)."

Page 23: In Table 18, the position of the characters "Upper epidermis" and "Lower epidermis" are reversed.

Page 24: The last line from the bottom of column 2 should read "54 percent" instead of "64 percent".

Page 25: The 5th line of column 2 should read "seeds that did not germinate" instead of "seeds that germinated".

Page 32: The 3rd line of the 3rd paragraph in column 1, "(hypocotyl enlongates and is the first to emerge)", and the 3rd line of column 2, "(epicotyl enlongates - hypocotyl does not enlongate and the cotyledons do not emerge)", should be deleted.

Page 58: In Table 9, Accession "333 - (cultivar) VC 48-1-2-1" should read "33 - (cultivar) VC 8-1-2-1".

Page 69: The "boron application" mentioned in the 6th line of column 2 and elsewhere should read "boron (as FTE) application".

Page 71: The 14th line from the bottom of column 2 should read "0.4 ha" instead of "4 ha".

Page 79: The caption under Figure 1 should read: "Comparative susceptibility to vernalization of heat-tolerant and heat-sensitive Chinese cabbage cultivars at both 5° and 10°C and at varying treatment durations (15, 20, 25 days)."

Page 123: The caption under Figure 1 should read: "Intra-clonal frequency distributions by tuber weight and diameter of *S. pinnatisectum* and *S. vernii* clones when grown under cool and warm night conditions."

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WITH THE COMPLIMENTS

of

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THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER
ANNUAL REPORT FOR 1974

The Asian Vegetable Research and Development Center
Shanhua, Tainan, Taiwan, Republic of China
1975

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About this report

This is the second annual report of the Asian Vegetable Research and Development Center (AVRDC), covering the experimental activities conducted during 1974. All dates used in this report will refer to 1974 unless otherwise noted.

Data are reported in metric units, e.g., "tons/ha" means metric tons per hectare. Monetary values have been converted to equivalent U.S. dollars at the prevailing exchange (e.g., in 1974, NT$ 37.9 = US$ 1.00). Control means an untreated experimental plot unless stated differently.

A single asterisk (*) means significant at the five percent (5%) level; a double asterisk (**) means significant at the one percent (1%) level. If the value for a control is given, a single asterisk means significantly different from the control at the 5% level and a double asterisk means significantly different from the control at the 1% level.

We are using the following system of indicating pedigrees in our breeding program. Instead of the multiplication sign (x), a slant bar (/) is used. For example, a cross between VC 9 and Saturn is expressed as VC 9 / Saturn. The sequence of crosses is indicated by the number of slant bars; (Tropi-Red x VC 48-1) x Manalucie is presented as Tropi-Red / VC 48-1 // Manalucie. Beyond 3, however, the crosses are designated /4/, /5/, and so on.

Soybean yield is calculated as seed weight in kilograms per hectare at 13 percent moisture, and protein content is reported as a percentage of soybean seed weight at 13 percent moisture. The yield data presented for mungbean were not calculated at a standard moisture level and, therefore, are only rough estimates.

The common and scientific names of the crops studied at AVRDC are as follows: (i) mungbean (called green gram in some countries), *Vigna radiata* (Syn. with *Phaseolus aureus*); black gram, *Vigna mungo*; adzuki bean, *Vigna angularis*; and rice bean, *Vigna umbellata*; (ii) soybean, *Glycine max*; (iii) tomato, *Lycopersicon esculentum*; (iv) sweet potato, *Ipomoea batatas*; (v) Chinese cabbage (heading type), *Brassica pekinensis*; and (vi) white potato, *Solanum tuberosum*.

For ease of reference, the discussion is organized by crops rather than by departments. Thus, the work of such departments as agricultural economics, chemistry, soil science, etc. is presented on a crop by crop basis.

Director's Introduction

RESEARCH HIGHLIGHTS

Although 1974 was only the second full year of operation of the Asian Vegetable Research and Development Center, we are pleased to be able to report significant advances for each of the six crops receiving the attention of our scientific staff. Only a few of the outstanding achievements will be presented in this introduction, whereas the main body of the report contains a complete account of the research activities.

SOYBEAN. At the close of 1974, the soybean germplasm collection numbered 5,133 accessions, coming from 42 different countries. In yield trials conducted in the summer of 1974 with 128 selected cultivars from the world varietal collection, 38 cultivars produced more than 2.5 tons per hectare, and 11 yielded over 3 tons.

Some 2,000 cultivars from the world collection were tested for sensitivity to photoperiod. More than 200 flowered within five days of each other whether the day length was 12 or 16 hours. More than 20 of them showed no difference in flowering date under either day length.

Too frequently, photoperiod insensitive cultivars selected at high latitudes flower too early to yield well when grown in the tropics. However, AVRDC breeders have identified a number of varieties that are insensitive to day length, yet do not flower until 35 to 40 days after planting. Since these qualities are necessary in soybean cultivars suitable for the tropics, cultivars with such characteristics are being used as parents.

Among the 1,000 crosses attempted during 1973 and 1974, 650 proved to be successful; the rest were selfed. From F_3 segregating populations, more than 6,000 single-plant pedigreed selections were made in 1974. This massive breeding and selection program should soon result in the development of superior varieties for the tropics.

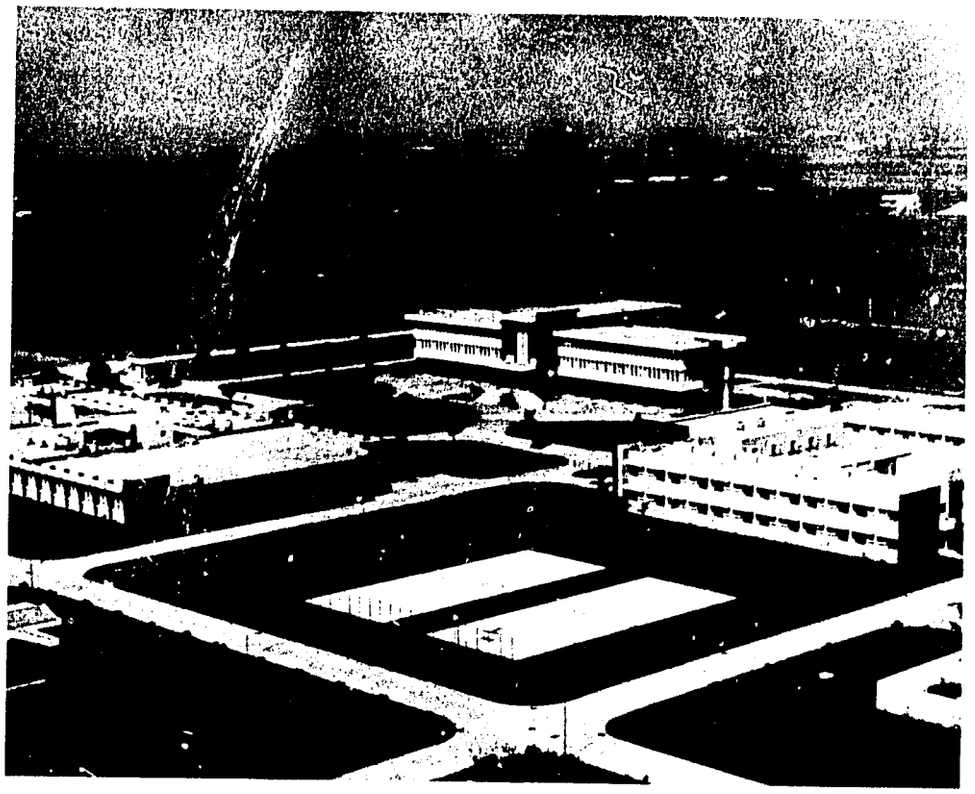
Cooperative work between the plant breeders and plant pathologists has identified cultivars and genetic lines with moderate resistance to soybean rust (*Phakopsora pachyrhizi*), and with strong resistance to downy mildew *(Peronospora manshurica)*, purple seed stain *(Cercospora kikuchii)*, and soybean mosaic virus.

The plant pathologists are conducting intensive studies of the soybean rust organism. Their investigations include the identification of physiologic races, host range, the disease cycle, and the production of spore-germination inhibitors.

The beanfly (mostly *Melanogromyza phaseoli*) is probably the most serious insect pest of soybean in Asia. AVRDC screening trials for varietal resistance to this insect were conducted in Taiwan, the Philippines, and Thailand. Eight cultivars appeared to have high levels of resistance at all locations, and 66 proved to be moderately resistant.

Studies by the soil scientists showed that NH_4-N is quite toxic to the soybean plant. Tests with nutrient solutions revealed that the seed yield at a concentration of 30 ppm of nitrogen was twice that of the NH_4-H pots when the nitrogen was supplied in nitrate form. Furthermore, field trials indicated that nitrogen fertilizer applied at the flowering stage increased yields.

Studies of carbohydrate synthesis in the soybean, conducted by the physiologists, indicated



A view of the laboratory building (left), the administration building (center), and the cafeteria-dormitory building (right). Some of the experimental fields are in the background.

that up to pod formation, source was the limiting factor and that after seed filling began, sink appeared to be limiting. These conclusions were based on studies of CO_2 enrichment and shading and on measurements of carbohydrate accumulation.

Marked increases in yields of the Shih-Shih cultivar were obtained as population densities were increased from 100,000 to 300,000 plants per hectare. However, densities of 400,000 and 500,000 plants per hectare produced only small increases in yield. Yield levels varied greatly with planting date. The causes of these fluctuations need further study.

One soybean cultivar (Acc. 2120) has produced as many as 1,200 pods per plant under conditions of wide spacing. The yields per hectare calculated from greenhouse tests were incredibly high. This accession is photoperiod sensitive and hence can be grown only in the summer and fall seasons. Nevertheless, because of its apparently high yield potential, it is being used in the crossing program. Accessions with such properties give us hope of a major breakthrough in developing soybean varieties for the tropics.

MUNGBEAN. During 1974, 546 mungbean cultivars were added to AVRDC's world collection, thus bringing the total number of accessions to 2,362. Other closely related species in the genus *Vigna* numbered 388. This germplasm collection was shared with scientists in other countries; 4,962 seed packages were sent to 24 scientists in 15 different countries.

Yield trials of superior cultivars from the world collection and from F_4 and F_5 generation progeny in the breeding program showed that relatively short, determinate plant types gave the highest yield under planting densities of more than 100,000 plants per hectare. In a yield trial of

20 elite cultivars, Tainan 1 gave a maximum yield of 2.46 tons/ha. The average yield of the 20 cultivars was 1.86 tons/ha. This average is about triple that obtained by the average farmer in Southeast Asia.

As with the soybean, CO_2 enrichment increased yields and shading reduced yields—principally by influencing the number of pods per plant.

Population density studies conducted in 1974 generally showed that yields increased with population densities up to 400,000 plants per hectare. We have tentatively concluded that there is a strong interaction between variety and population in mungbeans. These studies will be continued in 1975.

Large numbers of mungbean varieties were screened for resistance to *Cercospora* leaf spot, the most serious fungal disease of mungbeans in Southeast Asia. Three cultivars showed high levels of resistance.

The beanfly is the most serious insect pest of the mungbean. AVRDC entomologists conducted extensive resistance evaluation studies in Taiwan, the Philippines, and Thailand. A few cultivars proved to have low (less than 20%) levels of infestation at all locations. It appears that mungbean varietal resistance to insect attack exists and that undoubtedly this character can be transferred to otherwise superior varieties.

Root diseases cause serious yield losses in mungbeans, especially when the crop is continuously grown on the same field. Our plant pathologists have shown that damping-off, caused mostly by *Rhizoctonia solani* and sometimes by *Pythium* sp., causes high mortality at the seedling stage. Preliminary trials to identify resistant cultivars were only partially successful. More extensive screening trials will be conducted to determine whether truly resistant cultivars exist.

Pot culture experiments in the greenhouse, using soil from experimental fields, indicated that mungbean yields can be increased by the addition of zinc, but there was no consistent response to copper and manganese.

TOMATO. The world collection of tomato cultivars numbered 3,974 accessions at the end of 1974. In 1973 and 1974, 3,799 cultivars were screened for heat tolerance (the ability to set fruit when night temperatures remain above 22° C). Only 31 cultivars set fruit abundantly. It is interesting to note that the source of these heat-tolerant cultivars was not necessarily the tropics; 4 came from Canada, 2 from England, 4 from Hungary, and 3 from the U.S.A. Half of them, however, did come from tropical countries.

The major emphasis of the breeding program is to develop varieties with heat tolerance and bacterial wilt resistance. In 1974, the breeders made over 400 crosses, many of which were directed toward combining high ascorbic acid and vitamin A contents, crack resistance, and deep red color in addition to heat tolerance and bacterial wilt resistance. Moreover, cultivars that are resistant to tobacco mosaic virus, gray leaf spot *(Stemphylium solani)*, and a few less important diseases have been identified by the plant pathologists. These qualities are also being incorporated into the new varieties.

A breeding program attempting to introduce such diverse characteristics into improved varieties is bound to proceed slowly. However, lines combining tobacco mosaic virus and bacterial wilt resistance have been identified and are proving to be highly superior to local cultivars, particularly at low elevations in Thailand, Malaysia, and the Philippines.

The plant pathologists have mounted a major program to study the bacterial wilt organism *(Pseudomonas solanacearum)*. Already they have divided the different isolates found in Taiwan into four types based on morphological differences and have classified about 100 isolates in accordance with their virulence. Methods of inoculation and testing for varietal resistance have been developed. Actually, millions of individual plants in segregating populations have been inoculated and rated as to degree of resistance to bacterial wilt. This program, of course, is carried on in close collaboration with the plant breeders, and the resistant selections are used in

the breeding program.

We are confident that within the next few years, superior varieties for the fresh market and for the processing industry will be developed—varieties that are disease resistant and that can be grown throughout the year under tropical conditions.

CHINESE CABBAGE. Substantial progress was made during 1974 in developing improved varieties of Chinese cabbage *(Brassica pekinensis)* for the tropics. Several selections, resulting from crossing Korean and Taiwanese cultivars, formed heads in the hot summer months. These heads were three times larger than those of the heat-tolerant parent. This convinces us that in a few years we shall be able to breed new heat-tolerant varieties of Chinese cabbage that will produce large, dense heads during the summer months. This will increase farmers' income and stabilize prices for the consumer.

Studies of the morphological characters associated with heat tolerance revealed that the cultivars that withstood high temperatures had heavier and thicker leaves, shorter petioles, and larger main roots with more secondary branching roots, as compared with the heat-sensitive varieties.

In addition to soft rot, the pathologists have revealed that downy mildew *(Peronospora parasitica)* and turnip mosaic virus are important diseases of Chinese cabbage in the cool months. They have carried out extensive screening tests for varietal resistance to these diseases. The screening for resistance to downy mildew and turnip mosaic virus involved several hundred cultivars from the world collection (now numbering 593). Fortunately, a few cultivars were found that have high resistance to downy mildew and to turnip mosaic virus.

Using the results obtained by the plant pathologists, the breeders are combining multiple-disease resistance with heat tolerance. The outlook for success in this effort is bright.

The entomologists have screened Chinese cabbage cultivars for varietal resistance to insect attack. Although there are differences, the more resistant cultivars, unfortunately, are damaged to the extent of rendering the product unfit for marketing. This result is primarily due to the wide host range of such lepidopterous, leaf-eating insects as the larvae of the diamond-back moth, the cabbage worm, and the cabbage looper. The entomologists believe that the differences among varieties are sufficient to warrant the use of the more resistant cultivars in an integrated pest management control system.

Besides studying the use of chemical insecticides, the entomologists are investigating the control of cabbage insects by the use of granulosis viruses of insects. Early results are promising.

SWEET POTATO. The sweet potato improvement program, which got off to a slow start in 1973 because of difficulties in synchronizing flowering among cultivars selected as parents, moved ahead rapidly in 1974. Over 300 successful crosses were made from which 3,500 seeds were harvested. We obtained over 10,000 open-pollinated seeds from our nursery, and additional seeds were secured from Korea, from Louisiana State University and from IITA in Nigeria. Altogether, 16,557 seeds were sown during the year.

The original objectives remain the same—to develop varieties that produce roots containing high amounts of protein and vitamin A and that have acceptable eating quality for Asians. Naturally, earliness and high yielding capacity also are being sought.

Four yield trials of selected cultivars and genetic lines were planted at different times during 1974. The highest calculated yield in 107 days was 45 tons per hectare, and the top yield in 140 days was 63 tons. Although there is much yet to be achieved in sweet potato improvement, yields such as these demonstrate the potential.

Plantings were made in late September to determine the behavior of selected cultivars and genetic lines when grown without fertilizer, insecticides, or supplemental irrigation. The highest yield obtained was 39 tons/ha in 117 days.

Studies of the sweet potato conducted by the chemists showed that there is no correlation

between dry matter yield and protein content. This provides hope that a high protein, high yielding variety can be produced. Furthermore, the chemists revealed that the protein, starch, and sugar contents are essentially constant throughout the root.

The sweet potato weevil *(Cylas* sp.) is the most serious pest of the sweet potato. The entomologists carried out extensive trials designed to identify cultivars that are resistant to the weevil. Although there were differences, no cultivars proved to be completely resistant. These studies will be continued, but for the time being it appears that crop rotation is still the best method of control.

Sweet potato witches' broom is the only important disease of the sweet potato. It is considered to be a mycoplasma rather than a true virus disease and is transmitted by a leafhopper. Preliminary screening tests by the pathologist indicated that some cultivars were quite resistant. For reasons not yet understood, the disease occurs in some locations and not in others.

The soil scientists studied the response of sweet potato plants to N, P, and K; and found that the greatest yield increases came from the application of potassium, with less response to nitrogen, and the least to phosphorus.

WHITE POTATO. The primary aim of AVRDC's white potato breeding program continued to be to develop varieties that will yield well in the lowland tropics.

From hundreds of cultivars and segregating populations tested during the summer of 1974, about 30 were found to have produced marketable tubers. The largest tubers weighed about 100 grams, the average weight of all marketable tubers being a little over 50 grams.

The highest yield was obtained from a segregating population received from the University of Guelph (Canada). One selection produced, in a single hill, eight marketable tubers weighing 400 grams. This yield was three times greater than the top yield obtained in the summer of 1973.

Many new populations of true seed were received in 1974. These were being converted into tubers during the 74-75 winter season and will be screened for heat tolerance during the summer of 1975.

After two more years of testing segregating populations from diverse world sources, the likelihood of achieving the the objectives of the program should be known. The 300 percent yield increase obtained in 1974 over that of 1973 gives us real hope for success.

THE AGRICULTURAL ECONOMICS PROGRAM. The agricultural economists concentrated on three projects. One was to determine the area, production, and yield for AVRDC's six crops in South and Southeast Asia. This was accomplished for some of the crops in several countries.

Another activity was a survey, in cooperation with National Chung Hsing University, of farmers in two important vegetable-growing districts of Taiwan. Valuable information was thereby obtained on farm size, marketing problems, labor availability and costs, crops grown, etc.

The third activity was to arrange with two farmers, on one hectare each of AVRDC land, to grow some of the Center's six crops during the year. This made it possible to keep accounts of expenditures and incomes and to assess the farmers' opinions about the constraints involved in producing the crops that AVRDC has selected for study.

THE TRAINING AND CROP MANAGEMENT PROGRAM. The Center has placed its training and crop management activities in one department. The head of these programs did not arrive until September 1, 1974. However, considerable progress has been made in getting both programs under way.

A training brochure was printed and distributed to institutions throughout Asia and elsewhere. Several trips were made to interview prospective candidates for training at AVRDC. The cafeteria-dormitory building, an essential training facility, was completed in late September. The training program is expected to develop rapidly in 1975.

Early activities of the crop management program included studies on weed control for

The cafeteria-domitory building was dedicated in October. It has space for 40 trainees and includes a cafeteria, a guest house and a private dining room.

AVRDC's six crops, on wet season cultural practices, and on different levels of management for Asian farmers.

CONCLUDING STATEMENT

In the above paragraphs, we have reported the preliminary results of an intensive research program designed to increase the yield of six important crops, by the development of superior varieties and better methods of crop management.

This is being done by tapping the world's genetic resources in a massive way, followed by thorough screening programs to identify cultivars that have resistance to insect and disease attack, wide adaptability, and superior yielding ability. The individual cultivars selected from these screening tests are then utilized as parents in an intensive breeding program, seeking to combine in new varieties the superior qualities derived from many sources.

This work is supported by plant physiologists, chemists, entomologists, plant pathologists, soil scientists, crop management specialists, and agricultural economists who work as an integrated team in achieving the objectives.

We trust that the readers of this report will note that, although no unusual breakthroughs have yet occurred, there is substantial progress. Just the fact that we have found cultivars within the world germplasm collections of each of the six crops that consistently show resistance to the major insects and diseases, or which have heat tolerance, or both, gives us hope for the future.

This introductory section has mentioned a few highlights of the research programs.

Obviously, this work could not proceed successfully without the assistance of supporting departments. These include the Office of Information Services, the Experimental Farm, the Pesticide Residue Program, the Library, the Department of Buildings and Grounds and the Food and Dormitory Services.

Although the Center did not get specific funding for outreach activities in 1974, a sizable international program did develop on a scientist-to-scientist basis. These relationships are described in the main body of the report.

STAFF CHANGES

The Agricultural Economics Department was formed January 10, 1974 with the appointment of Mr. Merle R. Menegay, who came to us directly from the University of Tennessee where he did his graduate study.

In February, Dr. N. S. Talekar joined our staff to initiate the Pesticide Residue Program. He is from India and received his Ph.D. from the University of Wisconsin.

Dr. Edwin B. Oyer, Associate Director, resigned July 1, 1974, to become Director of International Agriculture at Cornell University. He was replaced by Dr. James J. Riley, who previously served as Director of the University of Arizona's Arid Lands Research Center in Abu Dhabi.

Dr. David R. MacKenzie resigned April 30, 1974, to accept the position of Assistant Professor of Plant Pathology at Pennslyvania State University. Dr. MacKenzie served AVRDC as head of the Department of Plant Breeding and also directed the mungbean improvement program.

Dr. Ruben L. Villareal became head of the Department of Plant Breeding on May 1, 1974. The mungbean breeder position was not filled until the arrival of Dr. Hyo-Guen Park on December 1, 1974. Dr. Park, a Korean citizen, came to AVRDC directly from the University of Minnesota, where he obtained his Ph.D. degree.

Mr. Teng-Hui Hwang was appointed as Librarian on March 1, 1974. He was formerly the Assistant Librarian at the Taiwan Theological Seminary.

Most tragically, the head of our Plant Physiology Department, Dr. Henry Bang-Fang Wu, passed away on July 8, 1974, as the result of a cerebral hemorrhage. His untimely death cut short what promised to be a brilliant scientific career.

Just as 1974 closed, we were able to find a new head for this department, Dr. Chung-Chi George Kuo, who will assume the position of Associate Plant Physiologist in May 1975.

On July 8, 1974, Mr. Charles S. Taylor was appointed as our Information Officer. Mr. Taylor joined us after completing graduate studies at Vanderbilt University.

Dr. Raymond D. William was appointed to the position of Head, Office of Training and Crop Management and assumed his duties on September 1, 1974. Dr. William came to us from Purdue University where he had recently received his Ph.D. degree.

Miss Li-Yung Huang was appointed Assistant Manager of the Food and Dormitory Services on July 1, 1974. At the end of the year, she was promoted to Manager.

Mr. Jung-Fu Fang resigned as Superintendent of the Experimental Farm on August 22, 1974. He was replaced by Mr. Yi-Sung Chen, who was promoted from Assistant Superintendent.

All staff members are directly hired by the Center except for the Director, who is a member of the Rockefeller Foundation and for the Soil Scientist, who is provided by the Japanese Government.

THE BOARD OF DIRECTORS

Dr. Nyle C. Brady was elected to the Board of Directors for a four-year term which began May 1, 1974. Dr. Brady is the Director of the International Rice Research Institute in the

Philippines.

In early 1974, Dr. Todayoshi Sugiyama was designated by the Japanese Government to serve as its representative on the Board of Directors. Dr. Sugiyama, Professor of Horticulture at Tokyo Horticultural University, replaced Dr. Nimoru Kajiura, who retired in 1973 after serving as Japan's representative on the Board since the Center was organized in May 1974.

At the October 1974 meeting of the Board of Directors, Dr. Vernon W. Ruttan, President of the Agricultural Development Council, was elected to the Board. Dr. Ruttan will begin his four-year appointment in January 1975.

FINANCES

The Asian Vegetable Research and Development Center is supported principally by seven countries. Expressed in U.S. dollars, funds received in 1974 totaled $1,608,119. The largest single donor was the Republic of China, which contributed $709,147. Next was the United States of America (USAID) with $629,195. Thailand, the Philippines+, Korea, and Japan gave $75,000 each. Japan also provided the salary of the Soil Scientist. Vietnam made a token contribution of $2,000.

The U.S.I. Far East Corporation provided a grant equivalent to $5,277, the National Distillers and Chemical Corporation made a grant of $12,000, and the Staufer Chemical Company gave $500 to the Center.

The Rockefeller Foundation furnished the services of the Director and also provided a grant of $25,000 toward the mungbean improvement program.

+ Funds for the Philippines were actually received in 1973.

Crop Environment

In this section, the general environmental conditions at AVRDC are described, with emphasis on climate and soil.

LOCATION. AVRDC is located at Shanhua in southwestern Taiwan (about 19 km north of Tainan City) at 120°17'E longitude and 23°07'N latitude. The site, formerly planted in sugarcane by the Taiwan Sugar Corporation, is approximately 20 kilometers from the west coast.

The Republic of China provided 116 hectares of land for AVRDC; 102 of which now constitute the AVRDC Experimental Farm; the research, training, support, and residential facilities have been constructed on the remaining 14 hectares *(Fig. 1)*. The experimental farm is flat with only four meters difference in elevation between the lowest and highest points with an average elevation of eight meters above sea level.

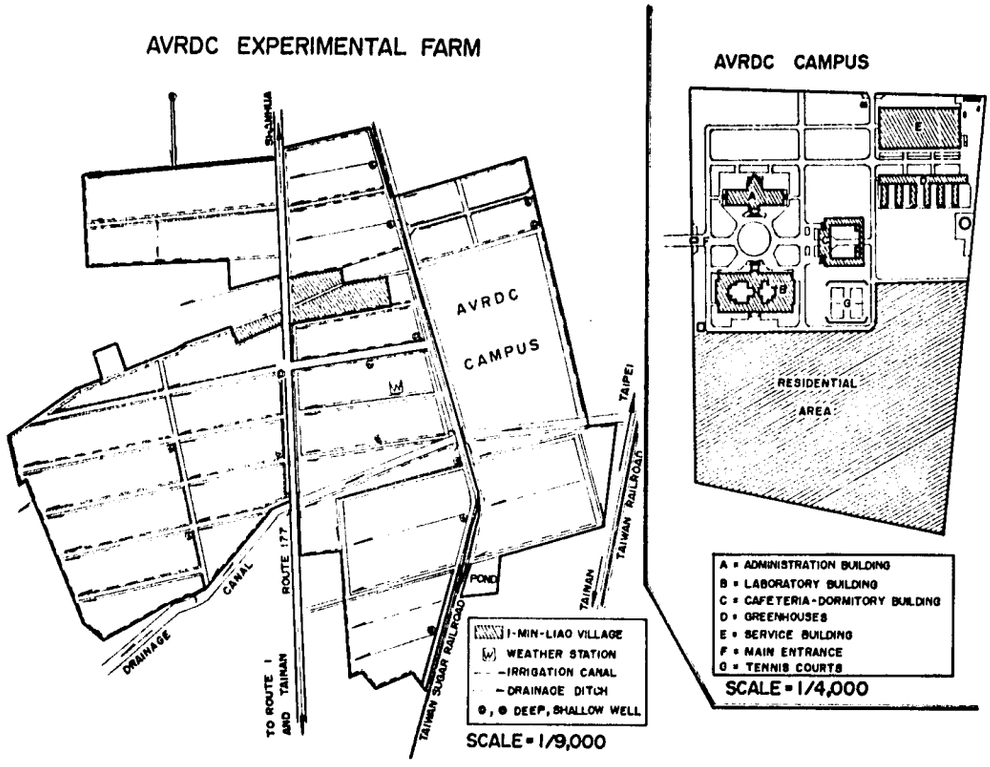


Fig. 1. The AVRDC experimental farm and campus.

WEATHER. The average annual rainfall at AVRDC is just over 1700 mm, *(Fig. 2)* most of it falling between May and September. The skies are usually partly cloudy, and only about 60 percent of the possible solar energy is available to crops *(Fig. 3)*.

Temperatures are high from May through September, with daytime values mostly ranging between 30°C and 33°C. Minimum temperatures are usually above 22°C *(Fig. 4)*. In the winter months (Dec.,

The AVRDC weather station began operations in October.

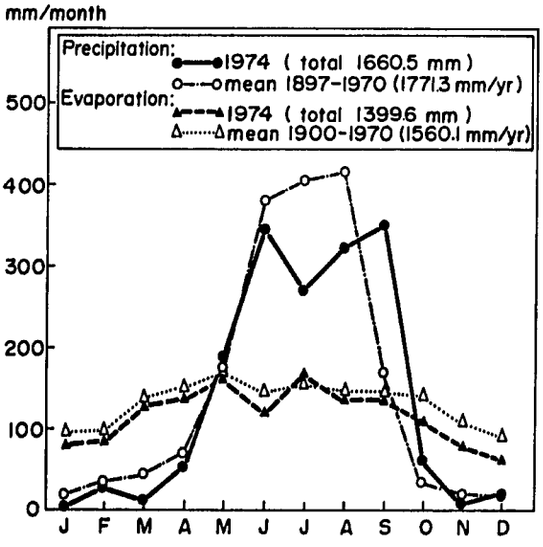


Fig. 2. 1974 monthly precipitation and evaporation data for Tainan City, Taiwan compared with the means from 1897 to 1970 and from 1900 to 1970, respectively. (Reference: Central Weather Bureau, 1974. Summary of meteorological data - Taiwan. Vol. III).

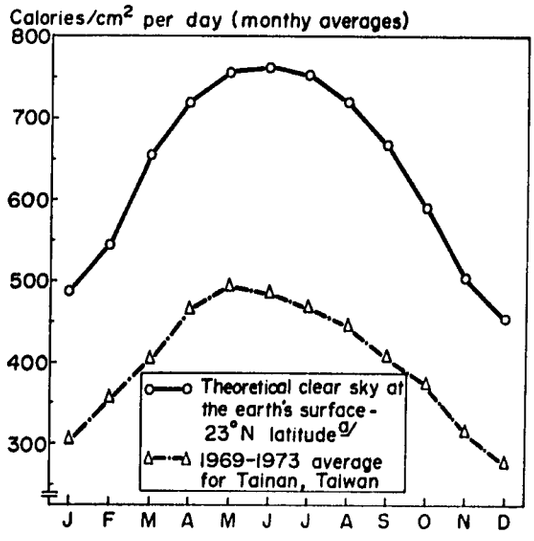


Fig. 3. Theoretical solar radiation under clear sky conditions compared with a 5-year average at Tainan City. a/ Courtesy of the Taiwan Agricultural Research Institute.

Jan., Feb.), temperatures are often below 12°C and daytime temperatures have mean maximum values of 22° to 25°C (see *Fig. 4*). During these months, it is too cool to grow good crops of soybean and mungbean; but tomato, white potato and Chinese cabbage do very well.

The day length at AVRDC ranges between 13 hours and 33 minutes on June 21 to 10 hours and 43 minutes on December 21. If civil twilight is considered, an additional hour and 20 minutes should be added *(Fig. 5)*.

In 1974, weather at AVRDC was reasonably normal, with a deficiency of only 100 mm in annual rainfall (see *Fig. 2)*. Temperatures were only slightly below normal throughout the year (see *Fig. 4)*.

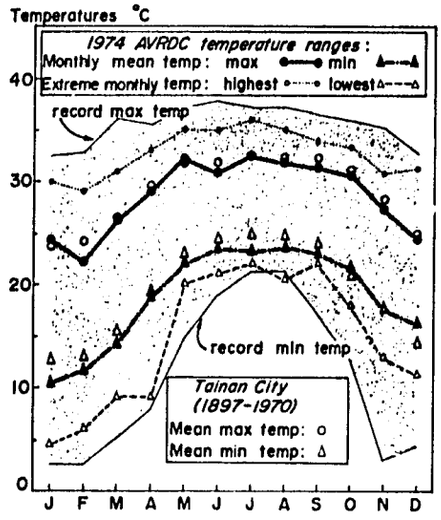


Fig. 4. 1974 temperature ranges compared with the mean for Tainan City (1897 to 1970). Shaded area includes the highest and lowest temperatures recorded in 73 years. (Reference: Central Weather Bureau. 1974. Summary of meteorological data - Taiwan. Vol. III.)

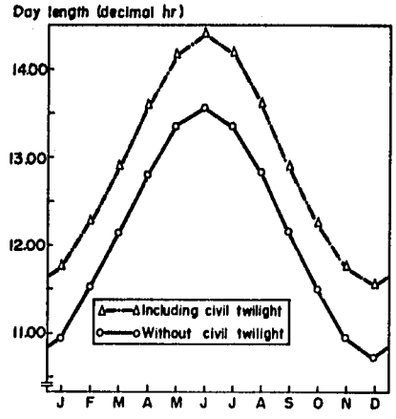


Fig. 5. Monthly variation in day length at AVRDC (23°N latitude) with and without civil twilight. (Reference: List, R. J. 1949, Smithsonian meteorological tables. Sixth Revised Edition. Smithsonian Institution Press, Wash., D.C.)

SOIL. Although four soil series are present in the experimental farm, 80 percent of the area consists of the Take series. In general, the soils are moderately well drained, deep, calcarious alluvial soils. Some physical and chemical characteristics of a typical profile are presented in *Table 1*.

Table 1. Physical and chemical characteristics of a typical soil profile from the AVRDC Experimental Farm; 1974.

Depth (cm)	pH	Texture			Organic matter content (%)	Cation exchange capacity (me/100g)	Available nutrients (ppm)					
		sand	silt	clay			P	K	Mg	Zn	Mn	B
		(%)										
0 to 12	8.6	22	54	24	1.67	9.2	5	28	199	10	127	2
15 to 29	8.2	24	52	24	1.50	9.5	6	19	189	10	142	1
29 to 64	8.5	24	48	28	1.08	8.8	2	17	331	10	122	2
64 to 77	8.6	16	54	30	1.04	10.7	4	24	375	12	122	2

The mean bulk density of the soil is 1.67 grams per cubic centimeter. The water available to plants ranges between 35 (field capacity) and 18 percent (wilting percentage).

The experimental fields are irrigated, when necessary, from wells ranging in depth from 20 to 50 meters. An analysis of the irrigation water is shown in *Table 2.*

Table 2. A typical analysis of AVRDC irrigation water.

	pH	EC (μ mhos)	Ca (ppm)	Mg (ppm)	K (ppm)	Na (ppm)
Rainy season (September)	7.2	740	84.8	22.8	2.6	7.9
Dry season (April)	7.6	780	86.5	20.5	2.3	37.8

Soybean

Our objective is to develop soybean varieties that are especially well adapted to the tropics and the subtropics, where too few soybeans are grown today and where yields on farmers' fields are low. The world collection of soybean germplasm was increased by 2,069 accessions to a total of 5,133 at the end of 1974. In a summer yield trial, a day-neutral cultivar (Acc. 1322) yielded 3.7 tons/ha in 95 days. Twenty cultivars did not vary in days to flowering when tested under different photoperiods. Several F_3 populations showed field resistance to soybean rust *(Phakopsora pachyrhizi)*, bacterial pustule *(Xanthomonas phaseoli* var. *sojense)*, and downy mildew *(Peronospora manshurica)*. Seventeen cultivars were identified as resistant to beanfly *(M. phaseoli)* attack. A pure-line selection (Acc. 2120) produced nearly 124 kg/ha per day of soybeans in a greenhouse experiment. Soybean yields increased when supplied with nitrogen just before flowering. In 1974, 5,070 seed packets were sent to 33 scientists in 21 countries.

GLYCINE SP. GERMPLASM COLLECTION:

Glycine max	*5,071*
Glycine soja	*61*
Glycine wightii	*1*

PLANT BREEDING

THE WORLD COLLECTION. By the end of 1974, our soybean varietal collection totaled 5,133 accessions, which came from 42 countries *(Table 1)*. In addition to *Glycine max*, the collection included the wild species *G. soja* (Syn. with *G. ussuriensis*) and *G. wightii* (Syn. with *G. javanica)*.

Table 1. Sources of *Glycine max* accessions.

Source	No. of accessions	Source	No. of accessions
Afghanistan	1	Italy	1
Argentina	5	Japan d/	1,484
Australia a/	299	Korea e/	786
Austria	1	Malaysia	1
Belgium	102	Mozambique	3
Brazil	3	Nigeria f/	222
Burma	3	Pakistan	3
Canada	9	Peru	5
China (Mainland)	733	Philippines g/	78
China (Taiwan) b/	128	South Africa	9
Colombia	56	Rhodesia	1
Costa Rica	1	Surinam	8
El Salvador	1	Sweden	37
France	84	Thailand	23
Germany	21	Turkey	3
Guatemala	21	U.S.A.	230
Holland	16	U.S.S.R.	10
Hong Kong	3	Venezuela	3
Hungary	7	Yugoslavia	3
India	64	Not Known	439
Indonesia c/	215		
Israel	11	Total no. of accessions	5,133

a/ University of Sydney.
b/ The Taiwan Agricultural Research Institute (TARI) contributed their USDA collection of 2,527 accessions. These have been distributed among the original donors to the USDA.
c/ Lembaga Pusat, Penelitian Pertanian, and Institut Pertanian Bogor.
d/ Partially from the Hiratsuka National Collection.
e/ Crop Experiment Station.
f/ International Institute for Tropical Agriculture.
g/ University of Philippines at Los Banos.

YIELD TRIALS. The entire collection was planted in the field during the fall (1973) and spring seasons. The 513 best performers wer selected based on the number of pods per plant Of these 513, 128 cultivars were evaluated in replicated yield trial during the summer. Th population density was 300,000 plants per hectare The highest computed yield was 3.7 tons/ha which was produced by Accession 1322 in 9 days *(Table 2)*. This cultivar is also day neutra (see *Table 5*).

The frequency distribution of the 128 cultivar by yield is shown in *Figure 1*. The extremely low yields of some of the entries was due to thei photoperiod sensitivity. However, when planted in the fall, they yield well. The 128 cultivars ranged in maturity from 89 to 113 days and in 100-seed weight from 5 to 19 grams. Some of them, such as Clark 63 and Taichung E-32, have been reported in the literature as performing well in the Philippines, Thailand, Laos, and Nigeria.

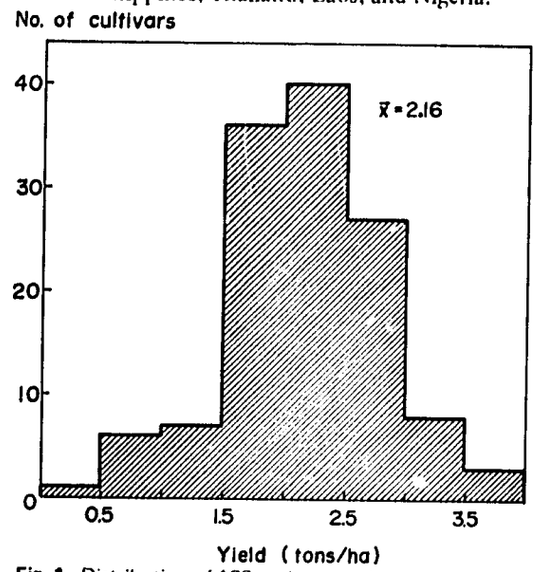


Fig. 1. Distribution of 128 soybean cultivars by yield.

The varietal collection was also screened in the late fall of 1973 at the District Agricultural Improvement Station (DAIS) in Pingtung (southern Taiwan) with the cooperation of Mr. A. T. Hung. From this screening, 33 cultivars were selected for inclusion in the breeding programs at both AVRDC and the Taiwan Agricultural Research Institute. The agronomic characteristics for the six best cultivars are presented in *Table 3*. Unfortunately, reliable yield data were not

Table 2. Agronomic data for the 13 highest yielding soybean cultivars.[a]

AVRDC acc. no.	Varietal name	Origin	Mean yield (tons/ha)	Days to maturity	Pods/ plant	100-seed wt (g)	Ht at maturity (cm)	Disease rating[b]	
								Soybean rust	Downy mildew
1322[c]	PI 248407	Not known	3.7	95	51	14	67	MR	R
882	89170	China	3.6	89	65	15	74	S	R
86	Clark 63	U.S.A.	3.5	91	93	13	76	MR	MR
74	Taichung E-32	Taiwan	3.5	95	34	13	68	MR	R
20	66-G-3	Taiwan	3.3	93	57	15	55	S	R
1704	68725 539	China	3.2	95	71	13	77	S	R
1612	85089-Ped	Korea	3.2	102	132	15	97	S	R
2135	1344	Indonesia	3.1	102	140	12	93	MR	S
2120	1039	Indonesia	3.1	113	132	6	88	MR	R
2142	1357	Indonesia	3.0	95	100	8	115	MR	S
2139	1354	Indonesia	3.0	102	165	8	100	MR	S
239	Hardome	Canada	3.0	89	47	14	92	S	R
1340	FC-19979-6	Japan	3.0	95	62	17	88	MR	R

a/ 128 elite cultivars were planted July 25 in a yield trial. Plot size was 6 m^2; 3 replications.
b/ Based on field observations: R-field resistant; MR-moderately resistant, and S-susceptible.
c/ Also day neutral (see *Table 5*).

Table 3. Agronomic characteristics of the soybean cultivars with the highest yields in the Pingtung DAIS yield trial.[a]

AVRDC acc. no.	Varietal name	Origin	Days to flowering	Pods/ plant	100-seed wt (g)	Days to maturity
2092	828 Klung Kung	Indonesia	46	135	9	101
2146	1390 DHS	Indonesia	59	190	6	101
2320	29 64036	Nigeria	53	123	10	101
2410	S-35	Nigeria	50	57	15	101
135	Crest	U.S.A.	35	50	17	95
1241	92577.425	China	34	80	6	87

a/ Planted Oct. 23, 1973 at the District Agricultural Improvement Station (DAIS) located at Pingtung in southern Taiwan; harvested Jan. 7 through Feb. 7; three replications.

obtained from the Pingtung trial.

An INTSOY+ variety-evaluation trial was planted in the spring at both AVRDC and the DAIS in Pingtung. However, the yields were reduced by heavy rains at harvest time. Two cultivars from Taiwan (Shih-Shih and Tainung 4) had slightly higher yields than any of the INTSOY entries when planted at AVRDC (*Table 4*).

THE CROSSING PROGRAM. Of the 863 crosses made in 73-74, 561 are now at the F_3 generation. The breeders were able to advance 20 selected crosses four generations in 1974 by using the single-seed-descent (SSD) technique (see

+ INTSOY, the International Soybean Program of the Universities of Illinois and Puerto Rico, cooperates with international and national organizations to expand the uses of soybean as human food.

Table 4. Agronomic data for the best 5 performers of the INTSOY variety evaluation experiment at AVRDC and at Pingtung.[a]

Location	AVRDC acc. no.	Varietal name	Yield (ton/ha)	100-seed wt (g)	Days to flowering	Days to maturity	Canopy ht at flowering (cm)	Plant ht at maturity (cm)
AVRDC	38	Shih-Shih	1.2	12	43	91	34	50
AVRDC	57	Tainung 4	1.2	15	52	101	47	63
AVRDC		Williams	1.1	13	36	87	17	44
AVRDC		Hill	1.1	11	50	99	37	56
AVRDC		Bonus	1.0	13	36	91	17	40
Pingtung		Cutler 71	1.0	18	35	91	26	50
Pingtung		Lee 68	1.0	17	37	93	24	34
Pingtung		Bonus	0.9	15	34	89	26	51
Pingtung		Harosoy 63	0.9	15	35	87	24	44
Pingtung		Bragg	0.9	15	37	94	29	41

a/ The experiment was planted at AVRDC March 5 and harvested June 1 to 15. The same cultivars were planted at the DAIS in Pingtung (southern Taiwan) on March 12 and harvested June 8 to 16. Population density was 400,000 plants/ha. Plot size was 14 m^2 with 4 replications.

Tomato: *Chart 1* for SSD procedure). These selections are now at the F_5 generation. Of the remaining 541 F_3 combinations, 370 were bulk harvested. From the rest (171), 1,300 single plants were selected to include in the pedigree-breeding program.

A total of 1,500 pollinations were made involving 300 different combinations, 20 different backcrosses, and 20 three- and four-way crosses.

To select cultivars for high yield potential and wide adaptability, disruptive seasonal selection was used on the pedigreed plants. Selections with high yield potential and varying maturities were identified for possible inclusion in multiple-cropping patterns.

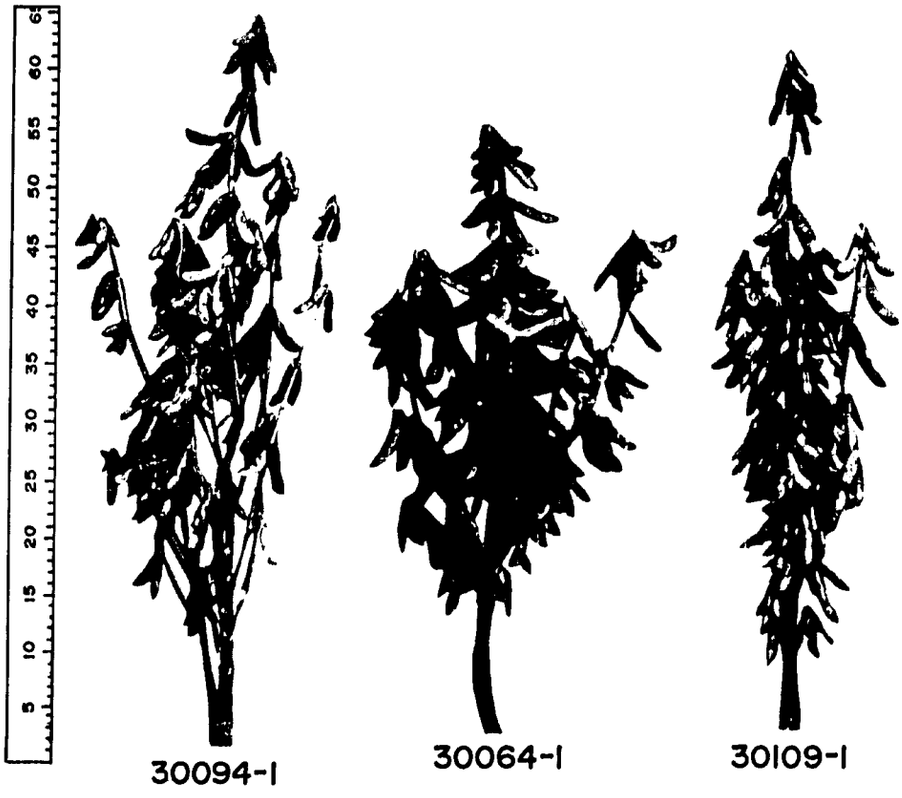
A F_3 segregating population was planted July 26 at a population density of 300,000 plants per hectare. The days to maturity of these selections varied from 78 to 98 days.

From a fall planting of the F_3 bulk populations, nearly 6,000 single plants were selected as pedigreed selections. These will be screened for yield stability during the spring, summer, and fall seasons.

Advanced generations of selections that are indeterminant and later in maturity at AVRDC (approx 23°N latitude) will be tested at lower latitudes; e.g., in the Philippines, Thailand, Indonesia, Malaysia, and southern India. On the other hand, the selections that are early maturing and determinant will be sent to Korea, northern India, Argentina, and southern Australia for further selection at higher latitudes.

PHOTOPERIOD INSENSITIVITY. Soybean is generally considered a short-day plant. Theoretically, nights must be longer than 12 hours before soybean plants will flower and mature (Sept. 22 to March 22 in the northern hemisphere and March 22 to Sept. 22 in the southern hemisphere). Obviously, many varieties have been developed that are sufficiently insensitive to long day lengths to allow them to grown at higher latitudes. AVRDC is trying to develop varieties suitable for regions located between the equator and 32.5° latitude (north and south), where the day length varies from 9.5 to 14.5 hours. The range of day lengths in the countries toward which we are directing our research efforts are presented graphically in *Figure 2*.

Although it might be possible to identify from our varietal collection types that are suitable for the specific seasons at each location, it would



These F_3 plants from our soybean breeding program averaged 142 pods per plant (see Table 7).

require that the entire germplasm collection be screened during each season at every locality. Any high yielding cultivars that might be identified, would be both season- and location-specific. Therefore, AVRDC has placed a high priority on screening for photoperiod insensitivity. A total of 1,978 cultivars representing each of the 10 U.S. maturity groups *(Fig. 3)* were selected for a spring screening in the field. One set of the cultivars were planted in a field with incandescent lights providing approximately 500 lux (5,000 ft-c) of light to the plants for 16 hours. The control was planted in a field without artificial light. The day length at planting was 12 hours and 10 minutes and was 13 hours and 30 minutes when the plants were maturing. The days to flowering under each set of conditions were recorded for each cultivar until 80 days after planting. Two hundred and twelve cultivars (11% of the total screened) were photoperiod insensitive+ under AVRDC conditions. Of these 212 cultivars, 20 had the same flowering date in both treatments *(Table 5)*. Cultivars found to be photoperiod insensitive were detected only in lines from the U.S. maturity groups 00, 0, I, II, III, and IV *(Fig. 4)*.

The screening trial was repeated during the fall. Of 2,042 cultivars screened, 505 were photoperiod insensitive (25%). The day length varied from 11 hours and 50 minutes to 10 hours and 50 minutes during the fall trial. The frequency distribution of the photoperiod insensitive cultivars screened during the fall arranged by U.S.

+ A photoperiod insensitive line is defined as one that will flower within a range of five days regardless of day length.

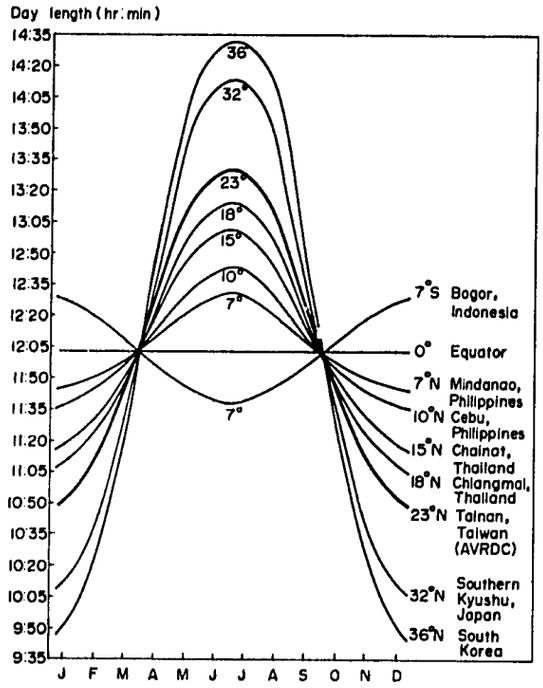


Fig. 2. Range of day lengths at various locations in Asia.

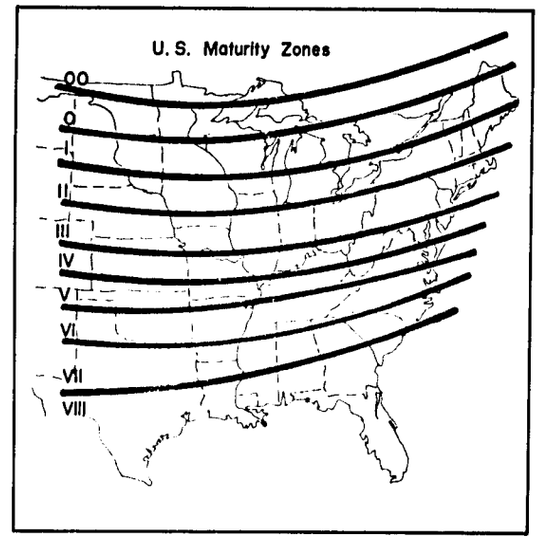


Fig. 3. The zones for which the 10 U.S. maturity groups are designated.

maturity groups is shown in *Fig. 4.* Of the materials found to be insensitive during the spring and tested again in the fall, 82 percent gave an insensitive reading. The questionable cultivars will be checked again. Although the relative number of insensitive cultivars is small, their existence indicates that it will be possible to incorporate this character in new varieties.

The evidence from various sources suggests that soybean first originated in the northern-most part of China. Manchuria is considered to be the secondary center of origin. If this is true, the greatest diversity for soybean should be present at these two locations. Therefore, any materials now grown at the same latitudes (40° to 45°N) could have the genetic diversity for wide adaptability. Most of the photoperiod insensitive cultivars came from the U.S. maturity groups 00, 0, and I, which are adapted to the latitudes above 40°N.

During 1973, cultivars from the University of Minnesota were tested and determined to be truly day-neutral *(72-73 Annual Report).* After the spring screening of the world varietal collection, the day-neutral cultivars were used in our crossing program to combine various agronomic characteristics with disease resistance. A number of these crosses are in the F_4 generation. Sixteen selections were consistently superior in both the F_2 and F_3 generations, and a number of single plants were selected from these crosses for further testing.

To better understand the inheritance of days to flowering and photoperiod insensitivity, a number of crosses were made between photoperiod insensitive and sensitive lines. In a genetic analysis of two crosses, the days to flowering values of the progeny exceeded that of both the parents, indicating the presence of overdominance, i.e., the heterozygote is the superior genotype *(Table 6).* Thus, late flowering is controlled by dominant gene(s), although the heterozygote is much later in flowering than the homozygous dominant. The F_2 data plotted in *Figure 5* show bimodality suggesting that this character is controlled by several genes. The distribution is skewed toward the late flowering type and the F_1

The breeders and physiologists use artificial lights to lengthen the day in our screening of the soybean and mungbean germplasm for photoperiod insensitivity.

generation; again indicating the overdominance of the heterozygote.

It is not known if early flowering and photoperiod insensitivity are controlled by linked genes. If there is a linkage between these factors, the probability of recovering late flowering types with photoperiod insensitivity would depend largely on the strength of the linkage. As there is a range of days to flowering among our photoperiod insensitive cultivars (see *Table 5*), it is probable that the linkage would not completely exclude any recombinants.

Cultivars having a high yield potential and other desirable traits are being crossed with selected insensitive lines to develop day-neutral varieties that will have wide adaptability.

SOURCES OF DISEASE RESISTANCE. Immunity to soybean rust *(Phakopsora pachyrhizi)* in the cultivated soybean has not yet been discovered. Among the wild species, a few specimen of *Glycine soja* showed some resistance, and our only accession of *Glycine wightii* showed considerable resistance. This species will be further tested, and if it proves to be truly resistant, attempts will be made to transfer such resistance to the cultivated species through wide crosses. Most of the soybean cultivars with moderate field resistance to soybean rust came from southern Japan.

The cultivar Shih-Shih is resistant to soybean mosaic virus and downy mildew *(Peronospora manshurica)* but is highly susceptible to rust. Therefore, Shih-Shih has been crossed with the cultivars possessing some degree of resistance to rust.

Table 5. Soybean cultivars that had the same mean num- of days to flowering regardless of day length.[a]

AVRDC acc. no.	Varietal name	Origin	Mean No. of days to flowering
166	PI 154190	Holland	44
200	PI 189952	France	37
205	PI 194631	Sweden	39
214	PI 194646	Sweden	36
215	PI 194647	Sweden	38
218	PI 194656	Sweden	34
219	PI 196486	Sweden	34
220	PI 196501	Sweden	36
222	PI 196525	Sweden	35
225	PI 196528	Sweden	34
226	PI 196529	Sweden	34
227	PI 196530	Sweden	34
233	PI 321172	Not known	37
291	PI 180532	Germany	37
296	PI 189861	France	36
782	81035	Japan	38
1038	68484-1 490	Not known	37
1309	227213 307	Japan	34
1322	PI 248407	Not known	37
1999	Ou-Yuan Early	Japan	37

[a] Given both 12-hr and 16-hr photoperiod treatments in spring (planted March 22) and fall (planted Oct. 8) seasons at AVRDC.

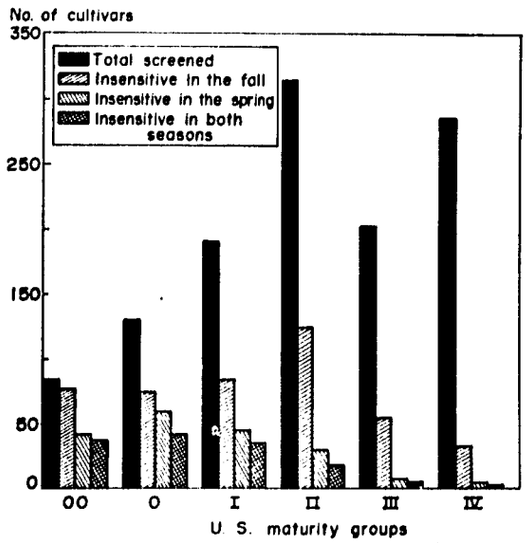


Fig. 4. The distribution of photoperiod insensitive soybean cultivars by U.S. maturity group in two screenings.

Both soybean mosaic virus (SMV) and soybean rust are serious problems in Indonesia. Lines with high yield potential from Indonesia are being crossed with SMV-resistant or soybean rust-resistant selections. The F_4 and F_5 populations with resistance to rust will be artificially inoculated with SMV, and the resistant selections will be grown in yield trials in Indonesia.

The original source of resistance to bacterial pustule *(Xanthomonas phaseoli* var. *sojense)* is Clemson Non Shatter. This cultivar has been crossed with other U.S. varieties. The progeny have been used in our crossing program with the expectation of obtaining plants resistant to bacterial pustule.

Some selected crosses where resistance to the various diseases has been combined, are shown in *Table 7.*

In addition to these major diseases, our soybean germplasm collection contains sources of resistance to leaf spots *(Phyllosticta* and *Septoria* sp.), *Phytopthora* root rot, bacterial blight *(Pseudomonas glycinea),* frog-eye leaf spot *(Cercospora sojina),* and cyst nematode. The lines containing such resistance are to be included in our future crossing program.

PLANT PATHOLOGY

FUNGAL DISEASES. Soybean rust, *Phakopsora pachyrhizi,* is the most serious soybean disease in Asia and Australia and can be regarded as a potential threat to other soybean production regions. In 1974, this disease was studied intensively by the patholgists.

A simple rust nursery was established to provide a year-round supply of rust inoculum for field screening trials. The nursery area was 180 m^2, and was divided into four sections. One section was planted each month in rotation with a susceptible cultivar such as Shih-Shih (or TK 5). To encourage rust development, a population density of 600,000 (or 400,000) plants per hectare was used.

Two artificial inoculations with uredospore suspensions (20,000 spores/ml) are made to assure that rust develops in the nursery. The first inoculation is made three weeks after emergence, and the second, 10 days later. After the first

Table 6. Mean number of days to flowering for two crosses between photoperiod insensitive and sensitive soybean cultivars with their standard errors and variance.

		Mean No. of days to flowering	S^2
AVRDC Cross 40301 Pedigree: 68671.523 / 153.212			
	Parent (P_1)	40.1	1.04
	Parent (P_2)	23.1	1.41
	Mean of parents	*31.6*	
	F_1 generation (mean)	44.2	1.21
	F_2 generation (mean)	33.4	20.16
AVRDC Cross 40081 Pedigree: 189.876 / CH 1			
	Parent (P_1)	23.0	2.25
	Parent (P_2)	35.3	2.49
	Mean of parents	*29.1*	
	F_1 generation (mean)	44.3	2.07
	F_2 generation (mean)	39.0	35.88

Table.7. F_3 populations with high number of pods per plant and field resistance to important diseases.

AVRDC selection no.	Pedigree	No. of selections	No. of pods/ plant	Mean No. of days to maturity	Field resistance to a/			
					Soybean rust	Bacterial pustule	Downy mildew	Soybean mosaic virus
30050-2	Higo Daizu / R-10	10	137	91	R		R	
30059-2	Shin 2 / Tainung 3	6	96	86	R		R	R
30064-1	Shin 2 / KS 469	4	149	98	R		R	
30065-1	Kairyou Shirome / KS 419	4	131	94	MR		R	R
30075-1	TK 5 / PI 200492	3	116	98	MR		R	
30088-1	KS 535 / Bragg	12	116	98	R	R	R	
30094-1	66-G-3 / PI 200492	24	151	98	R		R	
30096-1	66-G-3 / D 69-9801	3	124	98	MR		R	
30108-1	PI 200492 / CNS	23	132	98	MR	R	R	
30109-1	PI 200492 / Semmes	13	126	98	MR		R	
30138	Yagi 1 / PI 200492	3	119	88	R		R	

a/ Field observations: R - resistant; MR - moderately resistant.

inoculation, the plants are watered twice a day for 10-minute periods using a perforated surface pipe system. Rust symptoms are usually evident on soybean leaves 10 days after the first inoculation. The yield losses of heavily infected soybeans in the nursery generally were more than 80 percent, with yields as low as 0.3 ton per hectare.

The weather also exerts considerable influence on the development of this airborne pathogen. When the epidemiology of soybean rust is sufficiently understood, disease forecasting may become feasible for scheduling spray applications or destroying sources of inoculum. The annual variation of the spore concentration *(Fig. 6)* was determined using a simple spore trap *(Fig. 7)*.

In the warmer regions of Southeast Asia,

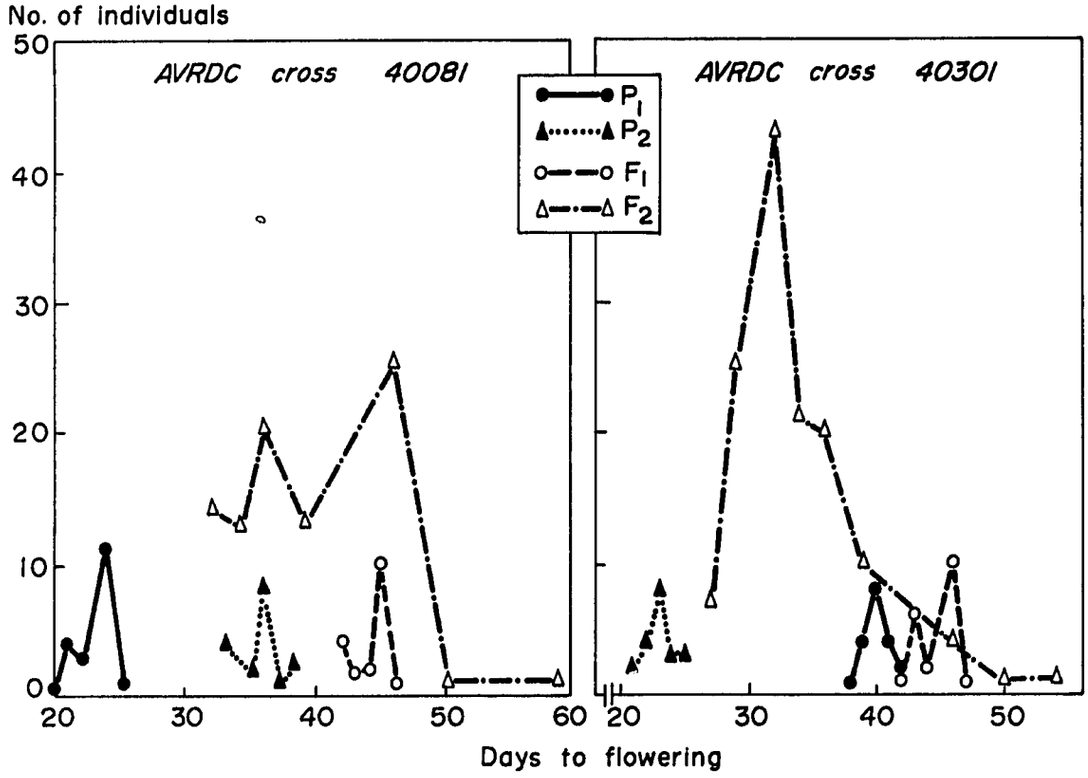


Fig. 5. Distribution of the parents and progeny (F_1 and F_2) of two crosses by number of days to flowering.

alternate hosts play only a small role in the overwintering of the soybean rust fungus. However, successful infection of other leguminous hosts such as the common bean *(Phaseolus vulgaris)*, the wild soybean *(Glycine soja)*, and the yam bean *(Pachyrrhizi erosus)*, with the rust uredospores has been accomplished under both field and laboratory conditions. *P. pachyrhizi* has a wide range of hosts, allowing the pathogen to go through repeated uredocycles on a succession of hosts grown at different times of the year. For example, uredospores taken from the leaves of the common purple nutsedge *(Cyperus rotundus)* can produce rust on soybean leaves. The role of nutsedge as a possible alternate host for the soybean rust fungus is under investigation.

In the mild, moist winter of southern Taiwan, the organism goes through the successive cycles of uredospore formation unimpeded. If, as with the leaf rust of wheat *(Puccinia recondita)*, a 1,000-pustule/leaf stage could be used to predict an epidemic, our spore-trapping system could be used to forecast outbreaks of soybean rust.

Soybeans in Taiwan suffer heavy damage in both the spring and fall seasons from serious outbreaks of soybean rust. Extensive surveys of both farmers' fields and our world varietal collection planted at different locations in Taiwan indicated that all the soybean cultivars surveyed were susceptible to rust. During the surveys, cultivars previously reported in the literature to be resistant to rust showed susceptibility. These were: PI 200492, PI 200451, TK 5, KS 3, CH 1, and CH 3.

Only Tainung 4 had some field resistance to rust with relatively few rust pustules and less chlorosis than other cultivars. Various degrees of field resistance to rust were identified among some soybean breeding lines and segregating populations. Further testing of these lines using artificial inoculation is necessary to determine their true resistance.

A soybean rust nursery was established to provide a year-round supply of rust inoculum for field-screening trials.

Because the rust fungus is an obligate parasite, it cannot be cultivated on cultural medium, but will only grow inside the plant tissues of a living host. Attempts to grow this fungus on soybean leaf discs floating atop various nutrient solutions failed due to bacterial contamination. However, in March, a detached whole leaf technique was used successfully as a means of growing rust fungus. Since then, this technique has been refined. Greenhouse-grown soybean leaves (free of rust) are carefully detached at the base of the petiole. After being disinfected with a solution containing two percent active chlorine, the leaves are rinsed in distilled water and dried aseptically by blotting. They are then placed on filter paper inside a sterilized petri dish. Filter paper is placed in the petri dish and saturated with distilled water. Three leaves are placed in each dish. They are inoculated with a uredospore suspension, and the dish is incubated inside a growth chamber at 24°C under alternate 12-hour light and dark cycles. Seven days of incubation are required before the first rust pustules become evident. The infected leaves can be kept green for 30 to 40 days, facilitating study of rust development after pustule formation.

To determine if there is any relationship between the concentration of uredospores in the inoculum and the formation of rust pustules on inoculated soybean leaves, a range of uredospore concentrations was tested on the leaves of Shih-Shih using the detached leaf technique. A linear relation was found between the log of inoculum concentration and the number of rust pustules formed on the leaves. This high correlation existed

Rust symptoms are usually evident on soybean leaves 10 days after inoculation.

within the inoculum range of 1,000 to 20,000 uredospores/ml, when one ml of the uredospore suspension from each concentration was applied to a leaf *(Fig. 8)*.

The incidence of disease in crops is difficult to accurately assess and the subsequent loss in yield is not easily expressed in economic terms. Yield-loss trials were conducted in the spring and fall to determine if rust could be responsible for the low soybean yields often obtained by local farmers. Three soybean cultivars (Shih-Shih, KS 3, Tainung 4) were treated with Dithane M-45 (a fungicide recommended for soybean rust control). An unsprayed plot served as control.

A split-plot design with four replications was used in a 576-m^2 field. This area was divided into 16 main plots (28 m^2) and then, 32 sub plots (12 m^2). The population density was constant at 400,000 plants/ha in each experiment. Uredospore suspensions were sprayed on the soybean plants twice. Moistened leaves covered with rust pustules were also placed between the rows as a source of extra inoculum.

At harvest, yield data on total seed weight and 100-seed weight from each sub plot were taken. The results presented in *Table 8* clearly indicate that rust caused a reduction in yield. The correlation coefficients between the standard disease index and the yield were -0.87 and -0.99 (spring and fall, respectively), meaning that yield loss and disease intensity were significantly related. When not sprayed with Dithane M-45, KS 3 had a 50 percent and 30 percent reduction in yield in the spring and fall trials, respectively (see *Table 8*). The results for both Tainung 4 and KS 3 (especially when compared with those of Shih-Shih)

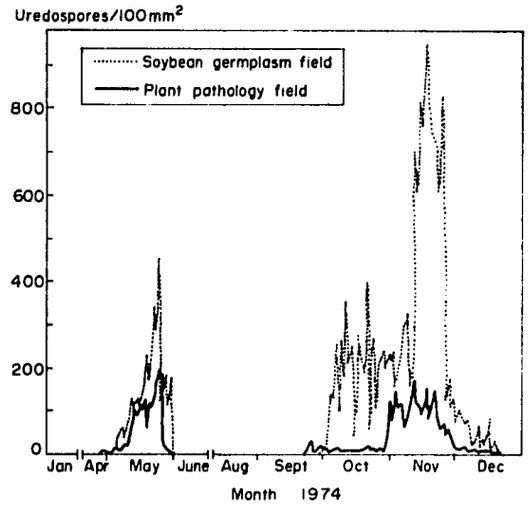


Fig. 6. Variation in the spore concentration of soybean rust *(P. pachyrhizi)* in two fields at AVRDC.

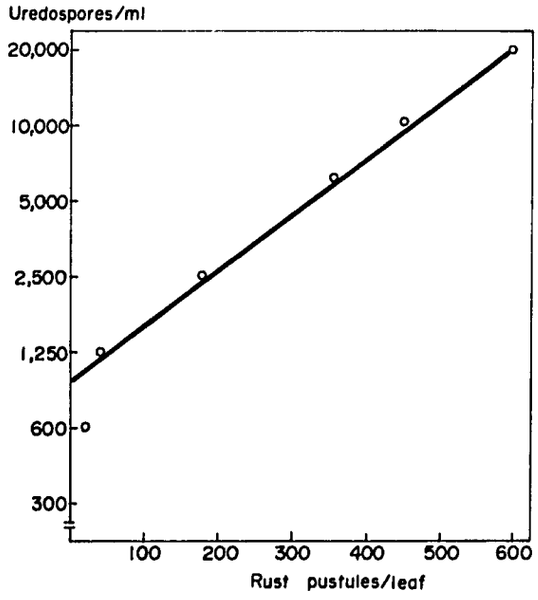


Fig. 8. Relation between the log of inoculum concentration and the number of rust pustules formed on the leaves.

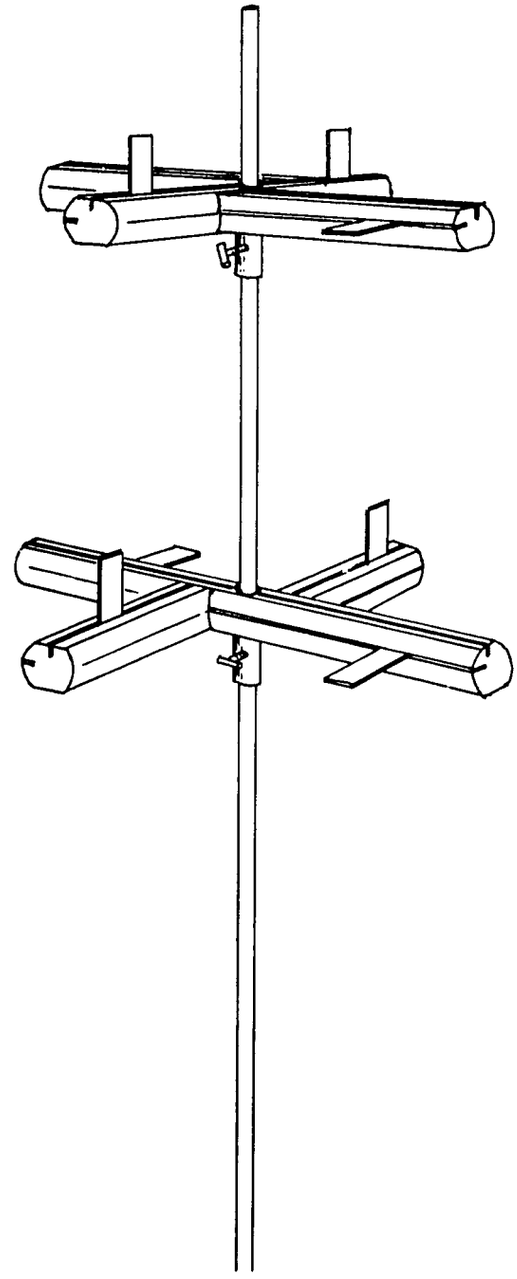


Fig. 7. A simple spore trap designed to collect uredospores from the atmosphere.

indicate that more needs to be known about the physiological factors influencing the yield loss by soybean rust infection. Such studies have been initiated.

Two trials were conducted to compare the effectiveness of six fungicides recommended by

Table 8. Yield loss caused by soybean rust (*P. pachyrhizi*). [a]

AVRDC acc. no.	Varietal name	Yield loss [b] Spring (%)	Fall (%)
38	Shih-Shih	23	12
57	Tainung 4	24	15
2043	KS 3	50	30

[a] Spring trial planted Mar. 6; the fall trial, Sept. 25. The population density was 400,000 plants/ha. Data were taken from 5.6-m^2 central strips of each 12-m^2 plot; 4 replications. Dithane M-45 wp (400X) was applied 7 times in the spring trial and 5 times in the fall to the protected plots.

[b] The yield of the control plots as a percent of the yield produced in the protected plots.

chemical companies for soybean rust control. These were Plantvax, Dithane M-45, HOE 13764, Previcur S-70, Saprol, Kumulus-S, and Polyram-combi. The cultivar Palmetto had a yield that was 34 percent higher than that of the control when treated with either Polyram-combi or Dithane M-45 *(Table 9)*.

Table 9. Relative yields of two soybean cultivars inoculated with soybean rust *(Phakopsora pachyrhizi)* and sprayed with different fungicides.[a]

Fungicide	Manufacturer	Ingredient (kg/ha)	Relative yield as % of control (%)
Polyram-combi	BASF	1.5	134 [b]
Dithane M-45	Rohm & Haas	2.0	134 [b] & 130 [c]
Plantnax	Uniroyal	2.0	123 [c]
Saprol	Celemerk	1.5	123 [c]
Control			*100*
Kumulus-5	BASF	2.0	99 [b]
Previcur S-70	Schering AG	2.0	98 [b]
HOE 13764	Hoechst	2.0	98 [c]

[a] The cultivars Palmetto and Shih-Shih were planted Oct. 1, and harvested Dec. 31 and Jan. 3, 1975, respectively. The population densities were 227,500 and 142,500 plants/ha for Palmetto and Shih-Shih, respectively. Each cultivar was inoculated 4 times.

[b] Tested on Palmetto.

[c] Tested on Shih-Shih.

Several isolates of *Phakopsora pachyrhizi*, designated by their local origin, e.g., the Filipino isolate, the Indonesian isolate, and the Taiwan isolate, have been reported. To date, no races of soybean rust have been reported. However, at least two physiological races of this rust fungus have been identified by the pathologists through their pathogenic reactions. One race, tentatively designated as Race 1, occurs in Taiwan and elsewhere in East and Southeast Asia. When a soybean cultivar is infected by this race, it produces leaf symptoms resembling the descriptions of soybean rust found in the literature.

The other race (tentatively designated as Race 2), though morphologically identical to Race 1 under microscopic examination, produces symptoms characterized by larger and less clearly defined lesions of brown to reddish necrotic spots on the infected soybean leaves. A single pustule or a compact cluster of pustules is usually located at the center of the lesions on the infected leaf's lower surface. The necrotic leaf tissues often appear as concentric rings. The color of the lesions may fade or turn dark if the disease development is favored by environmental conditions.

The Race 2 pathogen of rust attacked various soybean cultivars planted at Wandolio (Taiwan) as well as those planted at AVRDC. Only 31 soybean cultivars were susceptible to this race in a field screening of 4,112 cultivars at AVRDC. A majority of the cultivars attacked by the Race 2 pathogen came from Nigeria.

When detached leaves of Shih-Shih were rub-inoculated with a diseased leaf of the cultivar 8-3-2 (Acc. 2374), uredospores of the two races, isolated from one naturally infected leaf, two types of symptoms developed on the leaves. The leaves inoculated with uredospores of Race 1 produced typical soybean rust symptoms, i.e., small rust spots uniformly distributed on the leaf surface. Whereas, those leaves inoculated with spores of Race 2 produced large necrotic, coalesced lesions. Infection of soybean can take place when the plants are young, if there is an abundance of freshly released uredospores and weather conditions are favorable. Inoculation studies indicated that six to eight days are required for rust infection to become evident at a temperature range between 20° and 30°C and with a high

relative humidity in the early morning hours. Temperatures below 22°C and above 32°C, or successive rainy days, will prolong the time required for rust development.

Six to eight cycles of uredospores can be produced in a single growing season. Any number of these cycles might occur on the same leaf depending on the length of time it survives. It was observed that *P. pachyrhizi* went from the uredospore (asexual) stage to the teliospore (sexual) stage in the later phases of its life cycle. As a result of this transition, the number of teliosori formed on the infected leaves increased greatly compared to the number of uredosori. There are other factors that may cause this change to take place, e.g., temperatures above 32°C or below 19°C, or the presence of metabolites secreted by either the pathogen itself or the soybean leaf.

There were only a few days during the 73-74 winter at AVRDC when the air temperatures were below 15°C (see Crop Environment). Most of the uredospores that developed late in the soybean growing season are dislodged by the strong winds. However, laboratory studies indicate that the production rate of the rust pustules on the infected leaves slows down in cold weather, but fresh colonies of uredospores are still being generated. This suggests that both self-inhibitor and stimulator-like compounds are operating in the uredospore system of the soybean rust fungus.

Another fungal disease, purple seed stain *(Cercospora kikuchii)*, is the most prevalent and widely distributed seed disease of soybean. The leaf symptoms of purple seed stain are very difficult to distinguish from other common leaf diseases of soybean, but the symptoms are readily recognized on the seed. Besides purple discoloration, cracks often occur in the discolored areas, giving the seed a rough dull appearance.

Weather conditions during flowering and plant maturity apparently influence the percentage of discolored seeds, and more than 50 percent of the seed of susceptible cultivars may be discolored. The causal fungus overwinters on diseased leaves and stems as well as in the infected seed.

Seed infected with *C. kikuchii* can have markedly lower germination rates. Experiments showed that seeds completely discolored by this disease sometimes lose 90 percent of their viability *(Table 10)*.

Table 10. Effect of purple seed stain *(Cercospora kikuchii)* on the germination of soybean seeds.[a]

Purple seed stain	No. of seeds sown	No. which germinated	Germination rate (%)
With	48	5	10
Without	48	46	96

[a] The cultivar Shih-Shih was sown Feb. 10 and evaluated daily until March 7.

To date, several isolates of this pathogen have been identified, and their pathogenicity to soybean was confirmed through inoculation tests. In laboratory studies, the pathogen was multiplied by growing it on carrot or soybean leaf extract agar media at 28°C. An incubation period of two weeks under these conditions is necessary to assure good sporulation of the conidia.

BACTERIAL DISEASES. Soybean is attacked by a number of bacterial diseases, but the most important one in the tropics and subtropics is bacterial pustule caused by *Xanthomonas phaseoli* var. *sojense*.

Bacterial pustule is favored by high temperatures and humid climates. This disease is widespread in India, Indonesia, and in other countries where the cultivation of soybean is intensive.

The situation could become even more critical because the current commercial cultivars resistant to bacterial pustule are largely derived from only one resistant parent, Clemson Non Shatter, and the resistance is conditioned by a single recessive gene. If a highly virulent strain of the pathogen mutates, an outbreak of the disease could caused a considerable reduction in yield. Selected soybean cultivars were inoculated and grown in the greenhouse. Two types of lesions could be distinguished: (i) on resistant cultivars, a hypersensitive reaction resulted in small brown lesions that did not spread; (ii) on susceptible cultivars, watery-progressive lesions developed. In some cultivars with moderate resistance, a mixture of hypersensitive and watery lesions occurred.

VIRUS DISEASE, Soybean mosaic virus (SMV) is present to a limited extent wherever

soybean is cultivated. The pathologists have found SMV at AVRDC, in the Pingtung area (in southern Taiwan), and at Chiang Mai, Thailand.

Soybean mosaic virus isolated from soybean was identified by symptomatology, serology (SMV antiserum was obtained from Dr. John P. Ross of North Carolina State University), host range, and electron microscopy.

Soybean cultivars vary in their degree of susceptibility to SMV. Most cultivars, however, develop a transient systemic clearing of the veins followed by a distorting mosaic in the younger leaves causing dark green, puffy areas along the main vein with yellowing between the dark green areas. The plants infected with SMV are usually stunted and form few pods. On some cultivars, the leaves develop severe necrosis.

Experiments were conducted to assess the yield loss caused by SMV. A susceptible cultivar (Tainung 4) was inoculated with SMV and its yield was compared to that of a resistant cultivar (Shih-Shih). The two cultivars were planted at density of 400,000 plants per hectare in the split-plot design used for standard yield trials. The plants were inoculated Nov. 1 (2-leaf stage), Nov. 19 (flowering started Nov. 26), or Dec. 5. Non-inoculated plants served as control.

Tainung 4 showed a 50 percent reduction in yield when inoculated one week after germination, whereas Shih-Shih was not affected. The greatest yield loss for Tainung 4 occurred with the earlier inoculation and the reduction was primarily due to a decrease in the number of pods per plant and the seed weight *(Table 11)*. There was an apparent relationship between the time of the inoculation and the percentage of seeds with mottled seed coats. When Tainung 4 was inoculated shortly after germination, it had a higher percentage of mottled seeds than when inoculated at later stages. However, the seeds of Shih-Shih were unaffected.

A total of 1,883 soybean cultivars were screened in the field for resistance to SMV. Inoculation was made at the two-leaf stage by rubbing the leaves with sap from SMV-infected leaves. Any plants that showed no symptoms after three weeks were inoculated again. The cultivars that were still uninfected were further tested for resistance to SMV in four additional screenings (once outdoors in pots, twice in the greenhouse, and once in the field). Seventeen cultivars remained resistant after these severe tests and are being used in the breeding program *(Table 12)*.

Table 11. Response of Tainung 4 to inoculations of soybean mosaic virus (SMV) at different growth stages. a/

When inoculated b/	No. of pods per plant	100 seed wt (g)	Yield (g/10 plants)	Yield as % of control
2-leaf stage	8.8	16.1	94.87	48.96 **
Before flowering	13.1	16.3	145.00	74.83 **
After flowering	13.2	18.8	178.00	91.87 **
Control	14.2	18.9	193.75	

a/ Planted Oct. 20 in the field.

b/ Inoculations made Nov. 1 (at 2-leaf stage), Nov. 19 (flowering began Nov. 26), or Dec. 5 (after flowering).

** Significantly different from the control at the 1% level.

Table 12. List of soybean cultivars resistant to soybean mosaic virus. a/

AVRDC acc. no.	Varietal name	Origin
38	Shih-Shih	Japan
171	PI 159764	Korea
260	PI 153241	Belgium
270	PI 153262	Belgium
288	PI 180501	Germany
311	PI 189898	France
358	PI 248403-1	Not known
394	Norsoy	U.S.A.
452	PI 84668	Korea
453	PI 84668	Korea
519	PI 153263	Belgium
1096	PI 80461 201	Japan
1200	PI 89109	Japan
1501	PI 157409	Korea
1601	PI 62204-1	China
2021	PI 230973	Japan
2042	Tainung 3	Taiwan

a/ 1,883 cultivars were field-screened for resistance to SMV in May. The cultivars without infection after 2 inoculations were again tested outdoors in pots in June, twice in the greenhouse (Aug. and Sept.), and in the field (Nov.).

ENTOMOLOGY

Some of the more important arthropod pests of soybean in Southeast Asia are stinkbugs (e.g., *Nezara viridula*), spider mites *(Tetanychus* sp.), leafhoppers *(Empoasca* sp.), scarabid beetles, and several leaf- and pod-feeding lepidopterous larvae. However, probably the most consistently damaging insect pest of soybean in this region is the beanfly. Multiple beanfly infestations, especially when the plants are young, often result in high plant mortality, increased disease susceptibility, and reduced yields.

Although several genera of beanflies have been reported in Southeast Asia, only *Melanagromyza phaseoli* was identified at AVRDC. *M. phaseoli* has a host range that includes soybean *(Glycine max)*, common bean *(Phaseolus vulgaris)*, lima bean *(Phaseolus limensis)*, and mungbean *(Vigna radiata)*. This species has been found in Africa, India, Indonesia, Thailand, Malaysia, the Philippines, and Taiwan.

The beanfly eggs are oviposited one by one beneath the leaf's epidermis. Upon hatching, the larvae burrow until they reach a vein, which is then followed to the midrib and from there to the petiole. The larvae continue to mine down the stem and into the root. They generally pupate near the soil surface, but if necrotic or previously mined tissue is encountered during their migration, the larvae may change direction and pupate elsewhere in the stem.

Plants are attacked as soon as the first pair of leaves begin to unfold and successive attacks occur on new leaves. In older plants, the larvae frequently pupate in the main stem just below a node and do not reach the soil level. Depending on ambient temperatures, the eggs require two to three days to hatch, larval growth lasts nine to twelve days, the pupal period lasts five to seven days, and the adults live three to six days. About three to four weeks are required to complete a generation, and 15 to 16 generations a year may occur in subtropical regions.

Soybeans were sampled over a 9-week period from December 1973 to February. During that time, infestation rates rapidly increased from about 35 to 100 percent *(Fig. 9)*. This sampling supports the findings of Chen[+], who surveyed

[+] Chen, K. H. 1953. Control tests of stem miners in legumes. Taiwan Agr. Res. 4 (1) 90-104 (in Chinese).

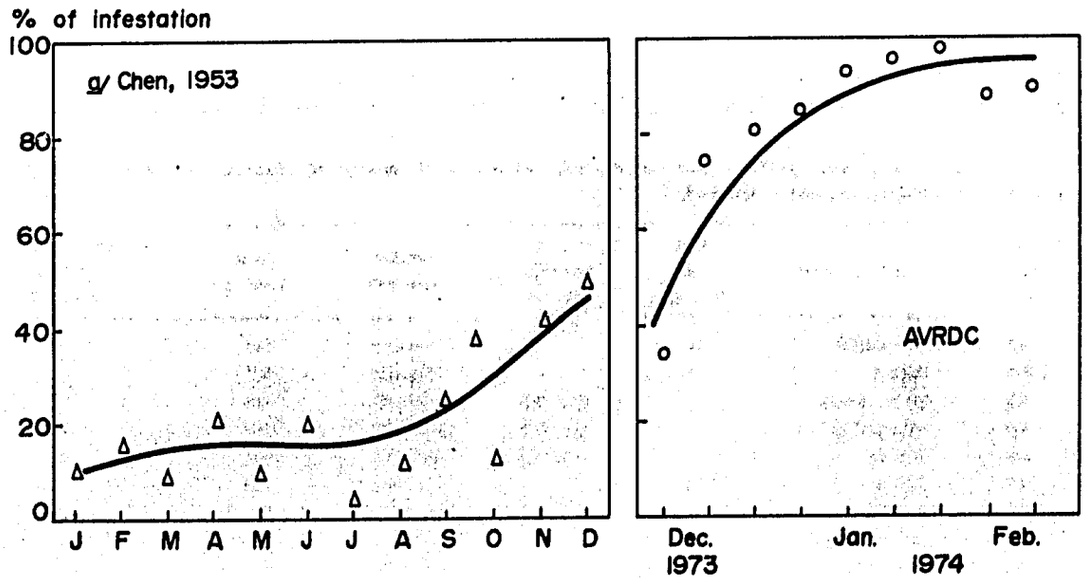


Fig. 9. The occurrence of beanfly infestation in soybean as determined by Chen in 1953 and AVRDC from Dec. 1973 to Feb. 1974. Reference: Chen, K. H. 1953. Control tests of stem miners in legumes. Taiwan Agr. Res. 4 (1) 90-104 (in Chinese).

beanfly populations over a 12-month period (see *Fig. 9)*. Beanfly-damage rates on soybean are generally lowest in the summer and increase in the fall when the crops are usually grown. Population increases beginning in September might be a result of either increased host abundance or more favorable climatic conditions. It would appear that the fall of the year is the most important time to use control measures, although some damage can be expected in the spring.

Because it is both expensive and labor consuming to control this pest with insecticides, which often are not too effective, screening for varietal resistance is being emphasized at AVRDC. For screening, 50 seeds of each cultivar are generally planted. The entomologists take two replicated samples of 10 plants each to evaluate cultivar's resistance to beanfly attack. Although germination and post-germination mortality counts are recorded, the degree of stem damage is the most reliable indicator of infestation and is determined by actually dissecting the stem. Either the percent of damaged stems per 10-plant sample or the actual number of beanfly larvae and pupae is used to determine infestation levels.

Because different beanfly species have been reported, and some variation in the same species or biotypes could be expected with insects in geographically isolated areas, field screening was conducted at AVRDC (spring and fall), in Thailand, and in the Philippines (October and November, respectively). From these field screenings, eight cultivars were identified as field resistant *(Table 13)* and 66 cultivars as moderately resistant. Thus, varietal resistance to beanfly does occur in soybean, and the development of high yielding varieties with resistance to beanfly attack should be possible.

However, until such varieties are developed, insecticides will continue to be required to prevent severe crop losses from beanfly infestation. Therefore, AVRDC has included insecticide testing for beanfly control as part of its research program. Because the beanfly larvae are inside the plant, the insecticides tested included systemics, which are capable of penetrating the plant tissues. The cultivar Shih-Shih was planted March 25 in 10-m^2 field plots with four replications in a random complete block design. The experiment was repeated in September. The results for the fall trial are presented in *Table 14*. Folimat, Hostathion, and Azodrin gave the best protection in the fall. A different set of insecticides were tested in the spring, of which Dimethoate, Furadan, and Disyston were the most effective in reducing beanfly damage.

PLANT PHYSIOLOGY

The results of four population-density experiments conducted in 1973 and 1974 are shown in *Figure 10*. The cultivar Shih-Shih was grown in

Table 13. List of 8 soybean cultivars that had the least infestation of beanfly *(M. phaseoli)* in screening trials at AVRDC, in the Philippines, and in Thailand. [a]

AVRDC acc. no.	Varietal name	% of stem damage	No. of beanflies per plant	Where screened	Season screened	Total no. of cultivars screened
183	PI 180520	10		Thailand	fall	126
1397	83868	10		Thailand	fall	126
25	SP Soybean		0 to 0.5	AVRDC	fall	150
40	Huang-Pau-Tsu		0 to 0.5	AVRDC	fall	150
48	Wilken		0 to 0.5	AVRDC	fall	150
947	92748	15		Thailand	fall	126
947	92748	25	0.5 to 1	Philippines	fall	126
2084	Indonesia 673	25		AVRDC	spring	1,000
2122	Indonesia 1288	25		AVRDC	spring	1,000

[a] At AVRDC two trials were planted Apr. 20 and Sept. 8, spring and fall, respectively). 126 cultivars were planted Oct. 27 in Thailand and Nov. 1 in the Philippines.

Table 14. List of insecticides that gave the most effective protection to soybean from beanfly *(M. phaseoli)* infestation. [a]

Insecticides [b]	Manufacturer	Active ingredient (kg/ha)	No. of beanflies [c]	No. of plants with damaged stems [c]	Reduction in stem damage as a % of control
Folimat	Bayer	0.5	0.25	0.25	98
Hostathion	Hochest	1.0	0.25	0.75	95
Azodrin	Shell	0.5	2.25	2.25	84
Furadan	FMC	2.0	9.50	6.75	55
Fitios-B 77	Snia Viscosa	0.5	12.75	11.0	21
Control	—	—	14.50	14.0	0

[a] The cultivar Shih-Shih was planted Sept. 12 in 10-m^2 plots with 4 replications. Only the fall trial is presented because of the higher populations of beanflies as shown in *Figure 8.*

[b] The following insecticides were also tested, but had infestation rates equal to or higher than the control: DDT, Union Taiwan; Thimet, Cyanamid; PP-505, ICI; and AC 92100, Cyanamid.

[c] From a 20-plant sample.

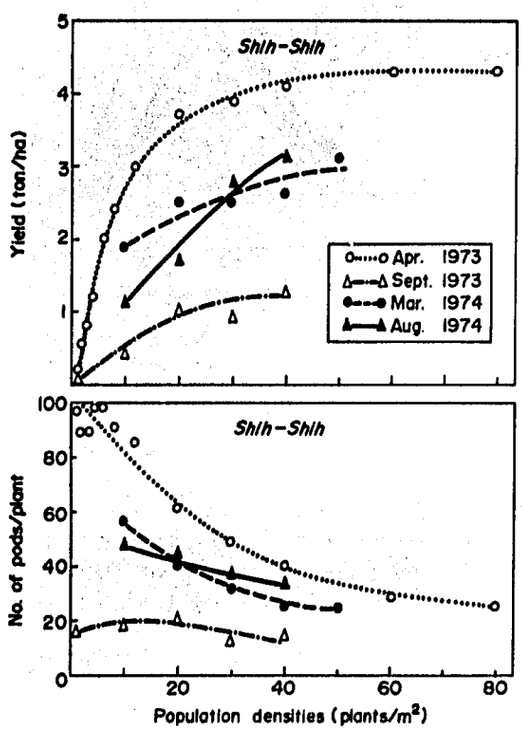


Fig. 10. Response in yield and number of pods per plant of the soybean cultivar Shih-Shih to different population densities in 4 separate experiments.

each experiment. Depending upon the treatment used, the yield varied from 1.2 to 4.0 tons/ha. The physiologists noted that a slight increase in yield is possible even at a population density greater than 400,000 plants per hectare, and that the variation in yield is primarily due to the number of pods per unit area *(Fig. 10, Table 15).* There was no significant difference between treatments in the number of seeds per pod or 100-seed weight. These observations indicate that the physiological factors that limit the yield were operating at the early growth stages, but not during the pod filling stage.

Another experiment was conducted to determine varietal response to different population densities. Four cultivars were planted at four different densities ranging from 200,000 to 500,000 plants per hectare. The results presented in *Figure 11* show the various responses, which indicate the interaction between variety and density.

A shading and CO_2-enrichment experiment was conducted in the spring. Shih-Shih was planted in the field at a population density of 250,000 plants/ha. Twenty-five days after germination, different plots were subjected to either CO_2 enrichment (450-750/ppm) or shading (50% of prevailing solar radiation) treatments for a 10-day period at different growth stages. Other plots

Table 15. Comparison of various plant characters when Shih-Shih was planted at different population densities.[a]

Plant characters	Population densities 10	20	30	40	Correlation coefficient
	(plant/m²)				
No. of flowers/m²	937	1,520	2,733	2,368	0.9426
No. of pods/m²	427	842	1,146	1,340	0.9866
Pod formation rate (%)	50	55	42	57	-0.082
Bean yield (kg/ha)	1,097	1,690	2,771	3,124	

[a] Cultivar Shih-Shih was planted 4 different times, (April 1973, Sept. 1973, March 1974, and Aug. 1974) at 4 different population densities. Data are the means of the 4 trials.

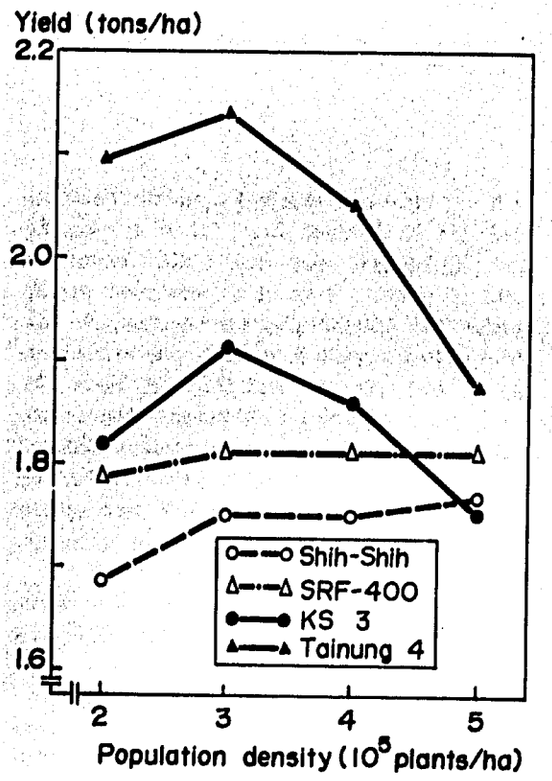


Fig. 11. Varietal responses in yield to 4 different population densities.

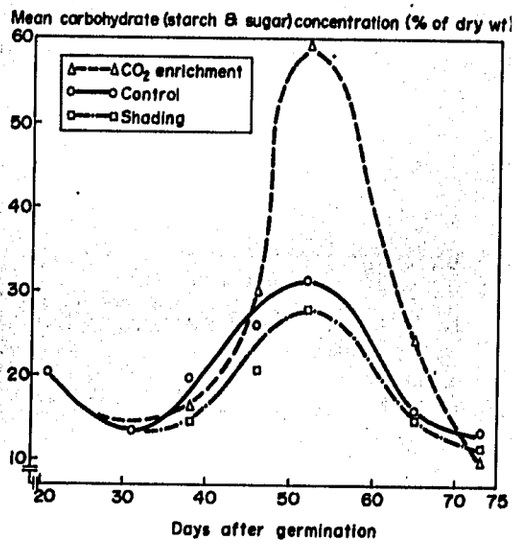


Fig. 12. The effect of CO_2 enrichment and shading on the carbohydrate content of soybean plants (leaf and stem) from 22 to 73 days of age.

received continuous CO_2 enrichment or shading.

The enrichment with CO_2 increased the bean yield, whereas shading reduced it. The yield increase or decrease under the continuous CO_2-enrichment or shading treatment, respectively, can be attributed to the increase or decrease in the number of pods per plant (r = 0.823). Although the number of flowers produced per plant was not significantly different between the two treatments, CO_2 enrichment or shading determined the number of flowers retained or dropped. Obviously, source was the major limiting factor for pod formation.

Because the 100-seed weight was unaffected by any treatment, it appears that source limits the yield up to the seed-filling stage. Comparisons of the carbohydrate (sugar and starch) concentrations in the leaf and stem at various growth stages under the different treatments demonstrated this even

more clearly *(Fig. 12)*.

Analysis of the carbohydrate concentration was begun 21 days after germination. The concentration decreased slowly reaching its minimum level around 30 days. Then it increased rapidly to attain its maximum level 50 days after germination. After which, the concentration level dropped sharply and was at its lowest level during flowering (see *Fig. 12)*. In the subsequent stages, apparently enough carbohydrates accumulated in the leaf and stem to fill the pods. The CO_2-enrichment treatment caused an accumulation of carbohydrates, and the reverse was true for shading.

The yields obtained with CO_2 enrichment at 25 to 35 days, 35 to 45 days, and 45 to 55 days were comparable to the continuous CO_2 enrichment treatment. There was no significant difference among the shading treatments during the three periods. However, all of them gave significantly lower yields than did the control. Enrichment with CO_2 for 10 days beginning at 55 days after germination did not result in an increased yield compared to that of the control plot. But shading during this period decreased the yield almost to the level of that produced by the continuous shading treatment.

Assuming that source limitation was operating at the later growth stages (pod filling), the data in *Table 16* show that the numbers of pods per plant of both treatments were comparable to that of the control. The low yield in the 55 to 65-days treatment is attributed to a slight decrease in the 100-seed weight. On the contrary, enrichment with CO_2 at this stage did not increase the yield; the number of pods was already determined; and seed expansion was evidently genetically limited. At the final stage (65 to 75 days after germination) when most of the leaves had matured and begun to fall, neither CO_2-enrichment nor shading affected the yield.

The source (photosynthesis) was the primary factor limiting yield for Shih-Shih under field conditions during the early growth stages. Increasing the photosynthetic rate in the early growth stages increased the number of pods per plant resulting in higher yield.

The breeders identified a pure-line selection (Acc. 2120), which produced a large number of pods per plant. Accession 2120 and Shih-Shih were planted in the greenhouse in a small population-density experiment December 3, 1973 under short day length and cool temperatures. Artificial light (incandescent bulbs) was provided a week after germination and was continued for 66 days. Shih-Shih and Accession 2120 were harvested May 8 (150 days after germination) and May 24 (165 days), respectively. *Table 17* compares the plant characteristics of the two cultivars. Their

Table 16. Effect of CO_2-enrichment and shading treatments on the yield components of soybean. a/

Treatments	Yield components					
	No. of flowers per plant	No. of pods per plant	Pod-formation rate (%)	Yield (tons/ha)	100-seed wt (g)	No. of seeds/pod
Continuous CO_2 enrichment	47	38	81	3.6	19	2.1
CO_2 enrichment during 55-65 DAG b/	51	36	70	2.9	17	2.0
Continuous shading	44	24	54	2.0	17	2.0
Shading during 55-65 DAG b/	49	34	69	2.3	16	1.9
Control	51	33	64	2.9	18	2.0

a/ Cultivar Shih-Shih planted March 12 at 250,000 plants/ha. Data are means of 3 replications of 25 plants per plot.

b/ DAG - Days after germination.

Table 17. Plant characters of Shih-Shih and Accession 2120 when grown in the greenhouse. [a]

Characters	When measured	Test cultivars	
		Shih-Shih	Accession 2120
Plant height (cm)	maturity	135	185
No. of branches	maturity	5	10
No. of nodes on the main stem	maturity	25	27
Length of internodes (cm)	maturity	6	7
No. of flowering nodes	maturity	13	19
Leaf size (cm^2/leaf)	during pod formation	53	42
No. of pods/node	maturity	2-3	4-5
Length of pod (cm)	after harvest	4.0	3.5
100-seed wt (g)	after air drying	19	7
Straw wt/plant (g)	after oven drying	16	70

[a] Planted Dec. 3, 1973.

responses to the various population densities in number of pods per plant are shown in *Figure 13.*

Both cultivars had similar responses to the different population densities. However, Accession 2120 gave a greater yield response to population density. The yields leveled off at a density of 30 plants per m^2 for both cultivars. Expressed as kilograms per hectare per day, the value for Accession 2120 was 124 while that of Shih-Shih was 56 in this experiment.

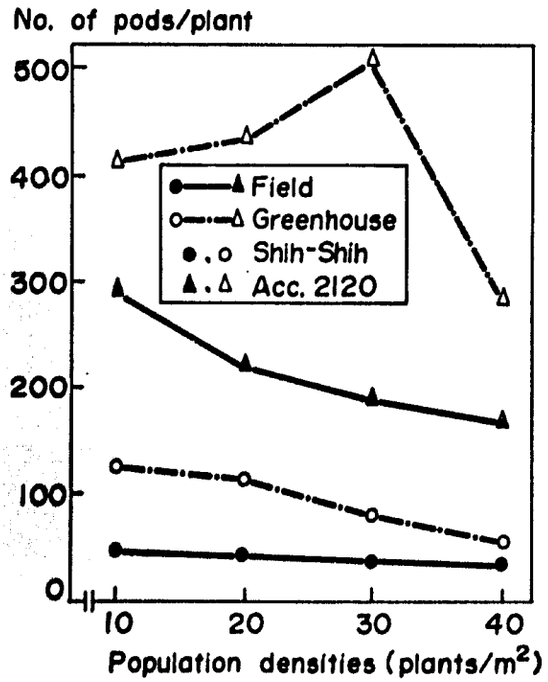


Fig. 13. The effect of population densities on the number of pods per plant of Shih-Shih and Accession 2120 when grown in the greenhouse and in the field.

A population-density experiment was then conducted in the field with Shih-Shih and Accession 2120. Four population densities were used (10, 20, 30, and 40 plants/m^2) with three replications. The plot size was 4.5 m x 8.5 m and received 40 kg/ha N, 35 kg/ha P, and 100 kg/ha K as basal dressing. The seeds were sown Aug. 22 and harvested Oct. 29 and Dec. 6 for Shih-Shih and Accession 2120, respectively. For both cultivars, the number of pods per plant showed similar trends in response to population density (see *Fig. 13).*

The population density did not alter the number of seeds per pod nor the 100-seed weight. Thus, even a cultivar with a computed yield of 7 tons per ha, as that obtained by Accession 2120 in this experiment, could have a much higher yield, since the number of pods is still limited by photosynthesis during the early growth stages. To determine if the higher yield of Accession 2120 was due to an increase in photosynthesis, a number of factors related to photosynthesis were tested. The results show that Accession 2120 has a higher photosynthetic rate than Shih-Shih *(Table 18).* This cultivar will be further tested under CO_2-enrichment and shading treatments.

Table 18. Comparison of the photosynthetic-related characters of Accession 2120 and Shih-Shih.

Characters	Cultivars	
	Accession 2120	Shih-Shih
Specific fresh weight of 18.85 cm^2 leaf (g)	0.30315	0.2572
Thickness of leaf (mm)	0.2845	0.2375
Leaf protein content (% dry wt.)	23.0	15.2
RuDP carboxylase activity (n mole/min/g fresh wt.)		
Early growth stage (30 DAP) a/	399	252
Late growth stage (60 DAP) a/	479	264
Net Photosynthesis rate (Warburg) ($mg\ CO_2/dm^2/hr$)		
Early growth stage (30 DAP) a/	4.7887	4.2437
Late growth stage (60 DAP) a/	4.3891	3.3318
No. of stomata ($1/mm^2$)		
Lower epidermis	180	163
Upper epidermis	294	240

a/ DAP-days after planting.

AGRICULTURAL CHEMISTRY

During 1974, the seeds of 653 cultivars were analyzed for protein content. The frequency distribution of the protein content is presented in *Figure 14*. The range of protein content was from 29.0 to 41.5 percent of dry weight. Eighteen cultivars were planted at AVRDC and at the DAIS in Pingtung to determine whether protein content is affected by location. The mean protein content for these cultivars was 37.1 for those grown at AVRDC and 36.0 for those grown in Pingtung. The mean absolute difference for a given cultivar was 1.45, which is a variation of less than four percent. Thus, it appears that the protein content for a given cultivar is fairly stable.

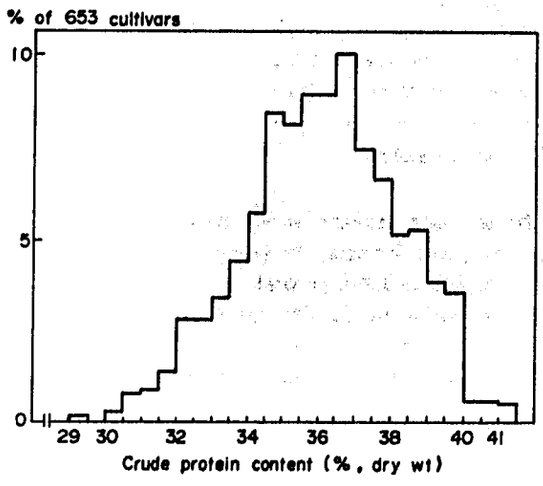


Fig. 14. Distribution of 653 soybean cultivars by protein content (N x 6.25).

The sulfur-containing amino acids are generally considered to be the limiting amino acids of soybean protein. It has been reported in the literature that breeding for high sulfur-containing amino acid content is possible. Assuming that the total sulfur content is an index of the sulfur-containing amino acids, we analyzed the seed of Shih-Shih and Accession 2120, planted at various population densities, for sulfur and crude protein *(Table 19)*. The crude protein as well as the total sulfur content were stable within a given cultivar, but differences between the two cultivars were observed. However, the sulfur to protein ratio showed no significant differences. Eighteen cultivars were analysed to further study this relationship, and their Micro-Kjeldahl nitrogen contents and total sulfur contents are listed in *Table 20.*

Table 19. Comparison of the sulfur and protein contents and sulfur to protein ratio of Shih-Shih to those of Accession 2120. [a]

Variety	Sulfur (% of dry wt)	Protein (% of dry wt)	Sulfur to protein ratio (%)
Acc. 2120	0.35	37.8	0.93
Shih-Shih	0.34	35.4	0.96
Significance level [b]	5 %	1 %	ns

[a] Data are the means of 12 replications.

[b] F-test used to determine significance.

Table 20. Soybean cultivars selected to show range of sulfur and nitrogen contents, and ratios of sulfur to nitrogen in a screening of 18 cultivars. [a]

AVRDC acc. no.	Varietal name	Total S content (% dry wt)	Total N content (% dry wt)	S:N ratio (%)
2036	Semmes	0.374	5.54	6.8
38	Shih-Shih	0.366	5.86	6.2
3688	Lee 68	0.358	6.42	5.6
57	Tainung 4	0.322	5.81	5.5
3556	Adelphia	0.327	6.35	5.1

[a] Planted March 5.

The nitrogen content varied from 5.54 to 6.42 percent, and the range of total sulfur content was from 0.322 to 0.366 percent.

The sulfur to nitrogen ratio varied from 0.051 to 0.068, indicating that the probability of identifying many cultivars with high sulfur-containing amino acids content for use in the breeding program is low. However, the low correlation coefficient between the Micro-Kjeldahl nitrogen and total sulfur content (r = -0.179) showed that protein quality can vary among soybean cultivars. The relationship between the total sulfur content and the available sulfur-containing amino acids will be studied in 1975.

SOIL SCIENCE

Experiments on the response of soybean to applications of nitrogen (chemical fertilizer and compost) were conducted in the spring, summer, and fall at AVRDC.

In the spring, an early maturing cultivar was used to avoid harvesting in the rainy season. The spring crop, of course, depends upon the availability of water for irrigation, whereas both the summer and fall crops are confronted with more competition from weeds and attack from disease and insect pests. The summer crop also risks the possibility of rain during harvest. The yields ranged from 1.8 (summer–without fertilizer) to 3.9 tons per ha (spring–20 tons/ha compost and 90 kg/ha N). The best yields in each season were produced when the plants were given both organic and chemical nitrogen.

Another experiment using four cultivars also showed a definite response to nitrogen. The number of pods was not affected. However, an increase in 100-seed weight resulted in the yield increases plotted in *Figure 15.* Among the four cultivars, Shih-Shih and SRF-400 showed the greatest response to nitrogen.

Having observed a lack of uniformity in soybean plantings at AVRDC, the soil scientists thought this might be due to differences in seed size. Seeds of Tainung 3 were separated into three categories by 100-seed weight (less than 5.7 g, from 5.7 to 9.8 g, and from 99 to 17.2 g). Five pots were used for each group, and two plants were grown in each pot. The plant height at 65 days after germination ranged from 66 cm for the larger seeds to 58 cm for the smaller ones *(Table 21).* The number of pods per plant of the larger seeds was 64 percent greater than that of the

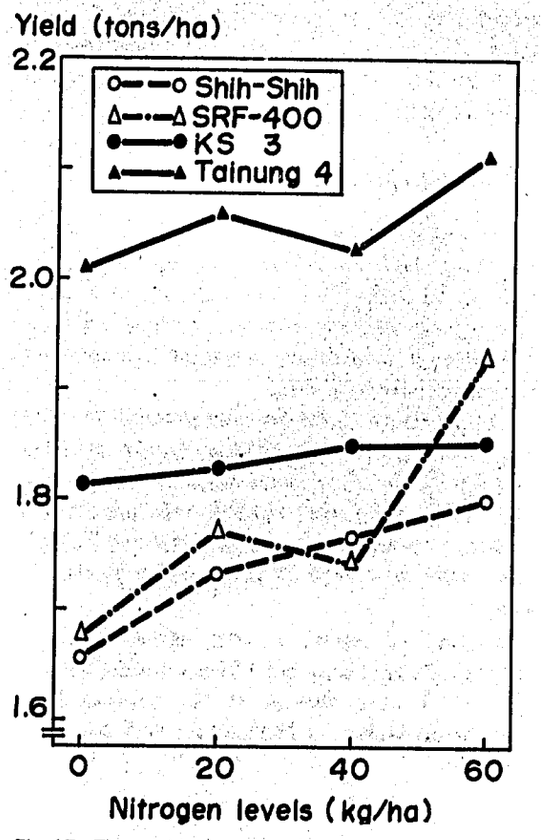


Fig. 15. The yield response of 4 soybean cultivars to nitrogen.

Table 21. Effect of seed size on soybean growth. a/

Range in 100-seed wt (g)	Plant ht (cm)	No. of pods/ plant	Plant dry wt (g)
9.9 to 17.2	66	88	39
5.7 to 9.8	59	66	29
less than 5.7	58	56	26

a/ The cultivar Tainung 3 was planted in pots on April 12; plant height was measured June 20; and harvest was on July 10.

smaller seeds. This indicates that within a single variety, large seeds are superior to small ones.

Seeds harvested from spring and summer soybean crops are often rained on while maturing. An experiment was conducted in the greenhouse to determine the effect of wetting and drying on the germination of soybean seeds. After being soaked in tap water for 12 hours, the germination rate was reduced by 50 percent *(Table 22)*. In addition, the seeds that germinated were observed to be vulnerable to attack from soil fungi. When the wetting and drying cycle was repeated more than twice, the time required to germinate was about one day longer.

Table 22. Effect of wetting and drying cycles on the germinability of soybean seeds.

Treatment a/ (no. of cycles)	Germination (% of seeds sown)	Seed vigor index b/ (%)	Average time required for germination (days)
One	56	40	5.8
Two	46	24	6.7
Three	30	13	6.9
Control	87	70	5.8

a/ Seeds soaked in water for 12 hours and dried at 40°C for 24 hours.

b/ A time-weighted index of germination.

Our experiments have shown that 70 kg/ha N must be supplied to the plants for each ton of expected yield. Thus, 280 kg/ha N are required for a yield of four tons/ha of soybean. These results are contrary to findings elsewhere. Generally, it is believed that the nodule bacteria provide sufficient nitrogen from the atmosphere to supply the N needs of soybean. Nevertheless, preliminary studies conducted on our experimental farm indicate that the application of nitrogen fertilizer just before flowering increases yield *(Table 23)*.

Table 23. Effect of nitrogen on soybean yield. a/

Nitrogen (kg/ha)	Yield (tons/ha)	
	Without compost	With compost
0	1.9	2.9
60 b/	2.7	3.1

a/ Cultivar TK 5 was planted Sept. 5. Before planting; 20 tons/ha compost (soybean straw), 35 kg/ha P, and 125 kg/ha were applied as basal dressing.

b/ Divided into 2 equal amounts, which were applied as top dressing at 8 days after germination and at 32 days.

A water-culture experiment in the greenhouse determined that (i) NH_4 is toxic to soybean plants; and (ii) in pots treated with NO_3 solutions, yields increased with each increment of N up to 50 ppm *(Fig. 16)*. The nitrate source of N was more beneficial to both plant growth and yield than ammonium nitrogen.

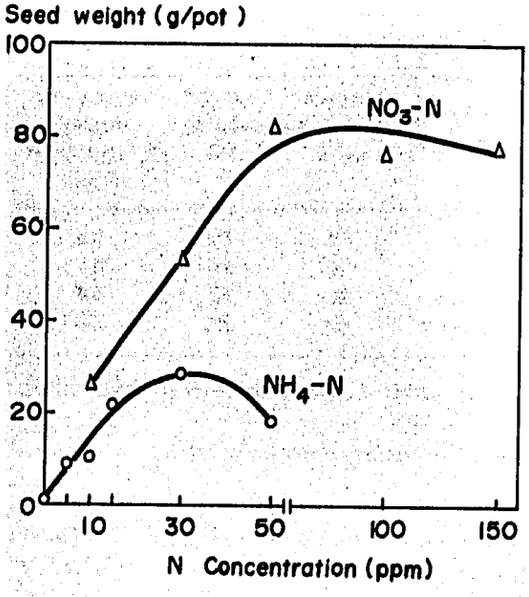


Fig. 16. A comparison of NH_4 and NO_3 as sources of nitrogen for soybeans grown in solution cultures.

AGRICULTURAL ECONOMICS

The literature was consulted to obtain an idea of soybean production costs and net returns in four Asian countries. *Table 24* presents five examples from the region. In these cases, soybean was a second crop, either following rice or intercropped with cotton. It was generally grown without much management. A study has been initiated to provide more information on the various methods of soybean cultivation observed in the region and the reasons for using them. Some of these local practices such as the 'no-tillage, rice-stubble soybean culture' used in southern Taiwan might be adaptable to other areas.

Table 25 presents data on soybean production, area, and yields for several Asian countries. Import records for 1973 indicated that although Taiwan, Japan, and Korea produce fairly high quantities of soybean; they import even more. Thailand is the major exporting country in the area.

INTERNATIONAL ACTIVITIES

During 1974, we distributed 4,719 soybean accessions, 11 F_2, and 340 F_4 segregating populations to 33 scientists in 21 countries *(Table 26)*. The majority of these seeds were screened in those countries for adaptability to specific locations and resistance to soybean rust.

In an effort to advance the generations more rapidly, a winter crop of the Korean soybean program (Crop Experiment Station) was planted at AVRDC. We planted three F_2 bulk populations during the spring season, and the harvested F_3 bulk seeds were sent back to Korea to be planted in June.

During December, a total of 400 selected cultivars, 22 elite lines and 128 segregating populations (F_4) were planted at the Chainat Rice Experiment Station in Thailand for evaluation and selection.

Table 25. Soybean production, area, and yields in selected Asian countries, 1972. a/

	Production (1,000 tons)	Area (1,000 ha)	Yield (tons/ha)
Taiwan, ROC b/	61	36	1.7
Japan	127	89	1.4
World average	*53,024*	*38,489*	*1.4*
Thailand	70	70	1.0
Philippines	1	1	0.9
Korea	224	280	0.8
Indonesia	515	685	0.8

a/ Adapted from *The FAO Production Yearbook, 1972* (Vol. 26, Rome). All estimates by FAO unless otherwise noted.

b/ *Taiwan Agricultural Yearbook, 1973 Edition.* Provincial Department of Agriculture and Forestry, Taiwan, July 1973.

Table 24. Relative production costs for soybean in Asia.

Item	Area				
	Sukhothai, Thailand a/ (interplanted)	Chiang Mai, Thailand a/ (no land preparation)	N. Luzon, Philippines b/ (direct sown)	Choongbuk, Korea c/ (direct sown)	Southern Taiwan d/ (rice-stubble)
	(US¢/kg)				
Revenue	10	11	18	12	26
Cost+	7	9	12	7	27
Net return	3	2	6	5	-1
+ Cost breakdown	(%)				
Material	13	20	21	17	38
Labor	51	55	42	74	35
Other	36	25	37	9	27

a/ Adapted from Tongpan, S., *et al.* 1974. "Production and utilization of selected food legumes and oilseeds in Thailand." Kasetsart University, Thailand. In Sukhothai soybean is mostly intercropped with cotton, and in Chiang Mai, without land preparation. Official exchange rate: US$ = 20 Baht.

b/ Adapted from Gonzales, F. H.; *et al.* 1974. "Soybean production and marketing in Northern Luzon." National Food and Agriculture Council, the Philippines. Official exchange rate: US$ 1 = 7.01 Pesos.

c/ Adapted from *Table 7*, Jung, J. M. 1968. "An economic study of soybean production in Korea." Agricultural Economic Research Institute, ORD; Korea. Official exchange rate: US$ 1 = 485 Won.

d/ Adapted from Provincial Department of Agriculture and Forestry. 1974. "A report on the survey of production costs of Taiwan's agricultural products." Taiwan. 'No-tillage, rice-stubble' soybean culture is a common practice of the farmers in southern Taiwan. Family labor was included in the total costs resulting in a negative net return. Official exchange rate: US$ 1 = 37.9 NT$.

Farmers in southern Taiwan often plant soybean immediately following their second rice crop. This practice is referred to as 'no-tillage, rice-stubble soybean culture'.

Table 28. List of cooperators and the number of accessions or segregating populations distributed in various countries during 1974.

Country	Cooperator	Organization	Number distributed	
			Accessions	Segregating population
Argentina	Dr. Oscar A. Klein	Criadero Klein	100	–
Australia	Dr. D. E. Byth	Univ. of Queensland	7	–
Bangladesh	Dr. Kamil Uddin Ahmad	Gov't. of Bangladesh	9	–
Brazil	Dr. Henry Minor	US AID/Brazil	149	–
Guatemala	Dr. Eugenio Martinez	ICTA	1409	–
Haiti	Mr. Jaures Leveque	Ministry of Agriculture, Haiti	7	–
India	Dr. B. A. Krantz	ICRISAT	500	–
India	Dr. R. W. Cummings	ICRISAT	10	–
Indonesia	Dr. Russell D. Freed	IRRI	2	48 (F_4)
Indonesia	Mr. Sjarkani Musa	Bogor Agricultural Univ.	6	–
Kenya	Dr. Walter Kaiser	East African Agriculture & Forestry Research Organization	10	–
Korea	Dr. Hyun OK Choi and Dr. Keun Yong Park	Crop Experiment Station	2	–
Malaysia	Dr. C. H. Cheah	Universiti Pertanian	5	–
Malaysia	Dr. Abd. Azuz Ravoof	Universiti Malaya	2	–
Malaysia	Dr. T. C. Yap	Universiti Malaya	20	20 (F_4)
Mauritius	Mr. Pierre Harel	Universal Development Corp., Ltd.	5	–
New Zealand	Mr. M. T. Malone	Dept. of Scientific & Industrial Resources	6	–
Paraguay	Ing. Nelson De Barros Barreto	Dept. of Agriculture, Paraguay	3	–
Philippines	Dr. R. M. Lantican	Univ. of the Philippines at Los Banos	4	–
Philippines	Mr. R. M. Payson	Univ. of the Philippines at Los Banos	–	11 (F_3)
Saudi Arabia	Mr. W. L. Chang	Chinese Rice Mission to Saudi Arabia	5	4 (F_4)
Sweden	Mr. Guen Holmberg	Holmbergs Utsaden	5	–
Tanzania	Mr. Richard Finlay	University of Tanzania	14	–
Taiwan	Mr. A. T. Hung	Kaohsiung District Agriculture Improvement Station	1075	–
Taiwan	Mr. Kuo-Lein Chan	Taiwan Agricultural Research Institute	378	–
Thailand	Dr. Arwoot Na Lampang	Dept. of Agriculture	422	128 (F_4)
Thailand	Dr. Dumrong Tiyawalee	Chiang Mai Univ.	49	12 (F_4)
Thailand	Mr. Amnuay Manitaya	Mae Jo Experiment Station	422	128 (F_4)
U.S.A.	Dr. Richard Shibles	Iowa State Univ.	1	–
U.S.A.	Dr. K. R. Bromfield	USDA	11	–
U.S.A.	Mr. Curtis R. Nissly	Univ. of Illinois	3	–
U.S.A.	Dr. L. V. Crowder	Cornell Univ.	10	–
U.S.A.	Dr. Mason E. Marvel	Univ. of Florida	67	–

Mungbean

Progress was made toward increasing the yield potential of this popular source of easily digestible protein for the Asian diet. In 1974, the world collection of mungbean germplasm was increased by 546 cultivars and totaled 2,362 accessions at the end of the year. This germplasm was shared with 24 scientists in 15 different countries. A cultivar from Taiwan, Tainan 1, produced a yield of 2.46 tons/ha in a yield trial at AVRDC. Twenty cultivars produced a mean yield of 1.86 tons/ha or about triple that obtained by most farmers in Southeast Asia. The most significant findings in 1974 were the identification of sources of resistance to several important mungbean diseases. Three cultivars were consistently resistant to *Cercospora* leaf spot. Accession 1140 was determined to be immune to powdery mildew *(Erysiphe polygoni).* More than 350 F_3 seeds were collected from an interspecific cross between mungbean and rice bean.

VIGNA SP. GERMPLASM COLLECTION

Vigna radiata	*2,362*
Vigna mungo	*178*
Vigna angularis	*133*
Vigna umbellata	*77*

PLANT BREEDING

THE WORLD COLLECTION. With the addition of 546 mungbean cultivars, the world collection of mungbean germplasm totaled 2,362 accessions at the end of 1974 *(Table 1)*. Most of the new accessions were obtained from Afghanistan and Korea. A few were received from collections maintained in the U.S.A. and England.

The collection also includes closely related species in the *Vigna* genus. In 1974, 21 black gram, 5 adzuki bean, and 2 rice bean cultivars were received, bringing the total to 2,750 accessions for the four *Vigna* species (see *Table 1*).

THE CROSSING PROGRAM. Two hundred thirty-eight crosses (including 87 multiple crosses) were made in 1974. A total of 1,140 crosses have been made since the inception of the program in 1972 *(Table 2)*. Of these, 315 have been advanced to at least the F_4 generation.

The advanced generations were screened for yield performance and disease resistance

Table 1. Distribution of *Vigna* sp. accessions among 31 countries.

Country	Number of accessions			
	Mungbean *(V. radiata)*	Black Gram *(V. mungo)*	Adzuki Bean *(V. angularis)*	Rice Bean *(V. umbellata)*
Afghanistan	209	6		
Australia	104	7		
Bangladesh	1	1		
Brazil	2		2	8
Burma	2			1
China (Mainland)	6	1	5	
China (Taiwan)	27		74	
Costa Rica			1	1
El Salvador		1		
England	42	19		
France	38	9	11	3
Guam	3		1	
Guatemala	3	1		
Hong Kong	13		5	6
India	913	65	2	17
Indonesia	117	30		8
Iran	42			
Iraq	2			
Ivory Coast	8	2	10	3
Japan			15	
Korea	75			
Pakistan	33	20		
Philippines	329	8	2	14
Senegal	1	1	1	1
South Africa	1	1		
Thailand	64	4		3
Turkey	7			
U.S.A.	230	1		
Vietnam	14		4	
Zaire		1		12
Not Known	76			
Total	2,362	178	133	17

Table 2. Progress of AVRDC's mungbean crossing program.

Year	No. of crosses made			Annual total	Seed generation	No. of selections [a]
	Single	Double	Triple			
1973	902			902	F_2	384
1974	151	68	19	238	F_3	76
	Grand total			1,140	F_4	186
					F_5	119
					F_6	10
					Total	765

[a] 375 selections were discarded in either the F_1 or F_2 generations due to poor field performances.

F_2 mungbean plants are being screened for desirable traits.

Table 3. Performance of the highest yielding selections in two yield trials. [a]

AVRDC selection no.	Pedigree (F generation)	Yield [b] Summer	Fall (tons/ha)	Mean [c]
227-4	CES 87-17 / S-8 (F_4)	1.9	1.5	1.7
15-6-1	MD 15-2 / MG 50-10A (F_5)	1.6	1.3	1.5
3-1-4	MG 50-10A / CES 55 (F_5)	2.0	1.0	1.5
4-7-1	MG 50-10A / MD 15-2 (F_5)	1.3	1.4	1.4
226-1	CES 55 / PI 282991 (F_4)	1.6	1.0	1.3
242-1	TH 1 / CES 55 (F_4)	1.1	1.4	1.3
Mean of 30 selections		1.3	1.1	1.2

[a] 18 F_4 and 12 F_5 selections were planted July 11 (summer) and Sept. 12, (fall). The harvest dates were Sept. 25 and Nov. 20, respectively.

[b] Yield data are from 2 replications (8-m^2 and 14.4-m^2 plots in spring and fall, respectively).

[c] Mean of the two crops.

repeatedly. Eighteen F_4 and 12 F_5 selections were planted in both the summer and fall seasons at AVRDC. The results for the selections with the highest yields are presented in *Table 3.* In the summer, Selection 3-1-4 (MG 50-10A / CES 55) had the highest yield (2 tons/ha). However, in the fall this selection produced only one ton/ha. Selections 227-4 and 15-6-1 had relatively high, stable yields (see *Table 3*).

INTERSPECIFIC CROSSES. As reported in the *72-73 Annual Report,* some of the closely related species in the *Vigna* genus have important traits such as resistance to disease and insect pests The rice bean possesses immunity to *Cercospora* leaf spot and some field resistance to powdery mildew, damping off, and beanfly infestation. The black gram is resistant to powdery mildew. Attempts to cross mungbean with black gram *(V. mungo)* and rice bean *(V. umbellata)* were made with some limited success *(Table 4).* Of 15 possible cross combinations between rice bean and mungbean, only six produced hybrid seed *(Table 5).* Note that the rice bean S-91 acted as a genetic bridge in five of the six combinations.

However, only 353 F_1 plants (or 18.9%) resulted from a sowing of 1,862 seeds. All 353 seeds germinated hypogeally (hypoctyl enlongates and is the first to emerge). This trait can be used to identify the true hybrid plants at the initial

Table 4. Summary of the interspecific crossing program at AVRDC.

Crosses	Mungbean / Rice bean (No. of crosses)	Mungbean / Black gram (No. of crosses)
Attempted	66	64
Producing viable F_1 seeds	46	34
Producing viable F_2 seeds	1	18
Producing viable F_3 seeds	1	18

growth stage. The rice bean (pollen parent) also germinated hypogeally, whereas the mungbean (seed parent) is epigeous (epicotyl enlongates—hypocotyl does not enlongate and the cotyledons do not emerge). This indicates that hypogeal germination is controlled by a simple dominant gene. The F_1 plants grew normally (some hybrid vigor was noted) and flowered profusely. But only one plant produced viable F_2 seeds (4).

Three of these F_2 seeds were sown under carefully controlled conditions in the greenhouse. They grew into healthy plants and produced about 350 F_3 seeds. In 1975, these will be sown and the resulting plants screened to determine if they have inherited the resistance of the rice bean parent to disease and insect attack. None of the crosses using mungbean as the pollen parent and rice bean as the

Table 5. Successful crosses between mungbean and rice bean in 1974.

Parents		No. of flowers crossed	No. of pods obtained	Pod-setting rate (%)
Mungbean ♀	Rice bean ♂			
M 839 / EG-MD-6D (F_1) // S-91		28	8	29
EG-MD-6D / M 257 (F_1) // HK		26	9	35
M 839 / M 90 (F_1) // S-91		25	8	32
CES 140 / ML 6 (F_1) // S-91 / HK (F_1)		23	6	26
M 91 / MG 50-10A (F_1) // S-91		10	1	10
MG 50-10A (Y) / M 280 (F_1) // S-91 / HK (F_1)		29	2	7

Table 6. Successful crosses between mungbean and black gram with the highest pod-setting rates.

Parents		No. of flowers crossed	No. of pods obtained	Pod-setting rate (%)
Mungbean ♀	Black gram ♂			
EG-MD-6D / M 257 (F_1) // L-35-5 / T-9 (F_1)		17	17	100
M 121 / EG-MD-6D (F_1) // PPSU-1 / TH 6 (F_1)		12	10	83
MG 50-10A (Y) / M 208 (F_1) // L-35-5 / T-9 (F_1)		12	9	75
S-9 / MD 15-2 (F_1) // PPSU-1 / TH 6 (F_1)		18	12	67
India 3 / ML 6 (F_1) // L-35-5 / PPSU-1 (F_1)		17	11	65

seed parent were successful.

The genetic distance appears to be less between mungbean and black gram, and several crosses produced viable seed *(Table 6)*. Progeny of 18 crosses have been advanced to the F_3 generation. However, all efforts to backcross the progeny of these crosses (and the ones with rice bean) have failed. In 1975, more backcrosses shall be attempted using chemicals to induce compatibility.

YIELD TRIALS. Four hundred cultivars were planted in two yield trials (spring and fall) at AVRDC. Although the highest yields were obtained in the spring, the fall crop has a higher mean yield and more pods per plant *(Fig. 1)*. However, cultivars varied greatly in yield in the two trials. The best 10 percent in the spring trial (mean yield 1.6 tons/ha) had a mean yield in the fall of only 0.7 ton/ha. *Table 7* presents the results for the top five cultivars in each trial. The reasons for the seasonal variability will be studied closely.

This seasonal variability was less evident in the spring and summer yield trials of 20 cultivars. The mean yields were 1.9 and 1.6 tons/ha for the spring and summer trials, respectively. The cultivar CES 87-17 had the highest yield in the spring (2.4 tons/ha), and the cultivar Tainan 1 proved to be a relatively stable performer, yielding 2.3 and 2.5 tons/ha in the spring and summer trials, respectively *(Table 8)*. However, Tainan 1 is susceptible to both *Cercospora* leaf spot and powdery midlew *(Erysiphe polygoni)* and, therefore, must be protected with fungicide. It will be used in the crossing program to increase yield potential.

POPULATION DENSITY EXPERIMENTS. In an experiment discussed in the *72-73 Annual Report*, the mungbean cultivar Thai Green Oil (TH 4) did not increase in yield after the population exceeded 120,000 plants per hectare. This cultivar was planted three additional times to verify its lack of response to higher population densities. In *Figure 2*, the September 1973 planting is compared with three plantings in 1974. For this particular cultivar, there was no strong response to higher population densities.

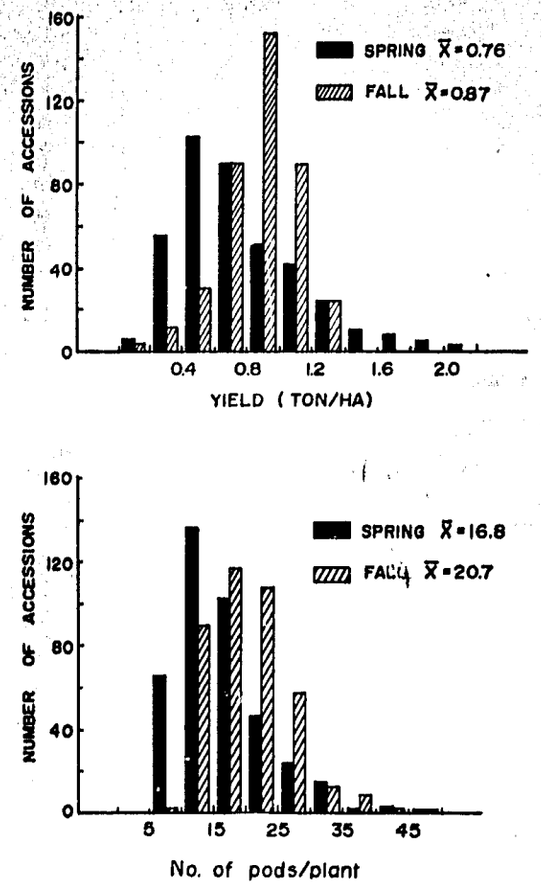


Fig. 1. Distribution of 400 mungbean cultivars by yield (top) and number of pods per plant (bottom) in spring and fall yield trials.

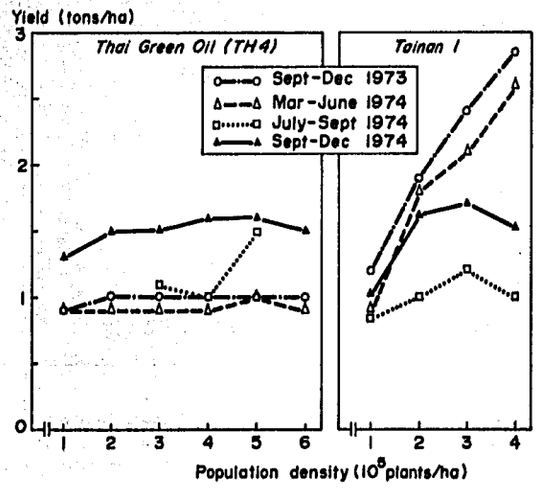


Fig. 2. The yield of 2 mungbean cultivars when planted at various population densities in 4 different trials.

However, another cultivar (Tainan 1) responded greatly to increased population density (see *Fig. 2)*. The last two trials were not protected from rodents, which might partially explain the lower yields. Population density trials will be conducted again in 1975 to clarify the relationship between variety, management, and density.

SENSITIVITY TO PHOTOPERIOD. In 1973, 47 percent of the mungbean germplasm (about 600 cultivars) were reported to be day neutral *(72-73 Annual Report)*. Further tests in 1974 verified those results. However, an additional criterion was considered in determining photoperiod sensitivity (or insensitivity)—the change in plant height. This criterion was considered after observing considerable differences in plant height among the same cultivars planted in different seasons. For instance, the mean plant height of 400 cultivars planted in the fall was 63 cm, whereas their mean plant height in the spring crop was only 37 cm. Plants were selected that varied no more than five days in flowering time and that exhibited less than a 50-percent difference in plant height regardless of photoperiod (12-hr and 16-hr photoperiods used). Of the 600 cultivars, 224 satisfied the two criteria.

PLANT PATHOLOGY

FUNGAL DISEASES. *Cercospora canescens* is an airborne pathogen. Thus, density and distribution of the spores in the air reflects the likelihood of a disease outbreak. A network of spore traps was installed on the experimental farm to record the spore density. By studying the seasonal fluctuations in spore density, it is hoped that a disease forecasting system can be established for *Cercospora* leaf spot.

Figure 3 shows that in 1974, the spores of *Cercospora canescens* were first found on the spore-traps (see Soybean; *Fig. 6*) during the last days in March. However, disease symptoms did not appear on the crop until late April. The spore

Table 7. Yield data and disease reactions of the best 5 cultivars in the spring yield trial and the best 5 from the fall trial. [a]

AVRDC Acc. no.	Varietal name	Spring trial	Fall trial	Reactions to [b] *Cercospora* leaf spot	Powdery mildew
		(tons/ha)			
Best cultivars in spring					
2100	Q 10595	2.2	0.7	MS	MR
2106	Q 10601	2.1	0.8	MR	MR
2092	CPI 130755 A	2.0	0.8	MS	MR
1119	M 177	2.0	1.0	S	MS
2105	Q 10600	1.9	0.7	MS	R
Best cultivars in fall					
1945	BPI Glabrous 3	1.0	1.3	MS	MS
1381	MG 50-10A	0.6	1.3	R	S
1380	EG-MD-6D	0.8	1.3	MS	S
1476	Stb. 129	0.5	1.3	MS	S
1480	Stb. 136	0.2	1.3	MS	S

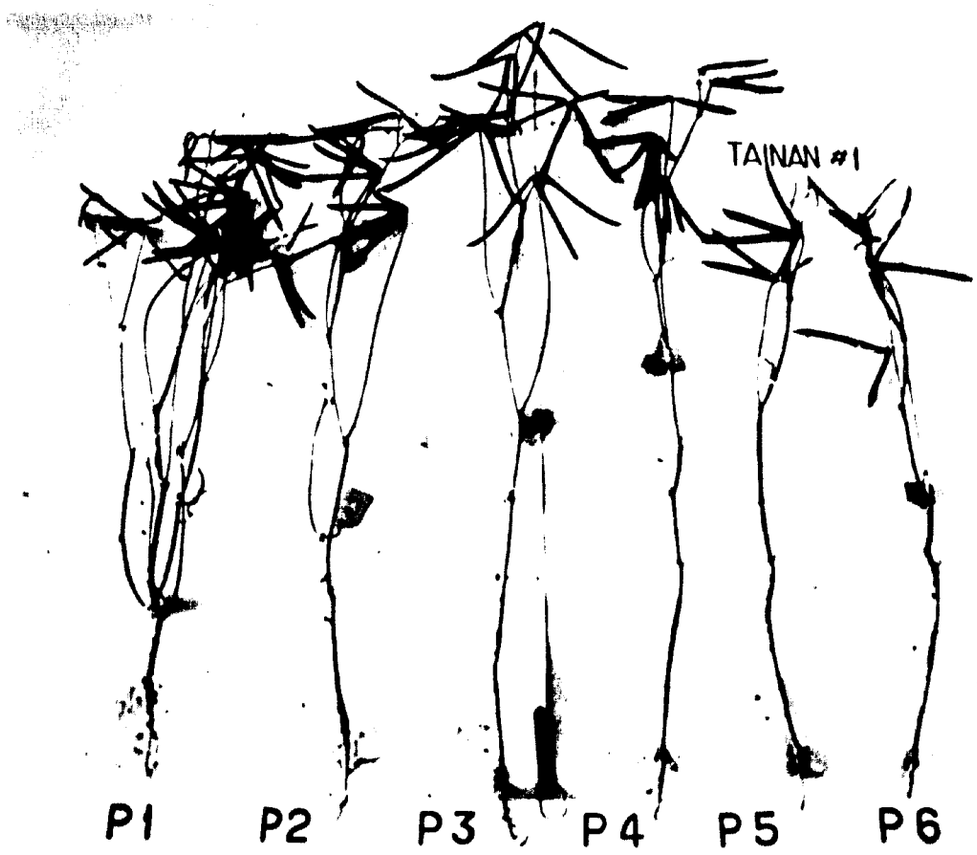
[a] Spring trial planted March 2.
Fall trial planted Sept. 12.
Plot size was 3.75 m^2; 2 replications.

[b] R - less than 25% infection
MR - 25% to 50% infection
MS - 50% to 75% infection
S - more than 75% infection

Table 8. The highest yields produced in two mungbean yield trials and the agronomic data from the spring trial. [a]

AVRDC acc. no.	Varietal name	Yield Spring (tons/ha)	Yield Summer (tons/ha)	Plant ht (cm)	No. of pods/ plant	No. of seeds per pod	1000-seed wt (g)
1948	CES 87-17	2.4	1.4	56	19	10	66
1484	CES 140	2.3	1.7	59	14	15	67
2013	Tainan 1	2.3	2.5	61	19	12	37
1387	CES 55	2.1	1.9	45	16	12	72
1945	BPI Glabrous 3	2.0	1.0	41	15	10	77
1947	CES 44	2.0	1.6	42	14	10	72

[a] Spring trial planted Mar. 1; summer trial planted July 11. Population density was 250,000 plants/ha; 4 replications.



As the population density increases, the number of branches and pods per mungbean plant become fewer. Of course, the number of pods per unit area will increase up to a certain limit. Experiments are being conducted to determine the optimum population densities for both mungbean and soybean. (P1, etc. denote population densities at 10^5.)

count increased gradually as the crop matured. The first peak of the spores in the air occurred late in May. The spring plantings of mungbean were then nearing harvest, and *Cercospora* infection was severe. The spore density decreased immediately after the spring crop was harvested. However, the airborne spores again became abundant in the summer. Distinct peaks were evident on Aug. 30 and Sept. 1 (*Fig. 3*). During this period, the number of plants infected by *Cercospora* leaf spot was at a maximum. The highest spore densities were generally evident the day after a heavy rainfall (*Fig. 3*). Spore counts indicated that spores remained in the atmosphere as long as mungbean was in the field.

During the rainy season in Southeast Asia, *Cercospora* leaf spot constitutes a major threat to the cultivation of mungbean. The infection of susceptible cultivars generally causes complete defoliation, reducing the yield. The infection of *Cercospora* leaf spot tends to taper off late in the fall and eventually no natural infection can be observed in the winter. Symptoms reappear with the return of the rainy season or when temperatures and humidity increase sufficiently in the spring.

Two cultivars (Tainan 1 and ME-3) were sown March 15 in 900-m^2 plots to study the rates of infection by *Cercospora canescens* as an indicator of primary and secondary inocula sources.

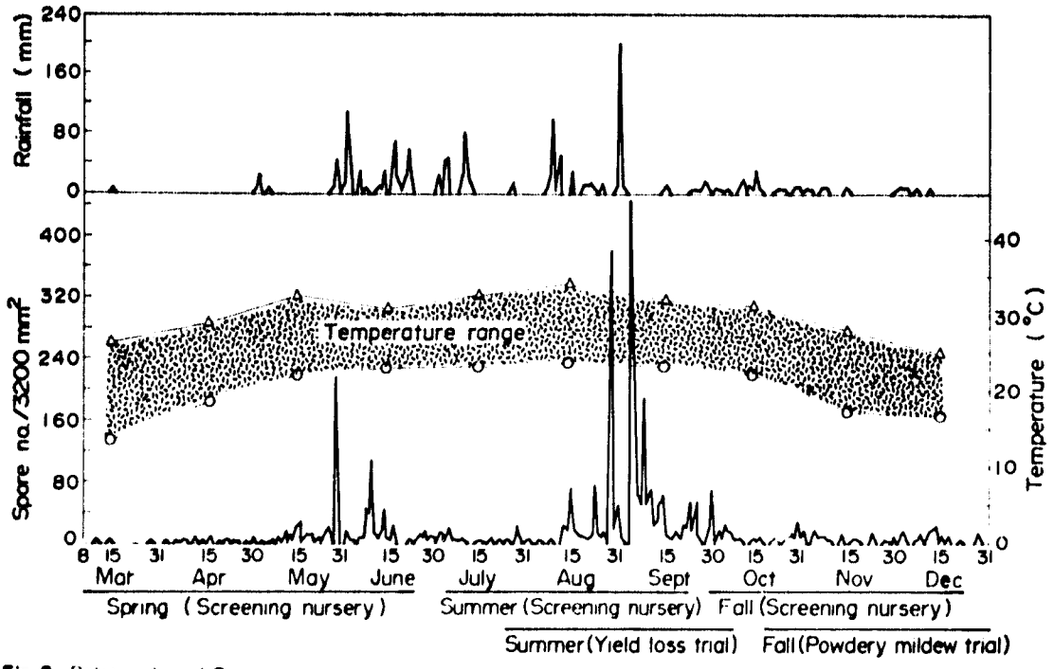


Fig. 3. Relationship of *Cercospora canescens* spore concentrations in the atmosphere to climatic conditions.

The initial infection was observed 31 days after planting (April 18). The infection was scattered, indicating that the primary inoculum probably came from an exterior source. Subsequent recordings of disease incidence showed that the secondary infection generally followed the same loci as the initial infections. When the increment of infection was tabulated as the number of infected plants per day, a logarithmic increase in infection rate was noted *(Fig. 4)*. It appears that the source of the secondary inoculum was within the plots.

Later studies showed that *Cercospora canescens* could be readily isolated from mungbean seeds. Thus, infected seeds may also be a source of primary inoculum.

When a spore suspension (2,000 conidia/ml) was sprayed on susceptible cultivars at different stages in growth, the plants showed no difference in response with age up to flowering, but lesion severity increased sharply from the flowering stage onward *(Table 9)*. The necrotic area per leaf was larger (significant at 1% level) during flowering than at other stages of growth. This agrees with

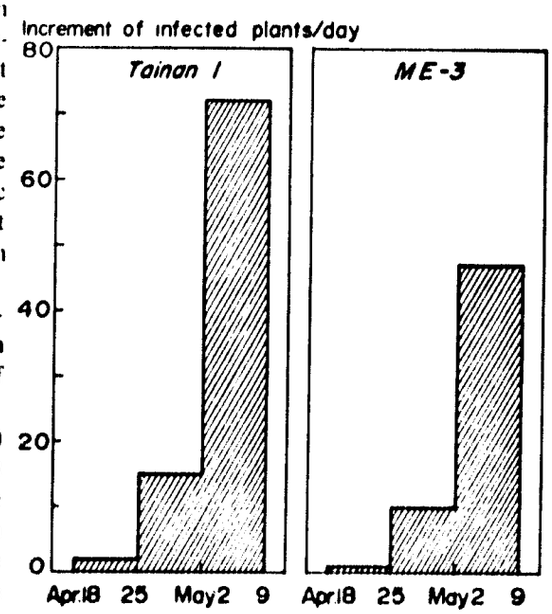


Fig. 4. The number of *Cercospora*-infected plants of 2 mungbean cultivars as the plants developed.

Table 9. The susceptibility of Tainan 1 to the infection of *Cercospora canescens* at different plant ages.

Plant age at inoculation (days)	Necrotic area/leaf surface [a] (%)
7	11.75 x
15	10.25 x
21	17.50 x
28	12.00 x
35	13.75 x
42	53.50 y

[a] For each treatment, percentages followed by the same letter are not significantly different; P = 0.01.

the observation that, with natural infection, this disease strikes with greatest severity in the field between flowering and pod formation.

Four cultivars were selected to determine the effect of inoculum density on resistance to *Cercospora* leaf spot. In general, the lesion numbers on leaves of the four cultivars were proportional to the inoculum density below 50 x 10^3 spores per ml *(Table 10)* and increased with time. However, the increment of lesions (calculated 20 days after initial infection) indicated that for resistant cultivars, the increment remained constant per day, e.g., Accession 2273, but increased mathematically with such susceptible cultivars as Accession 1416 and 1410 *(Fig. 5)*. The results indicate that the increases in lesion number for the resistant cultivars were independent of inoculum density, whereas the susceptible cultivars were dependent on the inoculum density. Therefore, resistance to *Cercospora* leaf spot in mungbean is likely conditioned by major genes.

The infection caused by *Cercospora canescens* generally results in the premature defoliation of the susceptible plants in the field, thus, reducing their yield potential. *Cercospora* leaf spot infection can cause reductions in yield of nearly 50 percent in mungbean *(Table 11)*. Defoliation was 46 percent at 60 days and 100 percent at 70 days after planting (see *Table 11)*.

Three cultivars (Acc. 2272, 2773, 2283) were consistently resistant in three screenings (fall 73, spring 74, summer 74). The infection of these three cultivars did not exceed 25 percent of the total leaf area. However, in the fall of 1974, Accession 2272 showed a 50-percent infection. This was surprising since the *Cercospora* pathogen had a lower concentration of inoculum in the fall than during the spring or summer (see *Fig. 3)*. The change in disease reaction might indicate that the resistance is unstable, the seed stock was impure, or the presence of a new pathogenic race. Since our studies revealed that resistance to *Cercospora* leaf spot in mungbean is probably conditioned by major genes, the development of new races is likely. The possible shift in pathogenicity of *Cercospora canescens* in the field will be studied in 1975.

More resistant cultivars were identified in the fall (1973) and spring crops than in the summer crop *(Fig. 6)*. The difference appears to be due to the variation in the level of natural inoculum. Because of this seasonal variance, future screenings will be conducted in the summer season when the natural inoculum is abundant and there is less chance for plants to escape infection.

In a screening of 10 cultivars, which were identified as resistant to beanfly *(M. phaseoli)* infestation, one (Acc. 2127) was also resistant to *Cercospora* leaf spot and moderately resistant to powdery mildew *(Erysiphe polygoni)*.

Powdery mildew *(Erysiphe polygoni)* seriously attacks mungbean during the dry season+. In Taiwan, Thailand, and the Philippines, this disease occurs mostly from November through April. The yield loss caused by powdery mildew is recognized, but no resistant cultivars are as yet available commercially. A field survey at AVRDC of 2,000 mungbean cultivars in the spring of 1973 indicated that varietal differences in resistance to powdery mildew exist. These sources of resistance are being used in the breeding program.

In the fall, a survey of 100 *Vigna* cultivars was made. Mungbean Accession 1104 (PI 164265) was immune (no infection) to the powdery mildew pathogen *(Table 12)*. Eight other mungbean cultivars showed various degrees of resistance, and three rice bean cultivars were consistently resistant.

Initial infection of *Erysiphe polygoni* can be observed at the cotyledon stage. But the most severe infections usually occur from flowering to

+ Dry season denotes the period of the year with little rainfall. The relative humidity may still be quite high.

Table 10. Relationship between inoculum density and infection of *Cercospora* leaf spot.[a]

AVRDC acc. no.	Varietal name	Reaction to *Cercospora* leaf spot[b]	No. of lesions / trifoliate leaf[c]			
			Inoculum density (x 10^3 spores/ml)			
			2	10	50	150
1410	MD 15-2	S	9	40	84	73
1416	CES 3	S	3	17	44	22
2273	ML 6	R	2	5	16	4
2773	ML 3	R	0	3	0	6

a/ Four mungbean cultivars were planted in the greenhouse.

b/ R - less than 25% infection
S - more than 75% infection

c/ 20 days following inoculation.

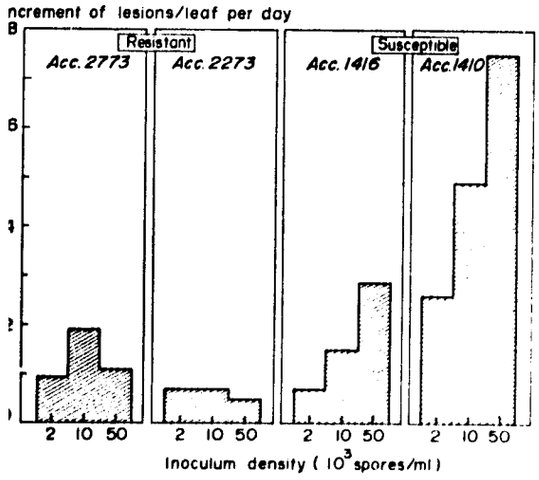


Fig. 5. Response of resistant (Acc. 2773, 2273) and susceptible (Acc. 1416, 1410) mungbean cultivars to different inoculum densities of *Cercospora canescens*.

harvest. Thus, evaluation for resistance cannot be based on one reading. In *Table 12*, readings taken December 27 indicated that 11 cultivars were resistant, but one week later (January 3, 1975), only seven cultivars out of the 11 were still resistant. In a final reading on Jan. 10, only five were rated resistant (see *Table 12*).

Powdery mildew attacks mungbean at all stages of growth, and, except for the roots, all of the plant is vulnerable. The initial infection is usually on the leaves. The first symptoms are characterized by faint, slightly dark areas on the leaf. These obscure areas later develop into small, white powdery spots, which enlarge and combine with others to form an almost complete coating of whitish powder over the leaf.

When infection occurs at the seedling stage, the plants never recover. Severe infection can result in a premature defoliation ranging from 40 to 100 percent shortly before harvest. The field studies determined that the reduction in yield could range from 20 to 40 percent. For example, plants sprayed weekly with Saprol (Triforine 20), a recommended fungicide, had only 50-percent infection, whereas those in the control plots showed almost 100-percent infection (*Fig. 7*). The disease progressed rapidly in the control plots, while its progress was retarded in the sprayed plots. Seven weeks after planting, the infection rating in the control plots was 100 percent, but still there was no infection in the sprayed plots. However, after the spraying was discontinued, the disease developed (see *Fig. 7*).

In 1974, root diseases frequently were the nemesis of mungbean at AVRDC. Many experiments were prematurely terminated because the plants succumbed to root infections. Severe root rot occurred in fields previously cropped with mungbean and soybean, and in newly developed land. In the fall, the F_4 segregating populations of mungbean were attacked by root rot fungi and nematodes; plant mortality among the populations ranged from 5 to 100 percent. Root diseases are also a severe problem in Thailand and the

Table 11. The effect of Benlate applications on defoliation, 1,000-seed weight, and yield of a mungbean cultivar susceptible to *Cercospora* leaf spot. [a]

Treatment	Defoliation 60 days [b]	Defoliation 78 days [b]	1,000 seed wt [c]	Yield [c] (tons/ha)	Yield reduction (%)
	----------(%)----------				
Control	46	100	33**	0.39**	47
Benlate [d]	0	18	43	0.83	

[a] The cultivar Tainan 1 was planted July 25 at a population density of 133,000 plants/ha. Data are means of 6 replications.

[b] Days after germination.

[c] Significantly different at 1% level. The yields and seed weights of the untreated control were compared with those of the plots protected with Benlate.

[d] Benlate is a fungicide used to control *Cercospora* leaf spot. A concentration of 150 ppm was sprayed every 2 weeks.

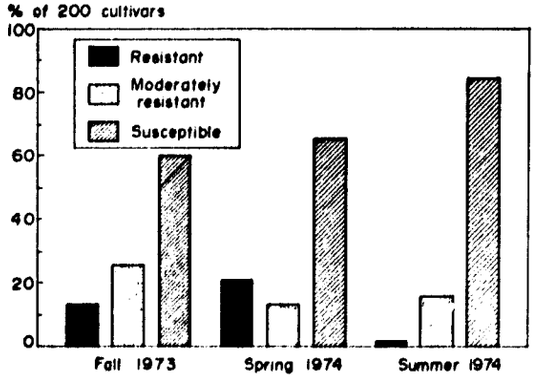


Fig. 6. Distribution of 200 mungbean cultivars by difference in resistance to *Cercospora* leaf spot in 3 field screenings.

Philippines.

Damping off in mungbean is caused mainly by *Rhizoctonia solani* and sometimes by *Pythium* sp. This group of fungal pathogens attack the roots of young seedlings especially during the cooler seasons, resulting in high mortality. They are unspecialized parasites and are unable to evade the defense mechanisms of their host. As the plants grow older, their roots acquire some resistance. They are less susceptible to these root pathogens as long as their growth remains vigorous.

Damping off, caused by *R. solani*, can usually be identified by a reddish brown lesion that is inscribed on the roots and stems below the soil's surface. However, it is not always distinguishable from damping off caused by *Pythium* sp. These two pathogens are widely distributed in soil and can survive as saprophytes over long periods. They are also parasitic on many different plants. Therefore, crop rotation is of little value as a means of control.

Mungbean seedlings are also vulnerable to beanfly *(M. phaseoli)*. Plants infested by beanflies can be mistaken for damping off if the roots are not examined. Beanflies and damping off fungi may attack seedlings simultaneously, or in rapid succession, thus hastening their death.

Root rot is caused by *Fusarium solani* f. sp. *phaseoli*, *Pythium* sp. (e.g., P. *aphanidermatum*, *P. ultimum*), and *R. solani*. Either one of these fungi can cause severe damage. Under natural conditions, root rot is most likely caused by a fungal complex or a combination of fungi and nematodes. Frequently, one pathogen follows another; this double infection is usually fatal to the host plant. Plant mortality caused by root rot can range from 0 to 100 percent.

Pathogenic *Fusaria* grow best in slightly acid, dry soil, whereas *Pythium* does well and is even favored by wet, alkaline conditions. Therefore, in the summer (rainy) season at AVRDC, *Pythium* root rot was more prevalent. *Pythium* sp. not only cause root rot, but also induce wilt symptoms and dark brown lesions on the stem. *Pythium aphanidermatum* was the most dominant *Pythium* species

Table 12. Reaction of 12 mungbean and rice bean cultivars to powdery mildew (*Erysiphe polygoni*) in the field.[a]

AVRDC acc. no.	Varietal name	Species	Reaction to powdery mildew[b]		
			Dec. 27	Jan. 3, 1975	Jan. 10, 1975
1104	PI 164265	*V. radiata*	I	I	I
1533	M 561	*V. radiata*	R	R	R
1548	M 576	*V. radiata*	R	R	R
4006	HK	*V. umbellata*	R	R	R
4050	Ph. 1	*V. umbellata*	R	R	R
4065	S-91	*V. umbellata*	R	R	R
2773	ML 3	*V. radiata*	R	R	MR
1586	M 614	*V. radiata*	R	R	MR
1125	M 186	*V. radiata*	R	MR	MR
2116	CO 970	*V. radiata*	R	MR	MS
2089	CPI 30067	*V. radiata*	R	MR	MS
1954	S-8	*V. radiata*	R	MR	MS

[a] Planted Oct. 15.

[b] I = no infection
R = less than 25% infection
MR = 25 to 50% infection
MS = 50 to 75% infection

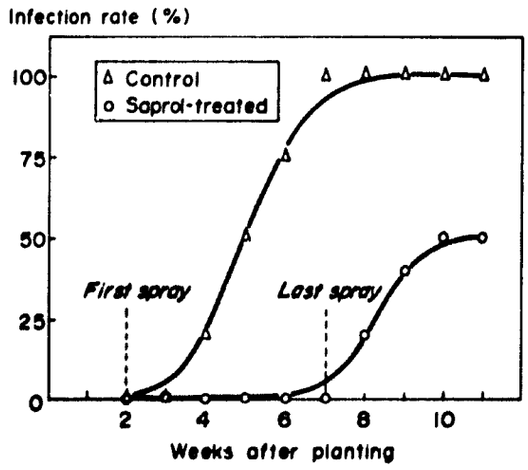


Fig. 7. Comparison of plots sprayed with Saprol, a recommended fungicide, and control plots of mungbean by infection rates of powdery mildew (*Erysiphe polygoni*).

isolated in the fields during the summer.

As mentioned earlier, *R. solani* usually does not attack mature root systems. Once a plant has passed the seedling stage, the injury caused by *R. solani* is confined to the outer layer of the peridem. The growth rate is affected only when a secondary infection by another pathogen occurs, or when the plant is under water stress. Since *R. solani* survives easily as a soil saprophyte, it colonizes readily on decayed root tissues infected with other fungi such as *Fusarium*. Thus, *R. solani* can continue to contribute to the general degradation of root systems.

In the fall 21 cultivars and several advanced generations of mungbean, planted in the field to screen for resistance to *Cercospora* leaf spot were severely infected by root-infecting fungi. The plant mortality caused by a root-rot complex was 100 percent for some cultivars and advanced generations. In a sampling of 134 plants from 21 cultivars, 98 percent had roots with lesions and 93 percent of these were also attacked by beanfly. Most of the plants had very poor root systems. Soil fungicides (PCNB and Captan) had been applied to the field at least twice, but still did not provide protection.

Since under natural conditions, a complex of pathogens is commonly involved in root rot, cultivars evaluated as resistant in artificially

inoculated soil under greenhouse conditions may not be resistant when planted in the field. On the other hand, there may be very few or no cultivars that are resistant to all the pathogens in the soil. However, it is possible that multiple resistance to the different pathogens can be incorporated into a single cultivar. Therefore, we screened for resistance to individual pathogens in flats and clay pots with pasteurized soil using artificial inoculation. The same materials were also screened in the root-disease nursery in the field.

The root-disease nursery was established during the 73-74 winter. Two crops of mungbean were followed by an intercropping of tomato, mungbean, and soybean during the summer. Pure cultures of virulent isolates of *Fusarium solani* f. sp. *phaseoli*, *Pythium aphanidermatum*, and *Rhizoctonia solani* were incorporated into the soil before and after each crop. With continuous cropping and the repeated incorporation of inocula, populations of root-infecting pathogens should build up to a level adequate to screen for resistance to a complex of fungal pathogens.

One hundred cultivars were screened for resistance to root diseases. Resistance to damping off was evaluated in artificially inoculated soil in wooden flats. Only two cultivars had infection rates below 10 percent. The same cultivars were also screened in the root-disease nursery. Plant mortality at the seedling stage was lower in the field than in the inoculated flats. This could be explained as (i) the seedlings in the field might acquire resistance sooner than those in the flats, and (ii) the inoculum density in the nursery was not as high nor as uniform as in the flats. The infection rates for damping off ranged from 0 to 43 percent in the field with a mean of 17 percent. In the flats, the range was from 8 to 93 percent with a mean of 55 percent.

Table 13 presents the top 10 cultivars selected from both screenings. The data indicate that the reactions of the same cultivars in the field often do not agree with those grown in the inoculated soil. Accessions 4006 and 4065 (rice bean) had the lowest rate of damping off in the flats and also produced healthy stands in the field.

BACTERIAL DISEASES. In the summer mungbean crop, a foliar disease attacked many cultivars in the field. The leaves of diseased plants, were covered with brown, circular (or irregular) raised spots. The infected leaf tissues were dry and necrotic from the early lesion formation. Later,

Table 13. Post-emergence damping off (*R. solani*) infection rates of the more resistant *Vigna* sp. cultivars screened in the root-disease nursery and in inoculated soil. [a]

AVRDC acc. no.	Varietal name	Species	Post emergence damping off	
			Flats [b]	Nursery [c]
			(%)	
4065	S-91	*V. umbellata*	8	3
4006	HK	*V. umbellata*	8	8
5124	Chien Shien	*V. angularis*	17	10
5122	KS 210	*V. angularis*	21	3
1399	CES 28	*V. angularis*	27	17
1334	Mo Phu Yen	*V. radiata*	34	5
1389	Berken	*V. radiata*	37	10
2267	CES Selection	*V. radiata*	37	13
1331	PT-18	*V. radiata*	38	8
1243	M 290	*V. radiata*	42	9
	Mean of 100 cultivars		55	17

[a] Planted in wooden flats with artificially inoculated soil in the greenhouse and in the root-disease nursery; Dec. 11.

[b] Evaluated at 33 days after sowing as % of the number of plants at 9 days.

[c] Evaluated at 28 days after sowing as % of the number of plants at 7 days.

these lesions were sunken or saucer-like, and the tissues became corky and rough. A translucent margin, or water-soaked border, was sometimes observed. Extensive infection resulted in defoliation.

The disease was caused by a bacterial pathogen comparable to the bacterial leaf spot of mungbean induced by *Xanthomonas phaseoli* that has been reported recently in India and China.

Field observation indicated that this disease may attack mungbean concomitantly with *Cercospora* leaf spot. However, it was more predominant in field plots where *Cercospora* leaf spot was controlled by fungicidal applications in the yield-loss trials.

A field survey of 100 mungbean cultivars indicated that varietal resistance exists. Ten cultivars were not infected by the bacterium *(Table 14)*.

Table 14. *Vigna* **sp. cultivars with field resistance to bacterial leaf spot** *(Xanthomonas phaseoli)*. [a]

AVRDC acc. no.	Varietal name	Species	Origin
2089	CPI 30067	*V. radiata*	Australia
2164	CQ 30065	*V. radiata*	Australia
2165	CQ 30067	*V. radiata*	Australia
3115	T-9	*V. mungo*	India
3122	PPSU-1	*V. mungo*	India
4006	HK	*V. umbellata*	Hong Kong
4050	Ph. 1	*V. umbellata*	Philippines
4065	S-91	*V. umbellata*	Philippines
5039	HK	*V. angularis*	Hong Kong
5042	Alcatsuki Dainagon	*V. angularis*	Japan

[a] Planted June 30; evaluated Sept. 12.

VIRUS DISEASES. Symptoms of four virus diseases were observed in several mungbean crops at AVRDC. There were: (i) mungbean mottling (MMV), (ii) mungbean yellow mottling (MYMV), (iii) mungbean crinkling (MCV), and (iv) mungbean witches' broom (MWB).

(i) Mungbean mottle virus is caused by a virus with long flexuous, rod-shaped particles. Host range studies and serological tests indicated that MMV is a new pathogen of mungbean. The symptoms of MMV show up as a mosaic of green and discolored areas on the mungbean leaf. If the plant is infected at an early growth stage, the young leaves become deformed with either a dark green 'island' or veinal mottling. Plants of susceptible cultivars (e.g., Acc. 2364, 2349, 2273) were mildly stunted; flowering was severely affected, resulting in the formation of fewer pods.

Less than 0.1 percent of the mungbean cultivars surveyed at AVRDC were infected by MMV. However, we observed farmers' fields in the Andin and Holi areas (southern and central Taiwan, respectively) that had infection rates as high as 82 percent.

The natural hosts of MMV included asparagus bean *(Vigna sinensis susquipedalis)*, wild *Chenopodium* sp., and mungbean. *Table 15* lists some of the species susceptible to MMV and their reactions when inoculated with MMV.

Table 15. Reaction of hosts when inoculated with mungbean mottle virus (MMV).

Plant species	Symptoms
Chenopodium amaranticolor	Local lesions (chlorotic spots)
C. quinoa	Local lesions and systemic mosaic
Phaseolus vulgaris cv. White sp.	Systemic mosaic, leaf malformation, and stunting
P. vulgaris cv. Pinto	Systemic mosaic, malformation, stunting
P. vulgaris cv. Taipei No. 2	Systemic mosaic, plant slightly stunted
P. vulgaris cv. Dwarf black pod	"
P. vulgaris cv Tendergreen	"
P. acutifolius cv. Mix 1-2	Systemic mosaic and stunting
Vigna mungo (acc. 3115)	Systemic mosaic
Nicotiana glutinosa	Mosaic, slight chlorosis, and stunting

In susceptible cultivars, MMV caused reductions in yield as high as 79 percent *(Table 16)*. The yield loss was generally due to a reduction in the number of pods per plant. These results indicate

Table 16. Effect of mungbean mottle virus (MMV) on mungbean yield.[a]

AVRDC acc. no.	Varietal name	No. of pods/ plant		Yield (g/10 plants)		Reduction in yield (%)
		Control	Inoculated	Control	Inoculated	
1388	EG-MG-7	21	6	67	14**	79
1586	PI 377006	12	10	56	26**	55
1954	S-8	15	6	63	23**	64
2013	Tainan 1	9	2	40	11**	73

[a] Planted Sept. 19; inoculated Oct. 3.

** Significantly different from the control at the 1% level.

that under natural conditions, when the MMV inoculum is substantial, the disease is highly destructive to mungbean.

The results of other experiments showed that MMV is likely transmitted by insect vectors. The disease generally develop around the edges of a field before spreading to the interior. When mungbean plants growing in wooden flats were protected with an insect-proof cage, no symptoms of MMV were evident.

During the fall, the leaves of 213 mungbean cultivars were rub-inoculated with MMV. Twenty cultivars did not show any infection and 10 were rated as moderately resistant.

(ii) Mungbean yellow mottle virus (MYMV) was observed only when the temperatures were below 30°C. The symptoms of MYMV are bright yellow spots on the infected leaves. Often the entire leaf turns yellow. In some cultivars, the virus does not infect the newer leaves and eventually disappears when the infected leaves fall off. With other cultivars, MYMV is more persistent and can accelerate senescence. It was difficult to transmit MYMV mechanically.

Experimental results indicated that MYMV is seed-borne, as it occurred sporadically throughout the field and on plants protected by insect-proof cages. In a screening of 400 cultivars, symptoms were first evident on the cultivars that came from India. Further study will be necessary to confirm these observations.

(iii) Mungbean crinkling virus (MCV) was observed in a fall screening of 40 cultivars, which were part of the collection received from the University of Missouri. This disease will be given further study.

(iv) Mungbean witches' broom (MWB) was first observed at AVRDC in a yield trial. The symptoms include tiny leaves, adventitious growth eminating from the buds, and suppression of the reproductive parts. The infected plants were usually sterile. In ultra-thin sections of the phloem cells of infected plants, mycoplasma-like organisms were observed, using electron mycroscopy. Fortunately, this new disease infected only about 0.1 percent of the plants surveyed.

ENTOMOLOGY

Agromyzid beanflies, *Melanagromyze phaseoli*, and other related genera are among the most damaging pests of mungbean throughout tropical Asia. They can cause a considerable reduction in yield.

Eggs are laid in the leaf tissue and the larvae mine downward into the stem where the principal damage occurs. Multiple attacks, especially when the plant is young, are usually fatal. If the plant survives the seedling period and is subsequently attacked by beanfly; pathogenic and saprophytic microorganisms may be introduced into the plants, stem breakage may occur, and decreased yield can be expected.

To screen for resistance to beanfly, 50 seeds per cultivar were planted in the field. Both germination and post germination mortality counts were made. Because *Rhizoctonia*, *Pythium*, rabbits, snails, cutworms, mole crickets, and other

environmental factors influence these counts; more reliance was placed on the stem-dissection method for determining the degree of infestation. Two 10-plant dissection counts were made for each cultivar. The stem was split with a sharp knife, and the interior carefully examined for the telltale zone of dead tissue and mining activity associated with beanfly infestation. The greenhouse screening test was similar to those conducted in the field except that less plants of fewer cultivars were screened.

Since other beanfly species have been reported and some variation within the same species or biotypes is expected, field-screening experiments were also conducted in Thailand and the Philippines. *Table 17* lists 10 cultivars that had low beanfly infestation rates in several screenings.

Beanfly populations were regularly sampled in the AVRDC mungbean fields from late August through December. Stem-infestation rates were used as a measure of the populations *(Fig. 8)*. The cultivar Tainan 2 was planted in 30-m^2 plots. Stem-dissection counts were made 10 days following germination and then at weekly intervals. A sample size of 100 plants was used to determine the percentage of infestation. There was a population peak from late August to early September when over 70 percent infestation occurred, followed by a sharp decline to less than 15 percent through the rest of September and into October (see *Fig. 8)*. Infestation rates then increased through November and surpassed the 80 percent level in December.

A plant species or variety may show resistance

Table 17. List of mungbean cultivars having relatively low beanfly *(M. phaseoli)* infestation rates in two or more screenings.

AVRDC acc. no.	Varietal name	Infestation rates[a]					
		AVRDC				Thailand	Philippines
		Fall 1973[b]	Spring 1974[c]	Fall 1974[d]	Greenhouse[e]	Fall 1974[f]	Fall 1974[g]
		(%)					
1550	India PI 37697	20		23			45
1667	PI 377087	25		29		5	25
2127	17587			12	30	35	25
2287	ML 20		25	24		35	50
2385	LM 18 (NP 17-2)			21	18	15	20
2397	LM 32 (NP 34)		20	17			35
2441	LM 81 (15034)			25			15
2500	LM 196 (1791)			7	27		25
2533	LM 220 (17331)		20	7			15
2552	LM 219 (178913)		10	18		35	55

[a] Total number of infested plants divided by the total number of dissected plants.

[b] 900 cultivars were planted Oct. 15, 1973 and evaluated Nov. 15; 794 cultivars had more than 50% infestation.

[c] 1,794 cultivars were planted Apr. 17 and evaluated June 5; 1,494 cultivars had more than 50% infestation.

[d] 150 cultivars were planted October 8 and evaluated Nov. 20; 42 cultivars had over 40% infestation.

[e] 72 cultivars were planted in wooden flats on Sept. 27 and exposed to beanfly populations in cages. Evaluated: Oct. 15; 61 cultivars had more than 30% infestation.

[f] 155 cultivars were planted Oct. 27 and evaluated Nov. 15 at Phraphutthbat, Thailand. 142 cultivars had more than 50% infestation.

[g] 155 cultivars were planted Nov. 1 and evaluated Nov. 19 at UPLB La Granja Research and Training (La Carlota City, Philippines). 85 cultivars had more than 50% infestation. Data included a second dissection count for those cultivars that had the lowest rates in the first count.

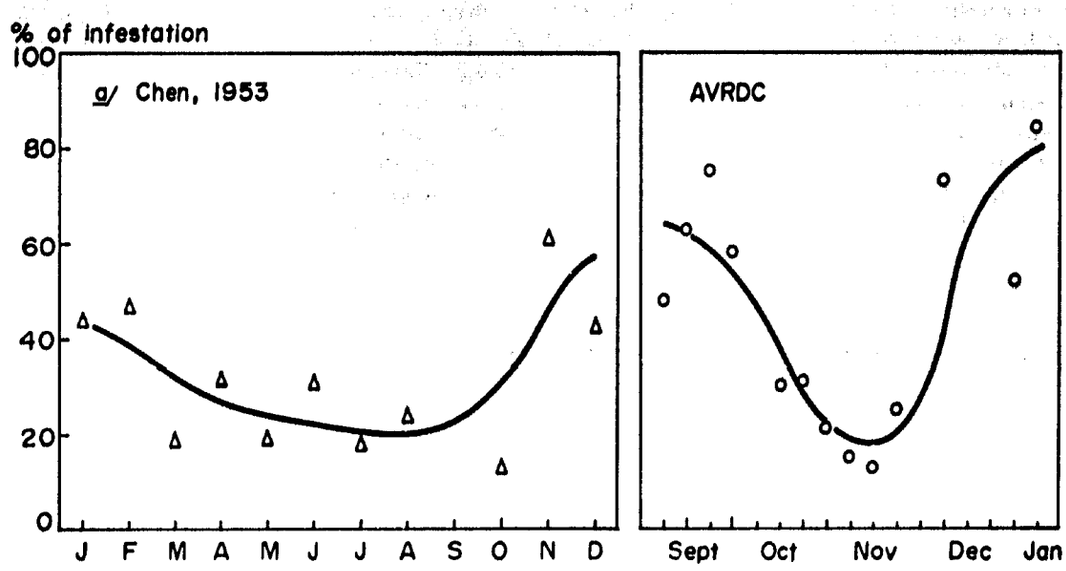


Fig. 8. Variation in beanfly *(M. phaseoli)* stem-infestation rates on mungbean measured by Chen in 1953 and at AVRDC from Sept. to Jan. (1975). Reference: Chen, K. H. 1953. Control tests of stem miners in legumes. Taiwan Agr. Res. 4 (1) 90-104 (in Chinese).

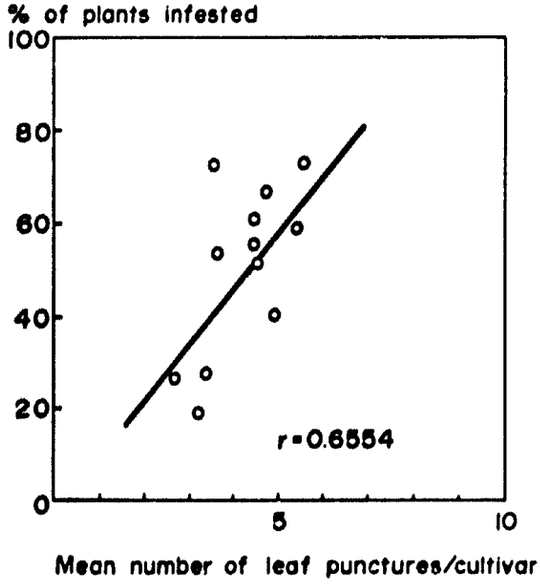


Fig. 9. Correlation between the number of leaf punctures and stem damage by beanfly *(M. phaseoli)* in 12 mung bean cultivars.

to the attack of certain insects for a number of physical or physiological reasons. These include: (i) the complete or partial nutritional inadequacy of the plant or its parts that are fed upon by the insect, (ii) the lack of an initial phagostimulant or lack of the proper feeding stimulant to maintain continued feeding, (iii) the presence of structural or physical characters of the plant which hinder feeding, (iv) the ability of the plant to grow faster than normal damage occurs, and (v) the presence of compounds that may be inhibitory or actually toxic from the onset. However, with so many different species of insects, which are adapted to nearly every ecological habitat and host in the world, practically every plant (particularly agricultural crops), has its set of insect pest species.

A mechanism of resistance to beanflies was investigated in the screenings reported in *Table 17.* This mechanism was the relative degree of oviposition stimulant or inhibitor present in different cultivars and its correlation to resistance as measured by the percentage of damaged stems.

The adult female beanfly uses her ovipositor to puncture the leaf surface to lay eggs and also to create wounds from which she may feed. The number of these puncture marks per leaf were counted and averaged for each cultivar and compared with the percentage of damaged stems for that cultivar *(Fig. 9).* In both the field and

greenhouse experiments, each cultivar was replicated in a randomized complete block design. In the greenhouse evaluation, there were three replications of eight plants each; and in the field, 50 seeds were planted for each cultivar with three replications.

The results clearly and consistently demonstrated a definite positive linear correlation between the number of leaf punctures and stem damage. Therefore, at least one factor in the relative damage resistance of some mungbean cultivars can be attributed to the interaction of the adult female beanfly with the plant leaf at the time of oviposition. The exact nature of this selective interaction is being studied.

PLANT PHYSIOLOGY

Because relatively little is known about the physiology of mungbean, it is often compared with soybean. For instance, the growth rate of mungbean (as % of total dry wt) is consistently less than that of soybean *(Fig. 10)*.

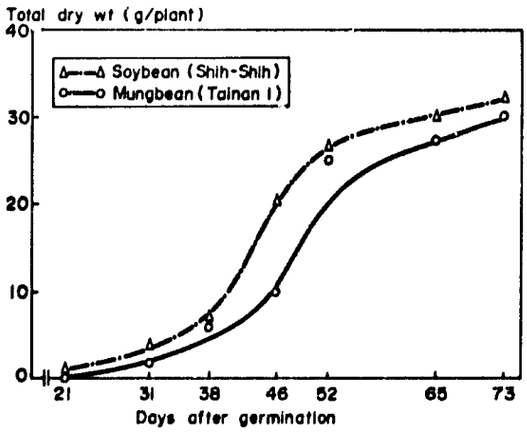


Fig. 10. Comparison of soybean and mungbean growth rates.

Soybean has a higher whole plant nitrogen content than mungbean. However, the average whole plant nitrogen content per unit dry weight over the entire growth period is about the same for both (30.7 and 30.3 mg/g for soybean and mungbean, respectively). The difference is evident in the partitioning of the total nitrogen content between soybean and mungbean *(Fig. 11)*. Our studies showed that almost 86 percent of the total plant nitrogen of the soybean cultivar Shih-Shih was in the pods and seeds at maturity *(Table 18)*. In contrast, the reproductive portions of the mungbean cultivar Tainan 1 contained only 61 percent of the total plant nitrogen at harvest (see *Table 18*).

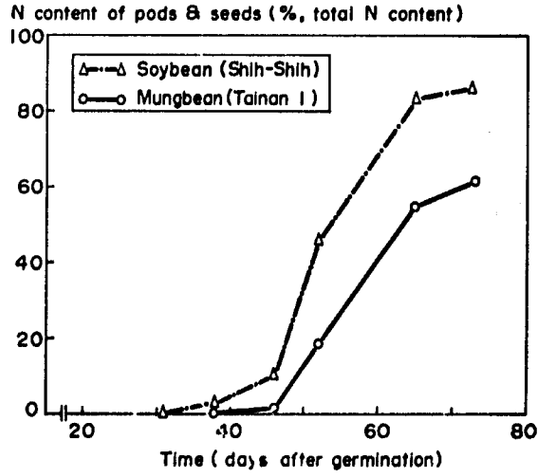


Fig. 11. Portion of the total plant nitrogen contained in the seeds and pods of soybean and mungbean plants.

Table 18. The effects of CO_2 enrichment and shading on the distribution of total nitrogen in soybean and mungbean. a/

	Percent of total plant nitrogen		
	Vegetative part (leaves+stems)	Reproductive parts (pods+seeds)	Total nitrogen content mg/plant
	(%)		
Soybean			
Shaded b/	16	84	700
Control	14	86	844
+ CO_2 c/	12	88	979
Mungbean			
Shaded	36	64	324
Control	39	61	645
+ CO_2	33	67	649

a/ Soybean cultivar Shih-Shih and mungbean cultivar Tainan 1.

b/ Approximately 50% shade.

c/ Approximately 450 to 750 ppm.

When the source was increased by enriching the environment with carbon dioxide (CO_2), the total nitrogen content of the soybean increased. Essentially all the increase went into the reproductive parts of the plant (see *Table 18)*. When mungbean was given the same treatment, CO_2 enrichment did not increase the total nitrogen, and only slightly more of the nitrogen was moved to the reproductive parts (see *Table 18)*. Even with this increase, the portion of the total nitrogen in mungbean seeds was only 67 percent. When the source was decreased by shading, the total amount of nitrogen decreased in both Shih-Shih and Tainan 1. The partitioning ratio remained unchanged.

AGRICULTURAL CHEMISTRY

The crude protein content (N x 6.25) of seeds from 1,658 mungbean cultivars was determined, using the Udy-dye-binding method. The range was from 19.5 to 28.5 percent of the dry weight with a mean of 24 percent *(Fig. 12)*. It appears that the crude protein content is influenced by environmental factors. For example, when the cultivar Tainan 1 was exposed to CO_2 enrichment and shading, the crude protein content of its seeds ranged from 22 to 30 percent of the dry weight *(Fig. 13)*.

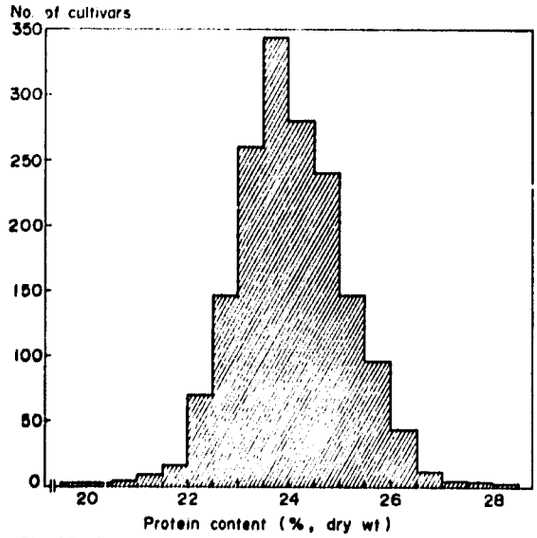


Fig. 12. Distribution of 1,658 mungbean cultivars by protein content (N x 6.25), as measured by the Udy-dye-binding method.

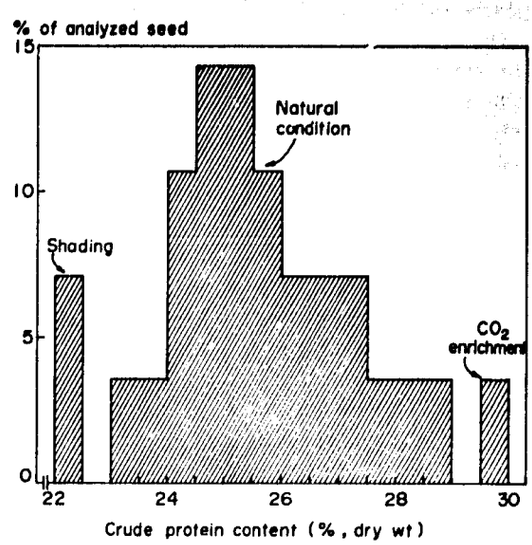


Fig. 13. Variation in crude protein content of mungbean seed (Tainan 1) when grown under CO_2 enrichment, natural conditions, and shading.

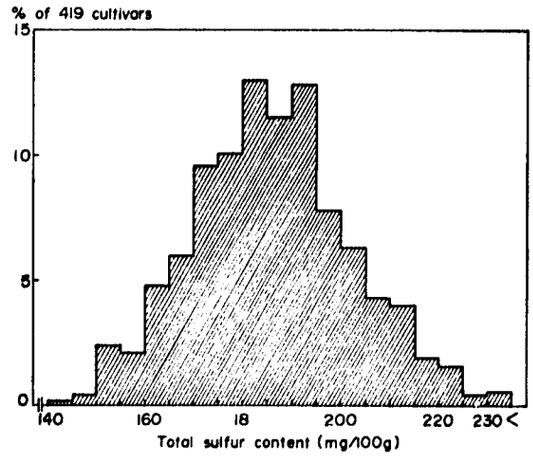


Fig. 14. Distribution of 419 mungbean cultivars by the total sulfur content of their seeds.

The possibility of improving protein quality was also investigated. The sulfur content of the seeds of 419 cultivars ranged from 140 to 249 mg/100 g *(Fig. 14)*. It is assumed that the sulfur content is an indication of the concentration of sulfur-containing amino acids, and that this, in turn, is a measure of protein quality. Therefore, it appears that there is a 56 percent variation in seed

protein quality within the sampled population. This is a significant difference and warrants continued emphasis on breeding for protein quality.

SOIL SCIENCE

Plants grown in calcarious soils generally have difficulty in absorbing minor elements such as zinc, manganese, iron, and copper. Thus, an experiment was conducted to determine the response of mungbean grown in the calcarious soils of the experimental farm (see Crop Environment) to application of Zn, Mn, and Cu. Pots in the greenhouse were filled with soil having a pH of 6.8. The cultivar Thai Green Oil (TH 4) was sown April 15. The response of mungbean was greatest when Zn was added *(Table 19)*. The effect of Mn and Cu were not as clearly defined.

In another experiment, 16.4 grams of gypsum were added to each pot to increase the concentration of the calcium cation. In this experiment, the response to applications of Zn, Mg, and Fe was studied. The plants were harvested before maturity (63 days after germination). The effects of the minor elements on the growth of mungbean are presented in *Table 20*. Note that the separate applications of Zn, Mg, and Fe increased the pod number and dry matter production (see *Table 20*). However, when Mg and Fe were combined, their

Table 19. The response of mungbean grown in calcarious soils to applications of Zn, Mn, and Cu. [a/]

Treatment	Pods per plant (no.)	(%)	Dry wt Pod	Leaf & Stems	Total	Total dry wt as a % of control
			(g/pot)			
Zn	63	157	26	27	53	135
Zn · Cu	58	145	26	33	59	151
Zn · Cu · Mn	60	150	20	26	46	117
Control	40	100	18	21	39	100

a/ The cultivar TH 4 was sown in pots containing calcarious soil (pH 6.8) April 15. Data are the means of 3 replications. The plants were harvested before reaching maturity (71 days after germination).

Table 20. The response of mungbean grown in calcarious soil fortified with gypsum to applications of Zn, Mg, and Fe (separately and in combination). [a/]

Treatment	Pods per plant (no.)	(%)	Dry wt Pod	Leaf & Stem	Total	Total dry wt as a % of control
			(g/pot)			
Gypsum	27	128	12	7	19	146
Gypsum, Zn	33	157	12	9	21	161
Gypsum, Mg	36	171	13	11	24	184
Gypsum, Fe	37	176	13	13	26	200
Gypsum, Mg, Fe	32	152	10	10	20	153
Gypsum, Zn, Mg	46	219	15	17	32	246
Control	21	100	8	6	13	100

a/ The cultivar TH 4 was sown in pots containing calcarious soil (pH 6.8) April 23. Data are means from 3 replications. The plants were harvested before reaching maturity (63 days after germination). Gypsum was applied at the rate of 16.4 g/pot.

effectiveness was likely lessened due to the competition between the two ions. The combination of Zn and Mg produced good growth. The probability of zinc deficiency in mungbean grown in the calcarious soils of the experimental fields was verified.

AGRICULTURAL ECONOMICS

Relatively little information is available regarding the production of mungbean in Asia. Production data were obtained for only four countries *(Table 21)*.

Table 21. Mungbean production, area, and yields in four Asian countries, 1972-1973.

Country	Production (1,000 tons)	Area (1,000 ha)	Yield (tons/ha)
Thailand a/	191	205	0.93
Taiwan b/	3	4	0.65
Philippines c/	19	40	0.48
India d/	392	1,488	0.26

a/ Adapted from Division of Agricultural Economics, Ministry of Agriculture. 1973. Agricultural statistics of Thailand. Crop year 73-74. Thailand.

b/ Adapted from Department of Agriculture and Forestry 1974. Taiwan agricultural yearbook, 1974. Taiwan.

c/ Adapted from Bureau of Agricultural Economics. 1974. Bureau of Agricultural Economics report for 1973. Philippines.

d/ Adapted from Directorate of Economics and Statistics, Ministry of Agriculture. 1973. All India final estimates of Kharif pulses. 1972-1973. New Delhi, India.

A study[+] in Taiwan indicated that the major production cost was labor, especially for harvesting. The AVRDC economists surveyed 12 farmers who were growing mungbean in the Shanhua area near AVRDC. They observed that in the fall mungbean was generally intercropped with sugarcane, although some pure stands were grown on small plots (averaging 0.2 ha). Emphasis was placed on minimizing production inputs and costs. For example, 75 percent of the 12 farmers did not apply chemical fertilizers, 83 percent did not apply manure, and 42 percent never irrigated their crops.

More attention will be given in 1975 to assessing mungbean production throughout Southeast Asia.

INTERNATIONAL ACTIVITIES

As discussed in the *72-73 Annual Report*, 38 selections were bulk harvested in the F_2 generation and the bulked F_3 seeds were distributed to 17 scientists from 12 different countries in 1974 *(Table 22)*. These lines are being tested for local adaptability throughout the region.

During 1974, 218 F_3 populations were planted at AVRDC and the best 20 were bulk harvested for distribution to cooperators. In addition, nearly 2,000 cultivars were planted in Thailand to evaluate their local adaptability and yield. This year, 4,962 seed packets were sent to 24 scientists in 15 countries.

Seventy-three cultivars and 77 advanced lines with resistance to either *Cercospora* leaf spot or powdery mildew *(Erysiphe polygoni)*, or both, were sent to scientists in the Department of Agriculture, Thailand. These resistant cultivars and selections have also been distributed to scientists in the Philippines and India.

About 1,800 cultivars were sent to the International Crop Research Insitute for the Semi-Arid Tropics (ICRISAT) in Hyderabad, India to screen for resistance to virus diseases. Only 10 cultivars survived, and five of them seemed to possess field resistance to both mungbean bud necrosis and mungbean yellow mosaic (Acc. 1729, 1735, 2366, 2500, 2551). They have been used in our breeding program, and the F_2 populations will be screened again at ICRISAT.

[+] Provincial Department of Agriculture and Forestry. 1974. A report on the survey of production costs of Taiwan's agricultural products. p. 72.

Table 22. List of mungbean researchers who received our bulked F_3 populations in 1974.

Country	Scientist	Organization	No. of F_3 population sent[a]
Canada	Dr. A. Slinkard	Univ. of Saskatchewan	6
Canada	Dr. M. Stauffer	New Crops Research Station	37
Colombia	Dr. L. Camacho	Instituto Colombiano Agropecuario	38
Ethiopia	Dr. L. Ohlander	Institute of Ag. Research	37
France	Dr. Bannerot	C. N. R. A.	22
India	Dr. H. Jain	India Ag. Res. Institute	38
India	Dr. B. Krantz	ICRISAT	37
India	Dr. R. Misra	Pulses Specialist	37
Indonesia	Dr. R. Freed	IRRI (Outreach)	22
Iran	Dr. M. Amirshahi	Univ. of Tehran	37
Korea	Dr. K. Park	Crop Experiment Station	22
Pakistan	Dr. J. Lockman	Technical Services Assoc.	7
Thailand	Dr. V. Finker	Ag. Center Northeast	19
Thailand	Dr. A. Nalanipany	Dept. of Agriculture	38
U. S. A.	Dr. J. Kirby	Oklahoma State Univ.	37
Vietnam	Dr. A. Hartman	US AID/ ADFA	38

[a] 5,000 seeds per population.

Farmers near AVRDC frequently intercrop mungbean with sugarcane.

Tomato

A comprehensive program is under way at AVRDC to overcome the many problems limiting tomato production in monsoon Asia and other tropical regions. Thirty-one cultivars from 12 different countries have been identified as heat tolerant, i.e., able to set fruit under high night temperatures. More than 400 crosses were made in 1974. Nurseries to screen for resistance to bacterial wilt and late blight were established. More than 300 selections were made for plant vigor, high fruit set, and good fruit quality from segregating populations with resistance to bacterial wilt *(Pseudomonas solanacearum)* and gray leaf spot *(Stemphylium solani)*. More than 100 isolates of *Pseudomonas solanacearum* were collected and classified according to degree of virulence and three patterns of resistance were identified. The F_4 generation had greater resistance to bacterial wilt than preceding generations. Five tomato selections were rated as resistant to late blight *(Phytopthora infestans)*. Accession 127 (*ah*TM-2[a]) was resistant to tobacco mosaic virus and field resistant to double streak virus.

LYCOPERSICON SP. GERMPLASM COLLECTION

Lycopersicon esculentum	*3,591*
Lycopersicon pimpinellifolium	*132*
Lycopersicon peruvianum	*20*
Lycopersicon cheesmanii	*1*
Lycopersicon hirsutum	*15*

Suspected crosses:

L. esculentum / L. pimpinellifolium	*163*
L. esculentum / L. hirsutum	*2*

PLANT BREEDING

THE WORLD COLLECTION. In 1974, AVRDC received 58 accessions of *Lycopersicon esculentum;* mainly from Korea, the United States, the Netherlands, the Philippines, and Gambia. The new accessions included nine that were purported to be heat tolerant, and three believed to be resistant to bacterial wilt.

During the summer, 540 cultivars were screened for heat tolerance (i.e., the ability to set fruit under hot, humid conditions). *Table 1* compares the results of this 1974 trial with those screened in 1973. To date 31 cultivars (1% of the total screened), which came from 12 different countries, have been rated as heat tolerant *(Table 2).*

CROSSING PROGRAM. More than 400 crosses were made in 1974; most of them were multiple crosses involving two F_1 hybrids and a cultivar with one or more desirable characteristics. Emphasis was given to improving selections found to be heat tolerant and resistant to bacterial wilt. Numerous crosses were made to increase the vitamin C and β-carotene[+] content of the fruit while improving fruit quality (shape, color, crack resistance). More multiple crosses (double-double to double-triple crosses) will be made to augment the recombinations of desirable genes.

SEGREGATING POPULATIONS. To facilitate screening for bacterial wilt resistance, a bacterial wilt nursery was established in the spring and 288 genetic lines (138 F_3[++] pedigreed, 104 F_3 bulked, and 47 parentals), consisting of approximately 142,000 seedlings, were inoculated. In this screening, only 55 percent of the lines thought to be resistant survived after being inoculated with the pathogen, whereas 31 percent of the entries originally believed to be susceptible proved resistant *(Table 3).* Two-way combinations of wilt-resistant lines had higher survival rates in the F_3 populations than either the mean of the resistant parents or the mean of a single cross with only one resistant parent *(Table 4).* This agrees with our hypothesis that resistance to bacterial wilt is controlled by multiple-recessive genes acting additively.

Some of the wilt-resistant seedlings transplanted into the field were individually inoculated with leaf mold *(Cladosporium fulvum),* and 26 lines with a moderate to high degree of resistance to leaf mold were identified. Unfortunately, these selections had only moderate fruit-setting ability.

Thousands of early generation lines, mostly F_3 and F_4 from crosses made in 1973, were evaluated for heat tolerance, bacterial wilt resistance, crack formation, blotchy ripening, determinate-growth habit, and earliness in a series of plantings *(Table 5).* The first and second plantings were not inoculated with the bacterial wilt pathogen. Thus, the selections from these trials were made only for heat tolerance, fruit quality, and growth characteristics and not for bacterial wilt resistance. After April 29, all of the seedlings were inoculated with bacterial wilt. The survivors were transplanted to the field. Although this procedure generally reduced our transplants by 50 percent, it enabled us to give more attention in the field to evaluating growth and fruit characteristics.

Only a small number of desirable recombinants with bacterial wilt resistance, heat tolerance, and other desired horticultural traits were selected from segregating populations (see *Table 5).* This was expected as the inheritance of bacterial wilt resistance and heat tolerance is believed to be complex. Furthermore, only plants with the best vegetative growth and fruit traits were selected. Promising selections from the August 1 planting were included in yield trials at AVRDC, in the Philippines, and in Thailand.

On September 11, wilt-resistant selections from 94 F_4 populations were subjected to natural epiphytotics of gray leaf spot, *Stemphylium solani.* This disease outbreak permitted selection for leaf spot resistance. At the same time 9000 seedlings in flats were individually inoculated with the bacterial wilt pathogen. When these were transplanted to the field, they showed only moderate symptoms of gray leaf spot. Evidently, the natural concentration of *Stemphylium solani* was less than in the earlier planting. From these two plantings, more

[+] βcarotene is a precursor of vitamin A. When βcarotene is injested, the body converts it to vitamin A.

[++] Screening was initiated in the F_3 generation, because the F_2 was planted during the 73-74 winter season, i.e., we could not screen for heat tolerance.

Table 1. Results of 1973 and 1974 screenings for heat tolerance (i.e., ability to set fruit under hot, humid conditions).

Observed fruit set	1973 screening		1974 screening		Total no. screened	
	No. of cultivars	% total screened	No. of cultivars	% total screened	No. of cultivars	% total screened
None	2,570	79	488	90	3,058	81
Light	509	15	39	7	548	14
Moderate	153	5	9	2	162	4
Heavy	27	1	4	1	31	1
Totals	3,250	100	540	100	3,799	100

Table 2. Origins of the 31 heat-tolerant tomato cultivars.

Country	No. of Accessions
Canada	4
China (Mainland)	1
Ecuador	3
England	2
India	2
Israel	2
Hungary	4
New Caledonia	1
Peru	1
Philippines	8
South Africa	1
U.S.A.	3
Total Number	31

Table 3. Survival rates of 47 cultivars when inoculated as seedlings with the bacterial wilt pathogen.

Original classification of entries a/	Number of seedlings		Survival b/ (%)
	Inoculated	Survived	
Resistant	5,452	2,985	55
Susceptible	1,224	378	31

a/ 31 cultivars rated as resistant and 16 cultivars that were supposedly susceptible were sown March 25 to 28 and inoculated April 25 to 27.

b/ Readings were made 10 days after inoculation.

Table 4. Survival rates of 242 F_3 populations inoculated as seedlings with the bacterial wilt pathogen. a/

Source of resistance	Number of seedlings		Survival b/ (%)
	Inoculated	Survived	
One parent	58,478	24,876	42
Two parents	77,283	47,954	62

a/ Sown March 25 to 28 and inoculated April 25 to 27.

b/ Only parents rated initially as resistant were used for these crosses. The parental survival rate was 55%. *(Table 3).*

than 300 selections were made for plant vigor, high fruit set, and good fruit quality. These selections were evaluated for such processing qualities as soluble solids, pH, and acidity. In addition, the more promising selections were also analyzed for vitamin C and β-carotene content *(Table 6).*

The growing importance of tomato processing in the tropics has led us to select for fruit characteristics required by canneries. Therefore, we look for plants that develop fruit during the warm season without cracking. The fruits must be firm, easy to peel, and have a deep red color. They should also have a high solids content (at least 4.5° Brix) and a low pH value (about 4). The total solids content tends to decrease as the yield increases. Low acid content and the resulting high pH are also undesirable in tomatoes for processing. A pH greater than 4.4 increases the activity of thermophilic organisms and makes it difficult to get a safe product with normal processing techniques. Firm fruits would be damaged less enroute to the factory; easy-peel quality would shorten the

Table 5. Summary of information on the screening of segregating populations for heat tolerance and resistance to bacterial wilt.

Date planted	Generation	Number of seedlings		Number of selections	Selection (%)
		Inoculated	Transplanted		
March 21	F_3		15,435	103	0.7
April 15	F_3		28,905	554	1.9
April 25	F_3	2,400 a/	600	511	0.5
April 23	F_3	1,600 a/	400	10	0.6
April 29	F_3	11,130 b/		61	0.6
July 10	F_3	41,062	17,970	20	0.05
August 1	F_4	15,374	7,468	112	0.7

a/ Segregating for purple (+) and green stem (ah); green stem is linked to TMV resistance

b/ Direct seeded and inoculated with the bacterial wilt pathogen.

Table 6. Fruit characteristics of the most promising processing tomato selections compared with three cultivars used for processing in Taiwan. a/

AVRDC selection (or acc.) no.	Pedigree or (varietal name)	No. of fruit/ kilo	°Brix	pH	Acidity (% citric acid)	Ascorbic acid (mg/100g)	β-carotene (mg/100g)
6d-0-1-1	VC 9 / Saturn	17	5.2	4.0	0.6	15	1.1
6d-0-2-1	VC 9-1 / Saturn	16	5.2	4.2	0.4	16	0.7
6d-0-2-5	VC 9-1 / Saturn	22	5.6	4.1	0.5	15	1.2
6d-0-3-9	VC 9-1 / Saturn	18	6.0	4.2	0.3	14	0.7
7-0-11-2	VC 11-1-2 / Florida MH-1	16	5.0	4.0	0.5	15	0.7
8d-0-6-2	VC 11-1-2 / Venus	12	5.1	4.1	0.5	18	0.9
10-2-0-1	VC 9-1-2 / Florida MH 1	15	5.8	3.9	0.7	20	1.3
143-0-8-8	VC 48-1 / Tamu Chico III	29	5.2	4.1	0.6	18	1.0
158-0-2B-1	VC 9-1 / KL 2	36	5.4	4.0	0.6	24	0.7
158-0-6-1	VC 9-1 / KL 2	21	5.2	3.9	0.6	20	0.7
246-0-3B-4	Tropi-Red / VC 48-1 // Manalucie	24	5.1	4.0	0.5	11	1.3
	Mean	*21*	*5.3*	*4.0*	*0.5*	*17*	*0.9*
(3975)	(TK 70)	16	5.2	4.1	0.5	17	1.0
(3976)	(TK 3)	20	4.1	4.2	0.4	14	3.2
(8J)	(Roma)	21	5.1	4.3	0.5	11	0.7
	Mean	*19*	*4.8*	*4.2*	*0.5*	*14*	*1.6*

a/ 94 F_4 populations were sown Sept. 11 in the field and 9,000 seedlings were sown in wooden flats August 3 and transplanted to the field Sept. 11.

time involved in removing the peel before processing; crack resistance would reduce fruit spoilage; and deep red color is an index of maturity directly related to the tomato's flavor.

The soluble solids and pH values of our selections (see *Table 6)* were within an acceptable range. The ascorbic acid and β-carotene contents were also normal. However, fruit size, as indicated by the number of fruits per kilo, was small.

In early November, there was an outbreak of late blight *(Phytopthora infestans)* in the fields of the Taiwan Seed Service Station near Taichung (Shinshih). Approximately 23,200 seedlings belonging to 116 breeding lines (with one parent resistant to late blight) were transplanted for observation at the station. Another 21,000 seedlings were transplanted for further late blight screening at AVRDC (see Plant Pathology).

YIELD TRIALS. Two yield trials, consisting of 20 cultivars each, were conducted in the late spring, one for processing tomato and the other for fresh market tomato. The results for the more promising cultivars and their reactions to bacterial wilt (taken from later screenings) are summarized in *Table 7.*

The yields of the best cultivars in both groups were substantial when grown in a wilt-free field and considerably higher than the Asian average. Their performance, however, must be tested in the bacterial wilt nursery, because most of these cultivars had a susceptible reaction to *Pseudomonas solanacearum.* The high coefficients of variance in both trials were attributed to spatial differences in the experimental plots.

SINGLE SEED DESCENT. Segregating populations are either pedigreed or bulked. In addition, a modified single seed descent (SSD) was used as a method of generation advance with some populations such as those coming from crosses involving three parents with resistance to bacterial wilt. With this technique, selection and testing are delayed until the F_6 generation when the plants are homozygous. It is being employed by the breeders as a means of developing new lines for small agricultural stations in developing countries. If a given line performs well in a specific country, its seed can be quickly produced for commercial planting. Therefore, seeds advanced through SSD can speed up the process of developing new varieties at national research stations with the minimal supervision of a plant breeder. Consultation with Dr. Laures T. Empig of the Philippines Sugar Research Institute (PHILSUGIN), resulted in the procedures listed in *Chart 1.*

Chart 1. Procedures used for single-seed-descent (SSD).

1) Ten F_1 plants are grown to obtain as many F_2 seeds as possible
2) 2,000 F_2 plants are grown and 10 F_3 seeds[+] of each genotype are retained.
3) Two F_3 seedlings are grown per genotype but only one plant is allowed to produce fruit[+].
4) Ten F_4 seeds are collected from each genotype. Again, two seedlings are grown, but only one is allowed to produce fruit.
5) All the F_5 seeds are collected from each genotype and are available to send to cooperators for screening at various locations.
6) Selections are made by cooperators for F_6 plants with plant traits desired at that locality.
7) Seeds from the selected genotypes are then increased in the F_7 generation.
8) At each location, the cooperators can introduce the selected cultivars into appropriate seed production and certification programs.

[+] Seeds are taken from the first fruit cluster for more rapid generation turn over.

STUDY OF MOISTURE TOLERANCE. One of our major objectives is to develop tomato varieties that will produce fruit during the summer monsoon season. Therefore, an experiment was conducted to screen for resistance to excessive soil moisture as well as high temperatures. Eight cultivars of *L. esculentum* var. *cerasiforme* were used, as they had been observed by Dr. Charles M. Rick (Univ. of Calif. at Davis) as able to survive excessively moist conditions. Eight heat-tolerant and four heat-sensitive cultivars were included for comparison.

The first trial was terminated after five weeks. Water was applied by sprinklers to simulate rainfall. The seedlings were given 44 mm of water per day the first week (about 300 mm/wk) and 22 mm per day beginning the second week (about

Table 7. Yield performances and bacterial wilt reactions of selected fresh market and processing tomato cultivars. [a]

Fresh market tomato				Processing tomato			
AVRDC acc. no.	Varietal name	Yield (tons/ha)	Bacterial wilt reaction [b]	AVRDC acc. no.	Varietal name	Yield (tons/ha)	Bacterial wilt reaction [c]
383	Green Skin	33	S	124	Shanhua-2	37	MS
21	VC 11-1	28	MR	283	Tarnu Chico III	34	MS
39	Tropi-Red / VC 11-2	27	MS	88	VC 8-2-1	28	R
1	VC 48-1	27	MR	80	VC 13-2-1	26	R
8	VC 9-1	24	MR	3856	Chico Grande	25	S
34	VC 11-2-2-7a	24	R	3857	Cold Set	25	S
32	2029	23	MS	82	VC 13-1	23	R
94	Florida MH-1	22	S	332	Roma VF	22	S
95	Venus	21	MS	126	Nova	21	
				276	Niagara VF 317	21	S
				3859	Heinz 39	19	S
				3874	VF 105-2	18	S
	Mean	25			*Mean*	25	
HSD	.05	11				17	
	.01	13				20	
CV (%)		24				31	

[a] Yield trials sown at AVRDC on April 25.

[b] Disease data recorded on these cultivars in other screenings by the pathologists.
R - less than 20% plants wilted.
MR - 20 to 40% plants wilted.
MS - 40 to 70% plants wilted.
S - more than 70% plants wilted.

[c] Disease data from a UPLB (Philippines) trial (Summer, 1972).

150 mm/wk). Although this was higher than the mean summer rainfall rates (100 mm/wk), it was not considered excessive. However, flooding of the experimental fields occurred and the seedlings were drawned. The experiment will be repeated in 1975 on a field with better drainage, using 100 mm per week simulated rainfall rate.

PLANT PATHOLOGY

BACTERIAL DISEASES. Bacterial wilt of tomato, *Pseudomonas solanacearum*, is an extremely mutable pathogen. More than 100 isolates were collected from diseased host crops at various locations in Taiwan. These isolates differed in virulence and pathogenicity, yet all infected susceptible tomato cultivars. The pathologists classified these isolates by colony morphology on a standard medium (TTC) and rated each isolate's virulence or pathogenic specificity by noting its effect on a set of differential tomato cultivars, whose response to similar pathogens was known.

Twenty-three isolates were classified into six pathogenic groups by evaluating their virulence on five differential cultivars *(Table 8)*. Eight cultivars, selected to classify isolates of *P. solanacearum*, are listed in *Table 9*.

More than 100 cultivars reported to be either bacterial wilt resistant or heat tolerant were evaluated in the field as seedlings and again at flowering. The plants were inoculated by clipping the lower leaves with scissors that had been dipped

Table 8. Differential interactions between 23 isolates of *Pseudomonas solanacearum* and 5 tomato cultivars.

AVRDC acc. no.	Varietal Name	Pathogenic group					
		I	II	III	IV	V	VI
8	VC 9-1	R	R	R	R	R	R
246	KL 2	R	R	R	R	R	R
96	Saturn	R	R	R	R	S	S
95	Venus	R	R	S	S	S	S
232	Nagcarlan	R	S	R	S	R	S
No. of isolates:		5	9	2	3	1	3

R - less than 20% plants wilted.
S - more than 70% plants wilted.

Table 9. Tomato cultivars selected to differentiate among pathotypes of *Pseudomonas solanacearum*.

AVRDC acc. no.	Varietal name	Origin	Bacterial Wilt reaction[a]
8	VC 9-1	Philippines	R
333	VC 48-1-2-1	Philippines	R
95	Venus	North Carolina, U.S.A.	MR
274	Kowalo	Hawaii, U.S.A.	MR
232	Nagcarlan	Philippines	MS
94	Florida MH-1	Florida, U.S.A.	MS
90	Pusa Ruby	India	S
3180	PI 303785	Ohio, U.S.A.	S

[a] R - less than 20% plants wilted
MR - 20 to 40% plants wilted
MS - 40 to 70% plants wilted
S = more than 70% plants wilted

in a bacterial suspension. The plants were surveyed daily for three weeks for signs of wilting. Most cultivars were rated either moderately resistant or moderately susceptible as seedlings (17 days after inoculation). By the flowering stage, however, it was possible to identify truly resistant cultivars.

Patterns of resistance were identified using both natural infection and artificial inoculation. Nineteen cultivars were planted in the bacterial wilt nursery and in a wilt-free field. The plants in the wilt-free field were inoculated with a mixture of *P. solanacearum* isolates two weeks later. Four cultivars (Acc. 1, 8, 15, 96) remained resistant after inoculation, whereas seven others, which had shown field resistance succumbed to the disease *(Fig. 1)*.

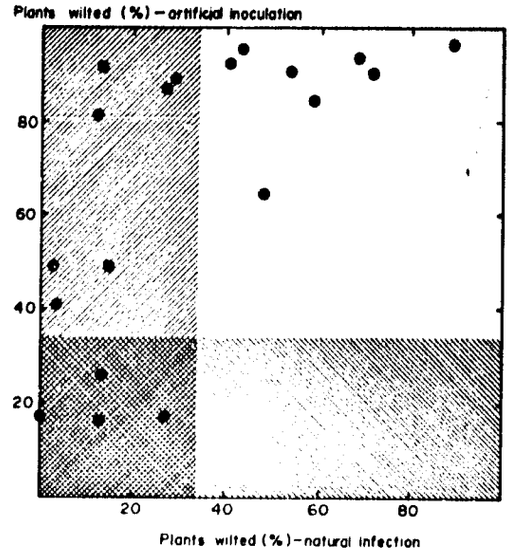


Fig. 1. Reaction of 19 tomato cultivars to bacterial wilt when grown in the wilt nursery (natural infection) and when inoculated. Four cultivars (Acc. 1, 8, 15, 96) were resistant under both conditions.

There appeared to be three patterns of resistance *(Fig. 2)*. The first pattern (represented by Acc. 1, 8) did not change whether in the nursery or inoculated. However, another pattern (Acc. 245, 274) had an acute log phase when inoculated, and a third pattern (Acc. 21, 33) showed only moderate resistance after inoculation. These three patterns of resistance can be described as major-gene resistance (Acc. 1, 8), field resistance (Acc. 245, 274), and a combination (Acc. 21, 33).

The incubation period for 10 tomato cultivars, including both resistant and susceptible lines, was recorded after inoculation with the bacterial wilt pathogen (Isolate 3). Among the four resistant cultivars, the incubation period ranged from 6 to 17 days *(Table 10)*. Cultivars with an incubation period of 17 days probably had major-gene conditioning for resistance, but cultivars with shorter incubation periods are believed to possess only field resistance.

The bacterial wilt pathogen prepared for the screening program consisted of different pathotypes

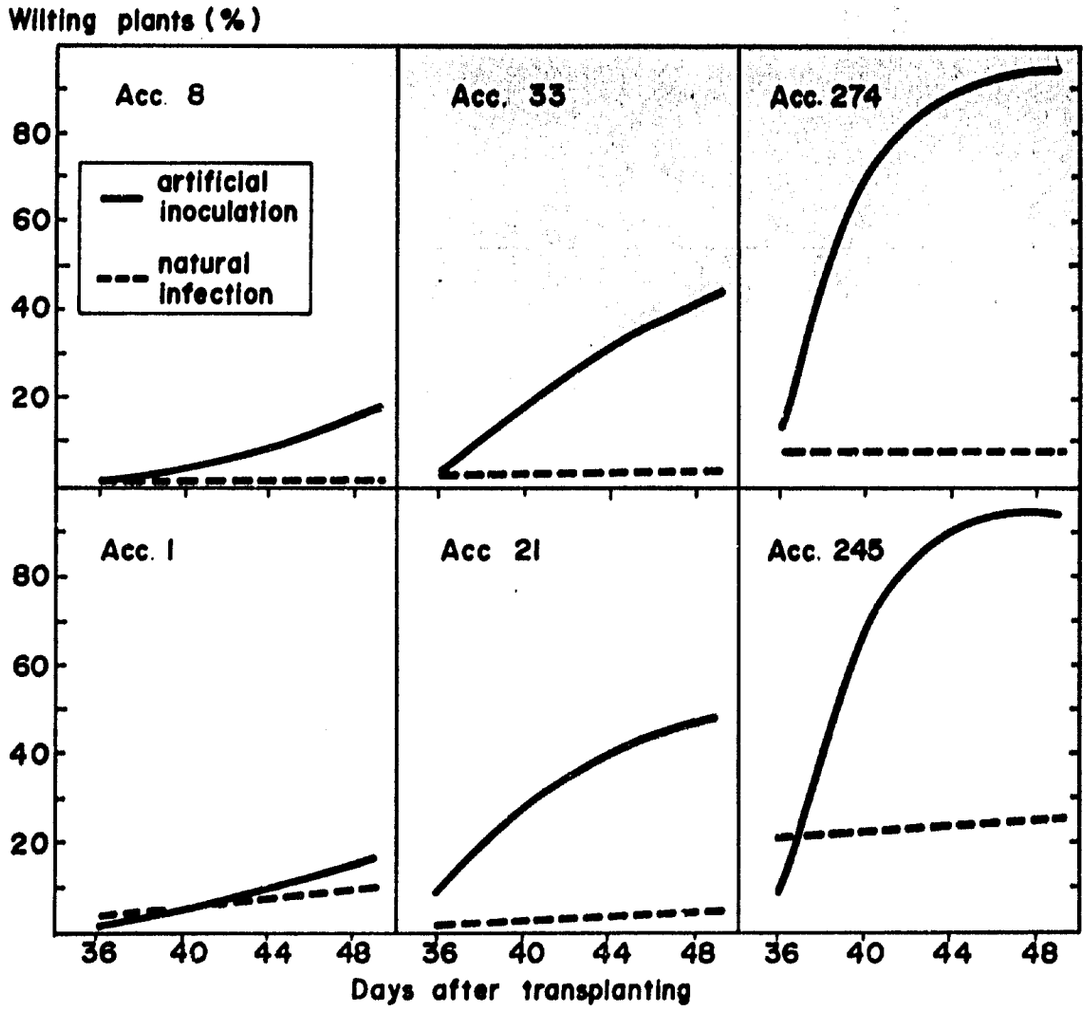
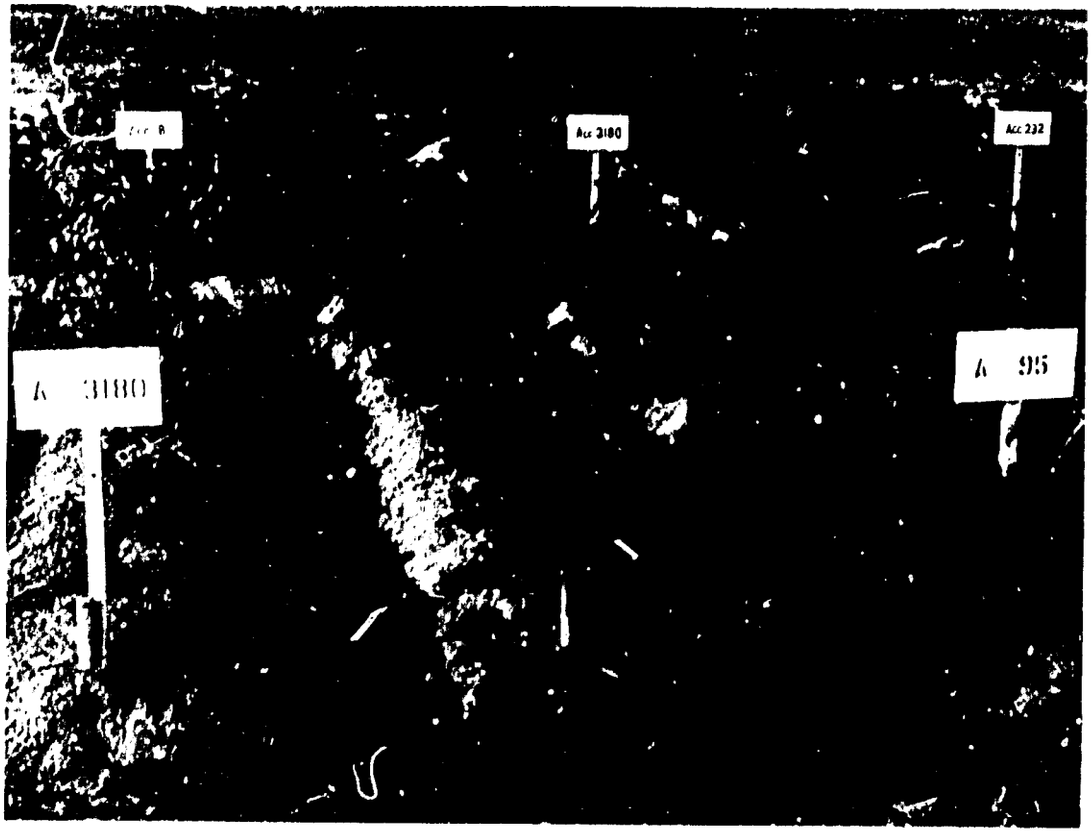


Fig. 2. Three reactions of 6 tomato cultivars with varying degrees of resistance to *P. solanacearum* when inoculated with a mixture of isolates.

and levels of virulence. This was done to avoid developing cultivars with a narrow range of resistance and to test for cross-protection, which may occur if the inoculum contains both avirulent and virulent forms of the pathogen. If such cross-protection occurs, the disease severity induced by the virulent pathogens is diminished by the presence of the avirulent pathotypes. However, examination of the plants' response to a combination of avirulent and virulent pathogyes showed that no cross-protection occurred.

By the end of 1974, the pathologists had screened over a million plants in the field from the F_2, F_3, and F_4 populations for major-gene resistance to bacterial wilt. The resistant selections were planted in the field to screen for resistance to other diseases. The F_4 populations had greater resistance to bacterial wilt than the F_3 populations *(Table 11)*. However, most of the wilt-resistant selections were from bulked instead of pedigreed populations.

FUNGAL DISEASES. Gray leaf spot, *Stemphylium solani*, is a very destructive disease common in the humid tropics. The first infection



Resistant (Acc. 8, 95) and susceptible (Acc. 3180) tomato cultivars were inoculated with bacterial wilt (*P. solanacearum*). This disease seriously limits tomato cultivation in the tropics.

Table 10. Differences in incubation periods of 10 tomato cultivars infected by *Pseudomonas solanacearum* Isolate 3.

AVRDC acc. no.	Varietal name	Incubation period (days)	Bacterial wilt reaction.[a]
1	VC 48-1	8	R
8	VC 9-1	17	R
21	VC 11-1	16	R
68	Tropi Red / VC 9-1 //4-2-6	6	R
203	Floradel	7	MR
232	Nagcarlan	5	MR
233	64-S 46-1	12	MR
93	Walter	4	S
234	69 AR 5-2	7	S
3180	PI 303785	4	S

[a] R - less than 20% plants wilted.
MR - 20 to 40% plants wilted
S - more than 70% plants wilted.

Table 11. Comparison of survival rates between F_3 and F_4 generations of AVRDC tomato breeding lines when inoculated with the bacterial wilt pathogen. a/

AVRDC selection no.	Pedigree	Survival rate	
		F_3	F_4
3	VC 48-1 / Saturn	71	72
12	VC 9-1-2-95 / Saturn	41	92
15	VC 8-1-2-7 / Saturn	42	86
24	VC 11-2-5_a / Saturn	52	100 b/
35	VC 49-1-5 / Venus	80	86

a/ F_3 populations planted Mar. 25; inoculated Apr. 25; and evaluated May 10.
F_4 populations planted June 28; inoculated July 17; and evaluated Aug. 2.

b/ Only 5 plants tested.

usually occurs on the older leaves with numerous dark-brown spots extending through to the lower surfaces. These spots generally remain small. But under favorable weather conditions, they enlarge and develop a grayish-brown, glazed appearance, and sometimes the center cracks and tears. Under epiphytotic conditions all the leaves, except the newest, can be affected, and few fruits are produced. This fungus carries over from season to season in diseased plant materials left in the soil, and can also be seedborne. Seedlings are often infected as soon as they emerge, and entire seedbeds are destroyed.

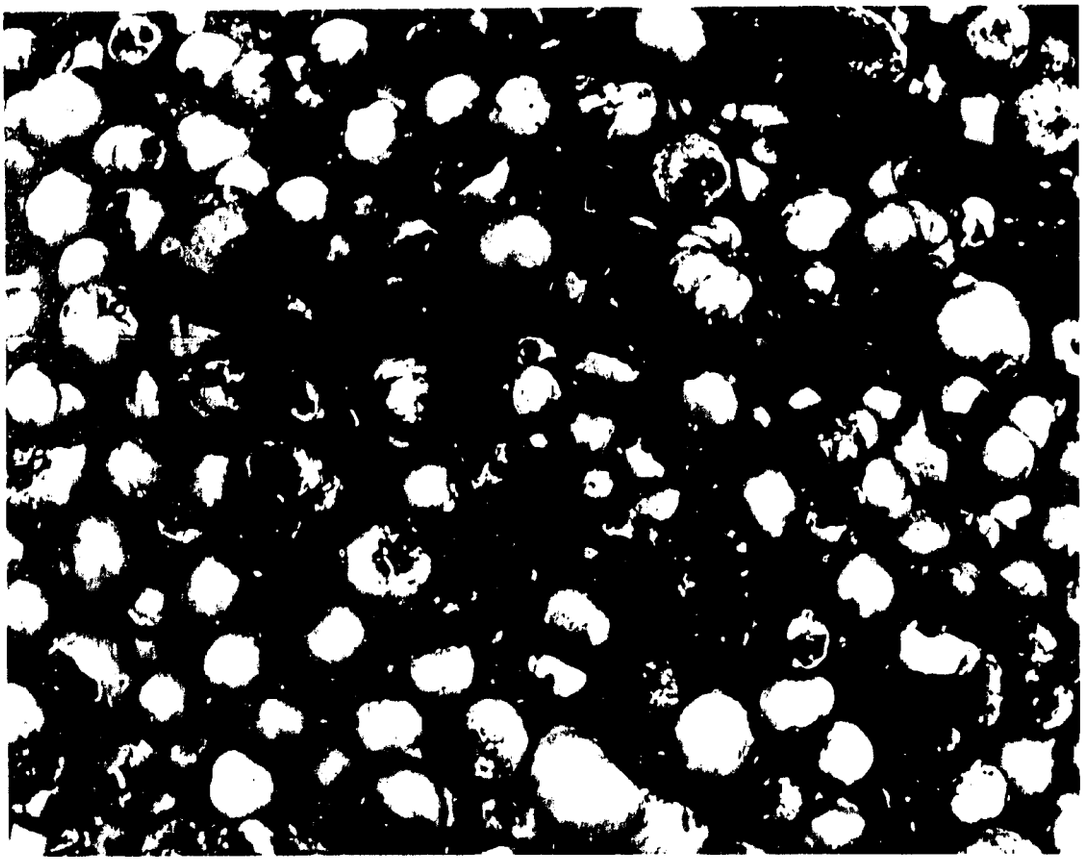
In 1974, there was an epiphytotic outbreak of gray leaf spot *(Stemphylium solani)* in the tomato screening fields. Strong resistance to this disease was found in five selections. Later, 1,821 tomato cultivars were surveyed in the field, and 110 were rated as field resistant to *Stemphylium solani.* After inoculation, the pathologists selected two cultivars (Acc. 203, 224) and 14 F_3 populations from both summer and fall plantings for inclusion in the breeding program.

Leaf mold, *Cladosporium fulvum,* is a serious disease common to tomato grown in greenhouses. However, under humid tropical conditions, this disease can also attack tomato in the field. The patches, which appear on the leaves, are covered with the velvety, olive-brown coating of the causal fungus. When conditions favor the development of this disease, much of the foliage falls and the yield is reduced. A relative humidity above 95 percent and a temperature range of 21° to 25°C are optimum for spore germination and growth. The conidial spores are produced in great numbers on the lower sides of the leaves and are spread by air currents, splashing water, and contact with other plants. The spores are resistant to drying and can survive in plant debris from one season to the next. Of 55 tomato accessions screened in the field, three cultivars (Acc. 94, 95, 96) were field resistant. When 98 F_3 populations were inoculated, 12 percent were moderately resistant, but none were resistant.

Late blight of tomato is caused by *Phytopthora infestans,* which also causes late blight in white potato. The leaf symptoms of late blight are similar on the two hosts. The disease causes a severe defoliation of the tomato plant as well as fruit rot. The lesions on the older leaves show irregular, greenish-black, water-soaked spots. These spots enlarge rapidly; in moist weather, a white, downy fungal growth develops on the under sides of the leaves. In a heavily infected field, almost all the foliage is affected and resembles frost damage. Infection of the fruit occurs at any growth stage; it is most common on the upper half of the fruit.

The late blight pathogen is extremely mutable. Some strains vary in the severity of their attack on tomato and white potato. For example, the common tomato strain of the fungus damages potato plants as much as the potato strains. However, the reverse is not true.

The pathologists isolated the late blight pathogen in the Shinshih area of Taiwan (near Taichung) in October 1973 and cultured it on PDA agar medium. A late blight nursery was established in the fall with the cooperation with the Taiwan Seed Service Station in Shinshih, and our tomato breeding lines were screened for resistance to late blight. Of the inoculated seedlings planted in the Shinshih nursery and later transplanted at AVRDC, only five selections were resistant to late blight *(Table 12).* In addition, the pathologists surveyed 1,823 cultivars. Of these, 222 cultivars or 12 percent showed field resistance against late blight. During the earlier stages of the late blight epidemic in our tomato fields, the tomato selections made in Thailand were also



These tomatoes will not go to market. Fruit rot, caused by late blight *(Phytopthora infestants)*, is responsible. The disease attacks tomato grown in the cooler seasons at all growth stages.

surveyed. Sixteen percent of these selections possessed field resistance to the disease.

The sporangial concentrations used in these screenings were estimated at 11,000 sporangia/ml for each inoculation, and two inoculations were made in each experiment. The leaf symptoms appeared on the inoculated plants within five to ten days, depending on the air temperature and the humidity.

Powdery mildew on tomato has been considered to be a minor disease. The pathogen *(Erysiphe polygoni)* is an ectoparasite, which penetrates only to the upper epidermal cell layer of the leaf surface. It does not cause much damage to the tomato crop. However, it enables other parasitic organisms to enter a weakened tomato plant.

This disease was identified in our 1973 tomato plantings, and the pathologists screened for resistance during the 74-75 winter season. Field resistance was exhibited by 1,736 of the 1,823 tomato cultivars screened. A similar survey of 44 cultivars, which was made in a heavily mildew-infested tomato field, identified 12 cultivars as resistant to powdery mildew.

VIRUS DISEASES. Two tobacco mosaic virus (TMV) strains caused mosaic of tomato at AVRDC. The more common one caused mosaic and mild stunting, whereas the second strain (yellow strain) produced a yellow mottling of leaves and sometimes affected the fruits and stems as well. The yellow mosaic often causes distortion, curling, and dwarfing of foliage; and can seriously reduce the yield.

In the United States, Japan, and Canada, the

Table 12. Five tomato selections that were resistant to *Phytopthora infestans*, both in the late blight nursery at Shinshih and at AVRDC.

AVRDC selection no.	Pedigree	Reaction to late blight [a]	
		AVRDC [b]	Shinshih [c]
309-1	VC 13-2-19 / PI 244957	R	R
309-2	VC 13-2-19 / PI 244957	R	R
849 F_2	VC 13-2-19 / NRG 6805 // PI 244957	R	R
608 F_2	VC 9-1-2-19 / Florida MH-1 // PI 244957	MR	R
847 F_2	VC 14-1-29 / Plum // PI 244957	MR	R

a/ R - no infection
MR - less than 5% infection

b/ Sown Oct. 30; transplanted Nov. 26; evaluated Jan. 14 through Jan. 17, 1975 (at maturity)

c/ Direct seeded Nov. 22; evaluated Nov. 26 and Jan. 6, 1974.

percentage of infection of TMV in tomato fields have been reported to be as high as 85 percent just before harvest. However, the yield loss attributed to TMV generally ranges from five to eight percent. The reason for this low yield loss is because the farmers avoid TMV infection during cultivation and transplanting, thus preventing TMV infection in the earlier stages of growth. Usually TMV will not affect the yield of tomato if the infection occurs after flowering.

Another reason for the low yield loss is that their farmers have been using cultivars with some resistance. For example, the fresh-market U.S. cultivars with large pinkish fruits are field resistant to TMV, nematodes, and *Fusarium* wilt.

One hundred and eighty-two tomato cultivars were planted in wooden flats and inoculated with TMV two weeks after germination on June 25. Plants of each cultivar in separate flats served as controls. Only 44 cultivars were grown successfully. When *Nicotiana glutinosa* (indicator plant of TMV) was inoculated with the plant sap of these cultivars to detect TMV, all except Accession 127 caused local lesions in the leaves. Accession 127 was also resistant to TMV in the field tests.

The double-virus streak, caused by a combined infection of the common TMV strain and potato virus X (PVX), is the most damaging virus disease attacking tomato. Tomato plants, when inoculated with PVX, only produced a very mild mottling on the foliage. However, when tomato plants already infected with TMV were inoculated with PVX, a streak disease resulted destroying the plants.

The first symptom is a light-green mottling of the leaves, accompanied by the development of numerous small, grayish-brown, dead-spots that have a thin, paper-like appearance. Many of the infected leaves fall in the early stages of the disease.

Initial tests indicated that Accession 127, which is resistant to TMV, has some field resistance to the double-virus streak.

During the fall of 1974, an unknown disease was observed in AVRDC tomato fields. The rate of infection in two fields was as high as 90 percent. Similar symptoms were also observed in farmers' fields near AVRDC. These symptoms were the yellowing of young leaves and stunting of the upper parts of the plants. Usually the disease became evident in the later growth stages, and the infected plants generally produced smaller fruits. It can be transmitted by graft-inoculation, but not by rub-inoculation. Attempts will be made to identify this disease in 1975.

PLANT PHYSIOLOGY

Our studies on the physiological nature of tomato continued to focus on determining why high night temperatures have such an adverse effect on fruit setting.

There are two factors essential for successful

fruit setting, which act independent of each other: (i) the availability of enough net assimilates, and (ii) the successful fertilization of the embryo. Temperature can affect both of these factors, and its effect varies depending on the cultivar.

Seventeen tomato cultivars were planted in the greenhouse and outdoors to study the effect of temperature on fruit setting. Cultivars identified as heat tolerant in previous studies generally had a higher fruit-setting rate than those considered to be heat-sensitive *(Table 13)*. However, some of these heat-tolerant cultivars did not have a high fruit-setting rate in this particular experiment.

Experiments were also conducted to determine a sampling technique for measuring the net photosynthetic ra . The rate varied from leaf to leaf according to i s position on the plant. Therefore, to compare varietal differences, the leaf samples should be taken from leaves in similar positions.

The net photosynthetic responses of a heat-tolerant cultivar and a heat-sensitive one to different temperatures were studied. The heat-tolerant cultivar (KL 2) had higher net photosynthetic rates at all temperatures *(Fig. 3)*. The difference was most noticeable at 30° and 35°C. Thus, the differential-temperature sensitivity of net photosynthesis might offer a means of screening heat-sensitive plants. This would be especially significant if it could be done in the seedling stage.

Six cultivars, four heat tolerant and two heat sensitive, were sown July 18. On August 13, treatment was initiated. One set of plants was grown in an environment with a mean maximum

Table 13. Effect of temperature on the fruit setting of 17 tomato cultivars. [a]

Type	AVRDC acc. no.	Varietal name	Fruit-setting rate	
			40.6° to 23.6°C [c]	32.1° to 23.1°C [c]
			Greenhouse	Outdoors
			(%)	
Heat tolerant	246	KL 2	67	64
	2991	PI 290856	52	83
	1834	PI 257489	45	61
	232	Nagcarlan	35	71
	243	Plum	27	74
	3042	PI 294445	14	44
	493	PI 114969	13	59
	126	Nova	0	30
Mean			*32*	*60.7*
Heat sensitive	1973	PI 289297	48	84
	297	Homestead 500	29	66
	118	Manalucie	25	64
	203	Floradel	25	63
	269	Manalee	16	51
	91	CO 1	13	32
	96	Saturn	9	74
	95	Venus	0	59
	205	Techumseh	0	51
Mean			*18*	*60.4*

[a] Planted July 16, transplanted Aug. 13; fruit setting began Aug. 20 and experiment terminated Sept. 28.

[b] These cultivars had been identified in previous studies as either heat tolerant or heat sensitive.

[c] Mean range of temperatures during fruit set.

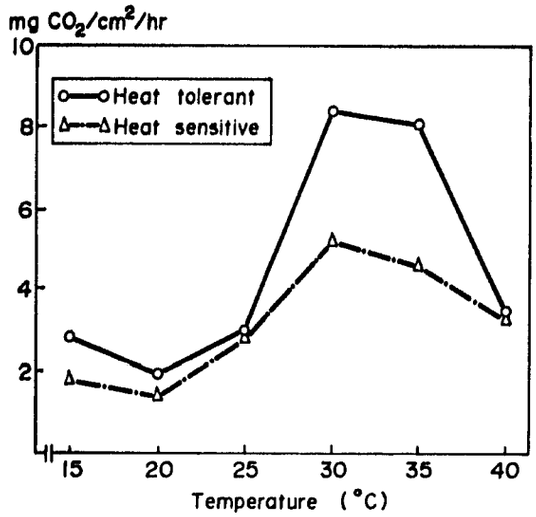


Fig. 3. The net photosynthetic rates of a heat-tolerant and a heat-sensitive tomato cultivar at different Warburg-apparatus temperatures.

temperature of 39°C (in a greenhouse), another group was grown under ambient conditions at AVRDC. The mean maximum ambient temperature during the period of growth was 31°C. On October 3, leaf discs were taken from each plant and the net photosynthetic rate was measured at 30° and 40°C. The results are shown in *Table 14.* The heat-tolerant cultivars had the highest net photosynthetic rate in all cases. The net photosynthesis of heat-tolerant cultivars tended to increase when either the growing temperature or the measurement temperature was increased. The heat-sensitive cultivars grown at 39°C and measured at 40°C had the lowest net photosynthetic rate observed. If differences in net phytosynthesis between heat-sensitive and heat-tolerant cultivars is to be used as a screening tool, it is necessary to subject the plants to some heat stress during the growth period and to measure the net photosynthetic rate at a high temperature in order for sufficient differences to appear.

The net photosynthetic rate for 17 cultivars was measured. The results are presented in *Table 15.* Although the sample was small, there was a tendency for high net photosynthesis to be related to the high fruit-setting rate. This will be investigated further using larger populations.

Table 14. Response of the net-photosynthetic rate of heat-tolerant (HT) and heat-sensitive (HS) tomato cultivars to different temperatures. a/

Warburg Temp. b/ (°C)	Mean maximum temperature treatments c/			
	31°C		39°C	
	HT d/	HS e/	HT d/	HS e/
	(mg $CO_2/dm^2/hr$)			
30	4.3	3.7	4.9	4.1
40	5.2	5.0	5.5	3.1

a/ Accessions 232, 2991, 246, 3042, 95, and 91 were sown July 18; transplanted in two groups (one grown in the greenhouse and the other, outdoors) on August 1973; and evaluated Oct. 3.

b/ Temperature at which the net photosynthetic rate was measured.

c/ Treatments were initiated Aug. 13 and lasted through Oct. 3. The mean minimum temperature for both treatments was 23°C.

d/ Mean of 4 heat-tolerant cultivars (Acc. 232, 246, 2991, 3042).

e/ Mean of 2 heat-sensitive cultivars (Acc. 91, 95).

Fruit setting in tomato is generally considered to be dependent upon pollination. The effects of the environment on fruit setting are often related to the success, or failure, of the reproductive processes. The flowers of heat-sensitive tomato plants grown at high temperatures have longer pistils *(Table 16).* This makes it more difficult for the pollen to reach the stigma for successful pollination. Mechanical pollination using a brush did increase the percentage of fruit set in the heat-sensitive cultivars grown under high temperatures *(Table 17).*

The effect of temperature on the number of seeds per fruit and the fruit-setting rate was also studied. The flowers were tagged at seven-day intervals to record the percentage of fruit set at each stage. The mature fruits were sliced open, and the seeds visible in the cut surface were counted.

Generally, the fruit-setting rate and the number of seeds per fruit were higher for the tomato plants grown outdoors than for those planted in the greenhouse. Again, varietal differences were observed. In tomato, fruit without seeds can occur

Table 15. Relationship between the net photosynthetic rate and the fruit setting of 17 tomato cultivars grown in the greenhouse.

Type	Fruit-setting rate					
	High (>29%)			Low (<29%)		
	AVRDC acc. no.	Varietal name	Net photosynthetic rate (mg $CO_2/dm^2/hr$)	AVRDC acc. no.	Varietal name	Net photosynthetic rate (mg $CO_2/dm^2/hr$)
Heat tolerant	232	Nagcarlan	6.0	3042	PI 294445	4.4
	246	KL 2	4.5	493	PI 114969	3.8
	1834	PI 257489	4.4	126	Nova	2.2
	2991	PI 290856	4.2	243	Plum	2.0
		Mean	4.8		*Mean*	3.1
Heat sensitive	297	Homestead 500	6.2	269	Manalee	5.7
	2973	PI 289297	4.9	96	Saturn	3.3
		Mean	5.6	118	Manalucie	3.2
				203	Floradel	2.4
				205	Techumseh	2.0
				95	Venus	1.8
			1.5	91	Co 1	1.5
					Mean	2.8

Table 16. The influence of temperature on the pistil length and fruit-setting rate of seven tomato cultivars. [a]

Type [b]	AVRDC acc. no.	Varietal name	40.6° to 23.6°C [c]		32.1° to 23.1°C [c]	
			Pistil growth [d]	Fruit-setting rate	Pistil growth [d]	Fruit-setting rate
			(%)			
Heat tolerant	246	KL 2	0	42	0	57
	2991	PI 290856	0	44	0	55
	232	Nagcarlan	63	24	0	42
Means			34	36	0	51
Heat sensitive	96	Saturn	45	30	11	37
	205	Techumseh	53	19	10	26
	203	Floradel	83	4	70	19
	95	Venus	100	0	20	61
Means			70	13	28	36

[a] Planted July 18; evaluated Oct. 11.

[b] Previously identified as heat tolerant or heat sensitive.

[c] r = -0.87 (greenhouse); r = -0.62 (outdoors).

[d] % of plants whose pistils were longer than the respective stamen.

Table 17. The effect of mechanical pollination on the fruit setting of seven tomato cultivars grown in the greenhouse.[a]

Type [b]	AVRDC acc. no.	Varietal name	Treatment	
			Natural pollination	Mechanical pollination
			·····fruit-setting rate (%)·····	
Heat tolerant	2991	PI 290856	33	56
	3042	PI 294445	9	90
	493	PI 114969	8	50
Means			*17*	*65*
Heat sensitive	203	Floradel	21	80
	2984	PI 289308	17	30
	96	Saturn	9	13
	205	Techumseh	0	0
Means			*12*	*31*

[a] Planted July 18; evaluated Oct. 11.

[b] Previously identified as either heat tolerant or heat sensitive.

naturally, so the number of seeds per fruit is not a major deciding factor in the retention or non-retention of the fruit. The number of seeds per fruit actually indicated the number of successfully fertilized embryos. The ratio of the number of seeds per fruit between the two temperature treatments should be a good index of the temperature tolerance of the reproductive processes. The average fruit set, the number of seeds per fruit, and the ratio of the number of seeds at these two temperature treatments are summarized in *Table 18.*

The relationship between heat tolerance and the tolerance index is evident. Most of the heat-tolerant cultivars had a high tolerance index and the reverse was true of the heat-sensitive cultivars. There were some cultivars that had a high heat-tolerance index but a low fruit-setting rate. However, most of these cultivars (e.g., Plum) also had a relatively low photosynthetic rate (see *Table 15).* The low fruit-setting rate combined with a high heat-tolerance index might be due to the lack of net assimilates.

Each heat-sensitive cultivar might have different factors limiting its fruit setting under high temperatures. It would be difficult to establish common criteria to cover all cultivars.

AGRICULTURAL CHEMISTRY

The chemists measured the toxicity of the residues left on tomato fruits by the insecticides used to control the tomato fruit worm *(Heliothis* sp.). The insecticides used, their formulations, and rates of applications are listed in *Table 19.*

It was first determined through a bioassay technique if any appreciable amount of toxic residues were present in the fruit samples eight days after applying organophosphate and carbamate insecticides. The mortality rate of the fruit fly *(Drosophila melanogaster)* after 24-hour exposure to four grams of tomato extract in bioassay jars was ascertained (see *Table 19).* No toxic residues were evident. This lack of toxic residue was probably because the insecticides used are not persistent and dissipate quickly under hot, humid conditions.

The effect of temperatures on pesticide residues both in the soil and in the edible portions of various crops is being investigated in a long-term experiment on the persistence of pesticides in field soils.

Answers are being sought to such questions as (i) what are the long-term effects of the increasing use of pesticides in the tropics; (ii) will toxic

Table 18. Comparison of fruit-setting rate, number of seed per fruit, and heat-tolerance index of 17 tomato cultivars grown under two temperature treatments. [a]

Type [b]	AVRDC acc. no.	Varietal name	Greenhouse		Outdoors		Heat-tolerance index
			Fruit-setting rate (1)	No. of seeds per fruit (2)	Fruit-setting rate (3)	No. of seeds per fruit (4)	(2) / (4)
			(%)		(%)		
Heat tolerant	2991	PI 290856	52	15	83	15	1.0
	243	Plum	27	15	74	18	0.8
	493	PI 114969	13	13	59	20	0.6
	1834	PI 257489	45	7	61	13	0.6
	246	KL 2	67	8	64	14	0.6
	3042	PI 294445	14	5	44	20	0.3
	232	Nagcarlan	35	5	71	23	0.2
	126	Nova	0	–	30	6	0 [c]
Mean			*32*	*9*	*61*	*16*	*0.5*
Heat sensitive	297	Homestead 500	29	12	66	16	0.7
	2973	PI 289297	48	9	84	13	0.7
	203	Floradel	25	9	63	15	0.6
	118	Manalucie	25	7	64	15	0.4
	269	Manalee	16	5	51	13	0.4
	96	Saturn	9	6	74	19	0.3
	91	CO 1	13	5	32	15	0.3
	95	Venus	0	–	59	16	0 [c]
	205	Techumseh	0	–	51	11	0 [c]
Mean			*18*	*6*	*60*	*15*	*0.4*

[a] Greenhouse temperature: mean 32°C; minimum 24°C. Outdoors temperature: mean 27°C; minimum 23°C. Planted July 18; terminated Oct. 31.

[b] Previously identified as either heat tolerant or heat sensitive.

[c] No fruit set inside the greenhouse.

residues accumulate in agricultural soils; (iii) will such residues change important soil properties like CEC, nitrogen fixation by both legumes and non-legumes, and the decomposition of organic materials so that subsequent crops will be adversely affected; and (iv) will these chemicals be absorbed and translocated to edible protions of the plants and become a hazard to public health?

This experiment was initiated in December and will continue for three years.

SOIL SCIENCE

For each ton of tomatoes harvested per hectare, approximately 2.5 kg/ha N, 0.1 kg/ha P, and 4 kg/ha K must be supplied during the growing period. Therefore, 250 kg/ha N, 13 kg/ha P, and 415 kg/ha of K would be required to obtain a yield of 100 tons/ha of tomatoes.

An experiment was conducted to determine the effects of different application rates of fertilizer on the growth of three popular tomato cultivars and the yield potential of tomato grown in the fall on calcarious soils (pH 8).

The three cultivars (Walter, Manalucie, Pearson) demonstrated considerable varietal differences in response to different fertilization treatments *(Table 20)*. For instance, the cultivar Walter increased in yield with each increment of nitrogen, both with and without compost. Manalucie and Pearson yielded best in the plots without compost at the level of 150 kg/ha N. Their yields were 40

Table 19. List of insecticides used to control the tomato fruitworm (*Heliothis* sp.) and the mortality rates of *Drosophila melanogaster* after 24-hour exposure to treated extracts. [a]

Insecticide	Formulation (%)	Application rate (kg/ha)	Mortality rate [b] (%)
Gardona	24 EC	1	2
Birlane	24 EC	1	2
Surecide	25 EC	0.5	2
Metacil	75 WP	1	1
Actellic	25 EC	1	0
Padan	50 SP	1	0
Lannate	90 WP	0.5	0
Reldan	22 EC	1	0
Control plot			2

[a] The cultivar VC 48-1 was planted June 25; treated Sept. 13, 20, 27, and Oct. 2; and the first harvest was made Oct. 10.

[b] The walls of a bioassay jar were coated with 4 g of tomato extract. Mortality rates of 100, 80, and 100% were observed when the extract was fortified with the equivalent of a 2 ppm dosage of Gardona, Surecide, and Lannate, respectively.

Table 20. Effect of different applications of nitrogen on the yields of three tomato cultivars. [a]

Nitrogen application (kg/ha)	Yields of 3 cultivars					
	Walter		Manalucie		Pearson	
	No compost	Compost [b]	No compost	Compost [b]	No compost	Compost [b]
	(tons/ha)					
0	27	38	9	11	16	30
150 [c]	49	54	42	35	44	43
200 [d]	63	72	40	40	46	52

[a] Transplanted Oct. 16, 1973 and harvested from Jan. 18 to March 9. All treatments received 45 kg/ha P and 125 kg/ha K as basal dressing.

[b] 30 tons/ha of compost.

[c] 90 kg/ha N applied as basal and 60 kg/ha as top dressing.

[d] 90 kg/ha N applied as basal and 110 kg/ha as top dressing.

and 45 tons/ha, respectively. The yield of Manalucie was not affected by the application of compost; Pearson's yield increased with increments of nitrogen in the plot with compost.

The yield in the plots without N fertilizer indicated clearly that both Walter and Pearson in the fall season, especially Walter, can use both soil nitrogen and the nitrogen in the compost efficiently. The fruit size in Walter and Manalucie increased with each increment of nitrogen, but Pearson's fruit size was not affected by N application.

In general, the boron level in tomato leaves ranges from 50 to 100 ppm. An experiment was conducted to determine the effect of boron application on tomato growth in the calcarious soil of our experimental fields during the dry

Table 21. The effect of boron on fruit setting, fruit weight, and nitrogen concentration in the leaves. [a]

Treatment [b]		No. of fruit per 30 m²	Fruit weight		(1) Total N (%)	(2) Soluble N (%)	Soluble N as % of total N (2)/(1) (%)
B [c] (kg/ha)	N (kg/ha)		(tons/ha)	(g/fruit)			
0	100	952	28	88	3.0	0.8	27
20	100	1,022	34	100	3.3	0.7	21
40	100	1,044	35	103	3.5	0.7	20
0	125	818	31	113	3.8	0.7	18
20	125	1,114	43	115	3.7	0.7	19
40	125	1,192	38	105	3.9	0.7	18
0	150	758	26	101	4.2	1.2	29
20	150	828	29	105	4.1	1.0	24
40	150	1,050	34	98	4.1	0.9	22

[a] Cultivar Floradel was transplanted Dec. 14, 1973 and harvested April 11.

[b] 45 kg/ha P and 125 kg/ha K were applied as basal dressing.

[c] Boron was applied as F.T.

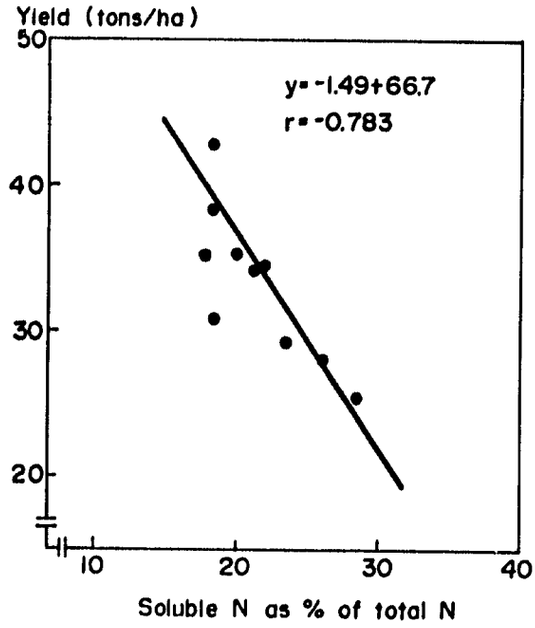


Fig. 4. Relationship between yield and the soluble nitrogen to total nitrogen ratio in a tomato leaf.

season. The relationship between the fruit weight per hectare and the soluble nitrogen to the total nitrogen ratio in the leaf is shown in *Figure 4.*

When the cultivar Floradel was grown without boron, the maximum yield was 31 tons/ha. Thus, the maximum amount of nitrogen that should be applied when boron is not used, is 125 kg/ha. When more than 125 kg/ha N was applied, the yield decreased to 26 tons/ha *(Table 21).*

The effects of boron application on tomato growth as measured by number of fruits set, fruit weight, etc. were notable at every level of nitrogen application, especially at the level of 150 kg/ha N. The amount of boron required by the plant increased with each increment of nitrogen.

At the level of 100 kg/ha N, the total nitrogen concentration in the leaves (3%) was increased and the concentration of soluble N was decreased by the boron application. At the level of 125 kg/ha N, neither the total nor the soluble N concentrations were affected by boron application. At 150 kg/ha N, the total N concentration was not affected, but the concentration of soluble N decreased considerably with the boron application. This indicated that the cultivar Floradel could not use nitrogen efficiently because the available boron was not enough.

The ratio of soluble N to total N in the leaf, which reflects the rate of nitrogen metabolism in the leaf, was affected by the boron application,

and (as shown in *Fig. 4*) a close relation between the fruit yield and this ratio was observed. The nitrogen metabolism of Floradel without boron was distorted. Furthermore, this result suggested that the vigor of a tomato plant is affected by the soluble N to the total N ratio

A field experiment using straw compost was conducted to determine the utilization of natural nitrogen sources by the tomato in the fall season. About 70 tons/ha of fruit was obtained from the cultivar Walter, which had demonstrated a yield potential of 70 tons/ha when given 200 kg/ha N, using 80 kg/ha N (ammonium sulphate), 30 tons/ha of compost, and intensive management.

When 80 kg/ha N (ammonium sulphate) was applied, the application of 30 tons/ha of compost increased the quantity of fruits by 12 percent, but did not affect the fruit size. The yields were 73 and 59 tons/ha in the plots with and without compost, respectively *(Table 22)*. Therefore, a yield of 70 tons/ha was obtained using small amounts (less than 50% the N recommended) of chemical nitrogen fertilizer and compost.

Table 22. The effect of compost and reduced applications of fertilizer on tomato yield. [a]

Treatment		Fruit per ha	Mean fruit size	Yield
Compost [b] (tons/ha)	NPK (kg/ha)	(000)	(g/fruit)	(tons/ha)
30	80, 35, 125	552	132	73
0	80, 35, 125	448	131	59

[a] The cultivar Walter was transplanted Sept. 17 and harvested from Dec. 6 to Jan. 24, 1975.

[b] Well-fermented rice straw.

Another experiment was conducted to observe the effect of applying humic materials on tomato growth in soil that is both calcarious and low in organic matter. The application of 600 kg/ha of Azumin increased the number of fruits, fruit size, and yield in the plots with compost *(Table 23)*. Generally, the application of 600 kg/ha of Azumin increased the tomato yield by about 7 percent.

AGRICULTURAL ECONOMICS

A general perspective of tomato production in Asia is provided by the FAO estimates for 1972 *(Table 24)*. In addition, a comprehensive study was made comparing the production and marketing of tomato for the fresh market with that of processing tomato. Although the results will not be published until late 1975, some of the findings have been summarized.

Since 1968, the tomato processing industry in Taiwan has expanded considerably. Correspondingly, farmers are producing relatively more tomato for the canneries than for the fresh market. From 1970 to 1973, the area planted to fresh market tomato declined by approximately 25 percent, whereas that planted to processing tomato increased by about 800 percent. Some of the reasons for this change were labor shortages in the agricultural sector, a guaranteed price from the canneries, and the lower production costs of processing tomato. In addition, the practice of intercropping processing tomato with sugarcane has permitted the farmers to intensify crop production without completely changing their patterns of cultivation.

Fresh market tomatoes were generally grown in small plots (averaging less than 0.2 ha). Many harvests were made and the field was occupied for five to six months. These tomatoes also required such labor-demanding practices as staking and topping and other high level management operations.

On the other hand, tomatoes produced for the cannery, were usually planted in larger fields (averaging more than 4 ha) and required less time (4 to 5 months), and, because of fewer harvests and the lower level of management, less labor. The total production costs for processing tomato were only 31 percent of those required by fresh market tomato. However, the net returns were 68% of what could be expected from a similar area of the latter *(Table 25)*.

Figure 5 presents the seasonal fluctuations in the supply and price of fresh market tomato in the Taipei City Wholesale Market (1972). Tomato production in the summer months would stabilize dramatic price fluctuations as well as enable canneries to operate year-round to supply Taiwan's

Table 23. The effect of Azumin applications on tomato yield. [a]

Treatment [b]			Fruit no. per ha (000)	Mean fruit size (g/fruit)	Yield [c] (tons/ha)
[illegible]	Fertilizer (kg/ha)	Azumin (kg/ha)			
[illegible]	80	0	506	123	62
[illegible]	80	300	521	125	65
[illegible]	80	600	535	138	74
[illegible]	215	0	571	133	76
[illegible]	215	300	565	136	76
[illegible]	215	600	585	140	82
[illegible]	80	0	480	126	60
[illegible]	80	300	471	127	60
[illegible]	80	600	505	126	64
[illegible]	215	0	564	136	77
[illegible]	215	300	578	133	77
[illegible]	215	600	574	135	77

[a] The cultivar Walter was transplanted Sept. 17 and harvested from Dec. 6 to Jan. 24, 1975.

[b] [illegible] were applied as basal dressing at 35 and 125 kg/ha, respectively.

Azumin (kg/ha)	Mean yield	Percent of control
Control	69	100
300	70	101
600	74	107

Table 24. Tomato production, planted area, and yields in selected Asian countries; 1972. [a]

Country	Production (1,000 tons)	Area (1,000 ha)	Yield (tons/ha)
[illegible]	972	19	42
World average	*32,190*	*1,561*	*21*
[illegible]	60	4	15
[illegible] [b]	54	4	14
[illegible]	650	69	9
[illegible]	134	16	8
Malaysia	25	5	5
Thailand	13	5	3

[a] Adapted from *The FAO Production Yearbook, 1972* (Vol. 26, Rome). All estimates by FAO unless otherwise noted.

[b] Taiwan: *Agricultural Yearbook, 1973 Edition*. Provincial Department of Agriculture and Forestry, Taiwan, July 1973.

In their study of tomato production in Taiwan, the agricultural economists interviewed farmers, such as this one in Shanshang (near AVRDC).

Table 25. Comparision of production factors between fresh market and processing tomatoes in Taiwan. [a/]

Type of tomato	Field size (ha)	Yield (tons/ha)	Labor time (man hr/ha)	Total costs (US$/ha)	Revenue (US$/ha)	Net return (US$/ha)
	(average)					
Fresh market	0.19	48	8,020	3,722	4,815	1,093
Processing	0.44	69	2,180	1,164	1,912	748
	(percent)					
Processing as a % of fresh market	232	144	28	31	40	68

[a/] Data from an unpublished AVRDC study of tomato production in Taiwan.

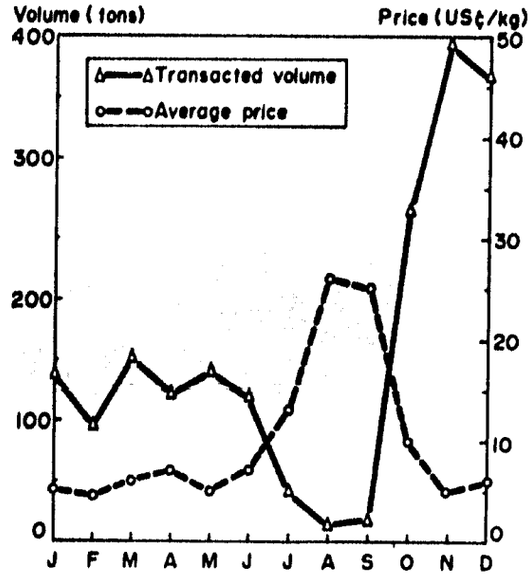


Fig. 5. Seasonal fluctuations in the supply and price of fresh market tomatoes in the Taipei City Wholesale Market (1972).

growing share of the world market of processed tomato products.

INTERNATIONAL ACTIVITIES

In 1974, 563 seed samples of both cultivars and selections were sent to more than 29 individuals or institutions in 16 countries *(Table 26)*. Segregating populations and cultivars from AVRDC planted and screened in the Philippines and Thailand by four cooperators are presented in *Chart 2*.

In the Philippines, our program has been strengthened with the decision of the Philippines Sugar Research Institute (PHILSUGIN) to experiment with multiple-cropping systems. AVRDC will provide PHILSUGIN with segregating populations of soybean, mungbean, sweet potato, and tomato to be intercropped with sugarcane. This is a unique opportunity to select genotypes that perform well under such conditions. The program will be initiated in early 1975.

In Thailand, 175 selections were made from AVRDC segregating populations for heat tolerance and bacterial wilt resistance by the breeder and Mrs. Manee Wivutvongvana of Chiang Mai University.

In Malaysia, Mr. Keng-Yeang Lum of MARDI assisted the pathologists in screening 10 F_4 populations and three cultivars for resistance to bacterial wilt *(Table 27)*.

Chart 2. Highlights of cooperative work in Thailand and the Philippines.

Scientists	Institution	Activities
Sivaloeporn Dejanakul	Division of Vegetable Crops Department of Agriculture Bangkok, Thailand	Conducted observational trial of 10 cultivars for two seasons and grew 5 segregating populations Selected Accessions 1, 6, 15, and 35, which were increased at AVRDC for commercial planting in the Bangkok area during the 1975 summer.
Manee Wivutvongvana	Department of Plant Science Chiang Mai University Chiang Mai, Thailand	Screened 10 cultivars and 11 segregating populations and made 175 selections for wilt resistance and heat tolerance. These selections were further screened for bacterial wilt resistance at AVRDC. In the summer of 1975, they will be planted again in Chiang Mai. Yield trials of processing varieties and advance generations were conducted in both Chiang Mai and Mae Jo.
Min-Nan Chiang	Visiting Professor Fang Agricultural Experiment Station, Chiang Mai, Thailand	Screened 10 cultivars, identified them as both heat tolerant and bacterial wilt resistant, found two accessions to be resistant to a virus complex, and made 50 selections.
Servillano R. Gumasing	UPLB La Granja Research & Training Station, La Carlota City, Philippines	Planted 15 segregating populations and made 20 selections. Yield trials of advanced generation lines are under way.

Table 26. Number of tomato accessions and selections sent to various scientists.

Name of scientist	Institution	No. of lines
Mr. W. W. Ko	Malaysian Agriculture Research Institute, Malaysia	10
Mr. Hendro Sunarjona	Horticultural Research Institute, Indonesia	10
Mr. Tan Bound Suy	Ministry of Agriculture, Khmer Republic	10
Mr. Roberto Monserrat	Direction de L'Agriculture Laos	10
Mr. Reongchai Chumpirom	Mae Jo Experiment Station, Thailand	10
Mr. Kasem Piluek	Horticulture Department, Kasetsart University, Thailand	10
Mr. Manoch Thongiem	Fang Horticultural Expt. Station, Thailand	10
Mr. Hong Van Minh	Saigon 2, Vietnam	10
Dr. C. R. Muthukrishnam	Tamil Nadu Agricultural University, India	10
Dr. Hamdy E. Eisa	Arid Lands Research Center, Abu Dhabi, U.A.E.	27
Dr. G. F. Wilson	IITA, Nigeria	27
Miss Sivaleeporn Dejanakul	Department of Agriculture, Thailand	27
Dr. Chung Il Choi	Horticultural Expt. Station, Korea	22
Mrs. Manee Wivutvongvana	Faculty of Agriculture, Chiang Mai University, Thailand	42
Dr. D. H. Skrdla	USDA, U. S. A.	38
Dr. R. R. Vega	Division of Agriculture, Marianas Islands	11
Dr. A. T. Zelenka	FAO, Rome	9
Mr. W. U. Chen	Known You Seed Co., Taipei	17
Dr. M. A. Stevens	University of California at Davis, U.S.A.	26
Dr. G. B. Reynard	Campbell Institute, U.S.A.	26
Dr. A. A. Johnson	Ford Foundation, India	9
Mrs. S. Manit	Mae Jo Experiment Station, Thailand	6
Mr. Jon Watts son	Peto Seed Co., U.S.A.	6
Mr. P. Mazereeuw	Enza-Zaden, Holland	6
Dr. K. McLean	FAO, Rome	9
Dr. R. Staples	Boyce Thompson Institute, U.S.A.	4
Mr. J. S. DeCourcy	U. S. Embassy, Malaysia	2
Mr. R. M. Payson	UPLB La Granja, Philippines	45
Mr. J. F. Sheen	Taiwan Seed Service	116

Table 27. Performance of 10 F_4 populations and three cultivars from AVRDC when screened for bacterial wilt resistance in West Malaysia.

AVRDC selection (or acc.) no.	Pedigree (or varietal name)	Plants wilted [a] (%)
	(Red Cloud grafted to Eggplant) [b]	0
(33)	(VC 8-1-2-1)	4
1-0-10	VC 47-1 / Florida MH-1	7
(1)	(VC 48-1)	9
30-0-3	VC 49-1-1 / Saturn	12
(11)	(VC 11-3-4)	13
30-0-1	VC 49-1-1 / Saturn	20
2-0-4	VC 48-1 / Venus	22
	(L. pimpinillifolium)	27
71-0-5	VC 12-1-1p / Saturn	30
2-0-1	VC 48-1 / Venus	32
34-0-5	VC 49-1-5 / Florida MH-1	36
34-0-3	VC 49-1-5 / Florida MH-1	39
71-0-7	VC 12-1-1p / Saturn	52
1-0-8	VC 48-1 / Florida MH-1	54
	(Red Cloud) [c]	100

[a] Evaluated three weeks after transplanting (at flowering stage).

[b] Common practice among Malaysian tomato growers.

[c] Popular cultivar in Malaysia.

Chinese cabbage

We made considerable progress toward developing superior heading varieties of Chinese cabbage, *Brassica pekinensis*, for cultivation during the hot summer months of the lowland tropics. Major problems of heat sensitivity, low yield, and vulnerability to insect pests and diseases were studied. Disease screening revealed sources of resistance to bacterial soft rot *(Erwinia carotovora)*, downy mildew *(Peronospora parasitica)*, and turnip mosaic virus. Many of the cultivars with disease resistance were also high yielding. In the segregating populations grown during the summer, there were several heat-tolerant segregants with heads triple the size of those of the heat-tolerant parents.

BRASSICA SP. GERMPLASM COLLECTION

Brassica pekinensis	449
other *Brassica* species	144

PLANT BREEDING

The world collection. By the end of the year, the collection of germplasm consisted of 593 accessions *(Table 1)*. The majority of the 290 varieties or genetic lines added in 1974 came from Japan through the courtesy of Dr. S. Nishi (Vegetable and Ornamental Crops Research Station at Ogosutsu) and the Japanese Ministry of Agriculture. The rest were local (Taiwan) collections and some breeding lines contributed by the AVRDC Sub-Center at Suweon, Korea.

Screening for heat tolerance. Two trials of the new *B. pekinensis* accessions were conducted in the 1974 summer season. Twenty-seven cultivars were planted July 3 in the field, and a second group of 140 cultivars was planted August 8. Only two cultivars produced heads under summer conditions *(Table 2)*. These were Accessions 344 and 362. Accession 344 had a mean head weight of 729 grams, whereas Accession 362 averaged 944 grams per head. Including the 61 heat-tolerant cultivars identified in 1973, we now have identified 63 accessions with this important attribute or 14 percent of the *B. pekinensis* accessions in our germplasm collection.

Table 1. Germplasm collection of Chinese cabbage (*Brassica pekinensis*) and related *Brassicas* species.

Species	Common name+	Number of accessions
Brassica pekinensis	heading Chinese cabbage	449
Brassica chinensis	non-heading Chinese cabbage	49
Brassica juncea	mustard cabbage	11
Brassica napur	winter rape	3
Brassica campestris	edible rape	59
Brassica rapa	tender greens	17
Brassica narinosa	Chinese flat cabbage	1
Brassica japonica	water cabbage	4
Total entries		593

+ Although common names vary considerably among the *Brassicae* species, we provide them here as examples to assist in their identification.

We reported in the *72-73 Annual Report* that mature plant turgidity was significantly associated with heat tolerance. If this relationship existed at the seedling stage, it could provide us with a more convenient selection criterion. The breeders tested this possibility using some of the earlier crosses between heat-tolerant and heat-sensitive parents. In addition to plant turgidity, glabrousness, and general phenotypic features; such characters as thick, dark-green, waxy leaves were also examined.

Table 2. Number of *B. pekinensis* accessions that headed under summer conditions, two trials.

Reaction to summer conditions	No. of accessions	
	Trial I	Trial II
Headed	0	2
No heads	27	138
Total entries	27	*140*

However, after conducting both greenhouse and field trials, it was concluded that heat tolerance (ability to form heads under summer conditions) could not be predicted by observing any of these morphological traits at the seedling stage.

Response to vernalization, as an indication of heat tolerance, was also examined. Although this apparent relationship was discovered in a 1973 test, the exact methods of vernalization were not established. Therefore, an experiment was conducted to determine if heat-tolerant cultivars could be selected by their response to vernalization treatments.

Two temperatures (5°,10°C) and three durations (15, 20, 25 days) of vernalization were used. Approximately 50 seedlings each of 56 cultivars were tested. After treatment, the young seedlings were planted in wooden flats, and the days to bolting were recorded. Unfortunately, none of the treatments clearly separated the heat-tolerant and heat-sensitive cultivars *(Fig. 1)*. Although an ideal treatment was not determined,

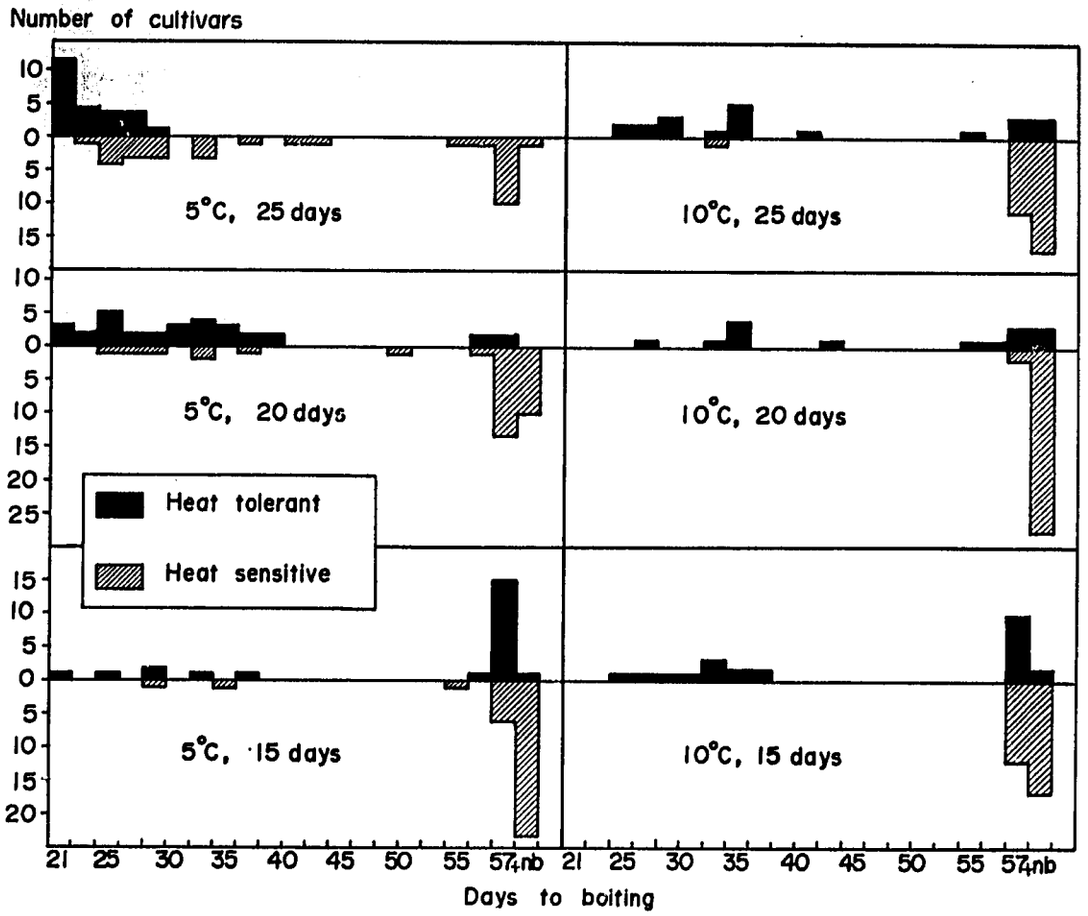


Fig. 1 Reaction of 19 tomato cultivars to bacterial wilt when grown in the wilt nursery (natural infection) and when inoculated. Four cultivars (Acc. 1, 8, 15, 96) were resistant under both conditions.

the higher temperature (10°C) differentiated between the heat-tolerant and heat-sensitive cultivars slightly better than the lower temperature (5°C).

Because of the importance of finding an efficient mass-screening technique for heat tolerance, the breeders investigated the morphological bases of heat tolerance.

Seeds of six cultivars (Acc. 23, 28, 31, 61, 71, 72) were sown in clay pots on August 19; three cultivars were heat tolerant and three, heat sensitive. The experiment was arranged in a randomized complete block design in the greenhouse and replicated twice. Two plants per cultivar were in each replication.

Measurements of various leaf and root characters, possibly related to heat tolerance, were taken 60 days after planting on October 18. The leaf qualities of each plant were measured twice and those of the roots, once. Investigation of the stomatal traits, included the determination of leaf cell conductivity (see Plant Physiology).

The means and mean squares of each character are presented in *Table 3*. Two leaf qualities (petiole length and fresh weight of 2.25 cm^2 of leaf area) and two root characters (midpoint diameter of the main root and number of main root branches) showed significant mean squares indicating that substantial difference existed among the cultivars examined. Although the mean squares were large, no significant differences were noted for the various stomatal characters measured.

Independent, single degree of freedom comparisons for traits, which showed significant mean squares in the analysis of variance, are presented in *Table 4*. All the traits measured were significant between groups, but not within groups. This

Table 3. Comparison of morphological characters between heat-tolerant and heat-sensitive Chinese cabbage cultivars.

Character studied	Mean [a/]		Mean squares
	Heat tolerant	Heat sensitive	
A. Leaf characters			
Total number of veins per leaf	30.4	31.9	13.090
Petiole length (cm)	3.5	5.9	7.170*
Fresh weight (g) of 2.25 cm^2 leaf area	0.3	0.2	0.008**
B. Root characters			
Fresh weight (g)	30.8	34.3	104.840
Root span (cm)	47.4	43.8	24.680
Midpoint diameter (cm) of main root	0.7	0.5	0.060*
Number of main root branches	13.0	6.0	28.570**
Root dry weight (g)	4.5	4.7	1.980
c. Stomatal characters			
Number of stomata per 1 mm^2 area			
Upper surface (no water stress)	161.0	160.0	350.490
Lower surface (no water stress)	251.0	239.0	943.950
Upper surface (water stress)	226.0	240.0	412.330
Lower surface (water stress)	286.0	248.0	1120.670
Percentage of open stomata			
Upper surface (no water stress)	34.6	34.2	6.670
Lower surface (no water stress)	38.1	37.6	5.270
Upper surface (water stress)	24.2	18.8	33.820
Lower surface (water stress)	26.0	18.9	32.910

* – Significant at P = 0.05

** – Significant at P = 0.01

[a/] Means are for all cultivars within each group.

indicated that any one trait might sufficiently distinguish a heat-tolerant cultivar from a heat-sensitive one. The fresh weight of a unit leaf area appeared to have the best potential as a distinguishing morphological character for heat tolerance because of its low coefficient of variation (2%). Heat-tolerant cultivars had shorter petioles and heavier leaves (see *Table 3*). They also had larger main roots with more secondary branch roots than the the heat-sensitive cultivars.

Although the stomata serve as one of the regulatory mechanisms for leaf-water retention, the similarity of the stomatal measurements indicates they are independent of heading response for these six cultivars. To determine transpiration rates, a water-loss experiment was conducted on plants of the same cultivars used in the preceding experiment. The seeds were sown in pots on November 11. On December 26, each plant was enclosed in a plastic bag with only the vegetative portion exposed. The bag was tied tightly around the base of the plant to minimize the amount of water lost by evaporation from the soil. The initial weights of the potted plants were taken, and then the plants were weighed after 10, 20, 30, and 60 minutes.

The difference in water loss of the cultivars was insignificant in the initial ten-minute period,

Table 4. Summary of mean squares from orthogonal, single degree of freedom comparisons and the CV of characters in heat tolerant and heat-sensitive Chinese cabbage cultivars.

Characters	Between HT and HS groups	Within HT group	Within HS group	CV(%)
Petiole length (cm)	17.81***	0.6919	2.8710	9.3
Fresh weight (g) of 2.25 cm^2 leaf area	0.04***	0.0002	0.0003	2.0
Midpoint diameter (cm) of main root	0.18***	0.0340	0.0370	6.2
Number of main root branches	136.69***	3.5200	0.5200	6.5

*** – Significant at P = 0.001
HT – Heat-tolerant
HS – Heat-sensitive

but was highly significant after 20 or more minutes *(Fig. 2)*. The heat-tolerant group (Acc. 23, 28, 31) lost water much more slowly than the heat sensitive group (Acc. 61, 71, 72).

The characteristic turgidity of heat-tolerant plants under high temperature stress might be due to their relatively low rate of water loss. Some of the leaf thickness of the heat-tolerant cultivars is thought to consist of waxy cuticle, which could prevent the excessive loss of water under hot conditions. This will be studied in 1975 with emphasis on determining differences in leaf diffusion resistance between heat-tolerant and heat-sensitive cultivars.

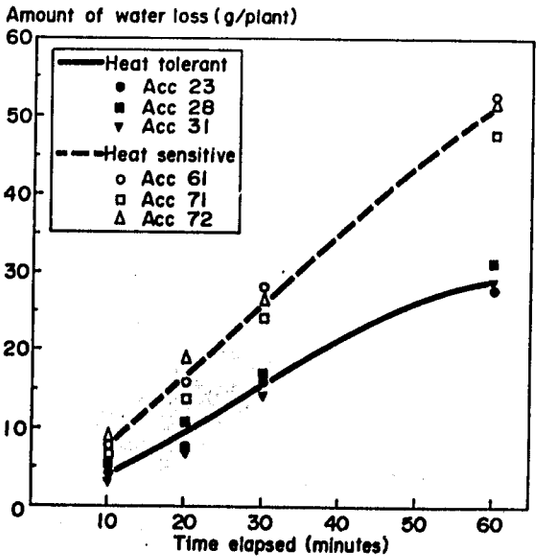


Fig. 2. Comparison of water loss over time between heat-tolerant and heat-sensitive Chinese cabbage cultivars.

Population improvement of local cultivars. As discussed in the *72-73 Annual Report*, the breeders selected 10 local (Taiwan) cultivars for population improvement. From a field population of 500 plants per cultivar, the best 10 percent were chosen because they possessed larger heads and healthy foliage. Soft rot infection further reduced the proportion selected to only two percent of the original population. The selections were selfed and also topcrossed to a heat-sensitive heterozygous cultiver (Acc. 282). Intercrosses among the selections of two cultivars (Acc. 129, 155) were made to test if general combining ability might be determined through the easier polycross method instead of the more tedious topcrossing method.

Seeds of the topcrosses were planted in the spring to identify the best selections for general combining ability based on yield. Only one population (Acc. 129) produced significant mean squares for plot yield for both topcross and polycross tests *(Table 5)*. Although the polycross involved only two populations, the findings were similar to those of the topcross test.

Based on these results, Accession 129 will be used as the base population in the next step of the population improvement program as outlined in the *72–73 Annual Report*. However, two other populations (Acc. 28, 189), which had insignificant mean squares, will be included to further test combining ability for yield.

Development of new varieties through hybridization. Because of the unexpected reduction

of materials in the population improvement program, our intervarietal hybridization program designed to develop better heat-tolerant cultivars of Chinese cabbage received greater emphasis. Parental lines were selected to recombine the heat-tolerance with high yield potential and disease resistance. These crosses were made during the 74-75 winter season.

Only 120 combinations of the 247 crosses made in 1973 were advanced to the F_2 generation. The F_1 seeds of these crosses were sown in small pots on February 20. Five potted plants per cross were vernalized in cold storage for one month. At flowering, intercrosses among the five plants of each cross were made in the greenhouse to obtain the F_2 seeds.

The F_2 seeds from an initial set of 48 combinations were sown at four different times (July 24, July 31, August 1, August 7). As many as 1,200 seedlings per cross were transplanted. Of the 48 combinations, only 16 produced relatively good-sized heads and appeared to be healthy under moderately heavy natural disease infection *(Table 6)*.

Where the number of selections from a particular cross was relatively large, they were separated by discernible phenotypes. Those selections with similar phenotypes were intercrossed only among themselves. This assortative mating of closely related types was to expedite the progress of the selected combinations toward commercial cultivars. Each selection was also selfed to create more phenotypically stable types, which could serve as parents of synthetic cultivars.

PLANT PATHOLOGY

The Chinese cabbage is vulnerable to many diseases, especially in the humid tropics. The pathologists screened the breeding plots for disease resistance and investigated the nature of the various diseases in the laboratory, in the greenhouse, in the field, and at various locations in Southeast Asia.

FUNGAL DISEASES. In the 73-74 winter trial, the reactions of mature plants to downy mildew *(Peronospora parasitica)* did not always agree with those of the seedlings under field conditions. Seven patterns of downy mildew development were identified *(Table 7)* indicating that varying degrees of resistance exist in our germplasm collection. Field resistance could

Table 5. Determination of general combining ability for yield for selections from 9 local heat-tolerant cultivars of Chinese cabbage. a/

AVRDC acc. no.	Varietal name	No. of selections	Mean squares for plot yield	
			Topcross	Polycross
28	Santung	9	149.4	
126		14	139.5	
129	Hsia Sheng (35 days)	10	413.3**	357.1**
152		12	116.3	
155	Ching Ho Improved	13	163.3	81.2
162	Hsia Sheng	12	213.6	
171	Homei	13	123.9	
175		14	91.8	
189		24	126.9	

** – Highly significant at 1% level.

a/ – Topcross selections were grown in the spring; polycross selections, in the summer.

Table 6. A list of elite F_2 populations of Chinese cabbage that produced heat-tolerant selections during the summer.

AVRDC selection no.	Pedigree [a]	Trait(s) intended to be recombined with heat tolerance
63	Kang Jang / Acc. 126	Multiple disease resistance and high yield
64	Kang Jang / Hsia Sheng	Multiple disease resistance and high yield
67	Kang Jang / Acc. 189	Multiple disease resistance and high yield
62	Neabeng Bulam / Acc. 189	Resistance to downy mildew and mosaic, high yield
99	Se Mouchuk / Hsia Sheng	Resistance to downy mildew and mosaic, high yield
51	Tongil Shinkang (F_1) / Acc. 175	Multiple disease resistance
43	Tongil New 2 (F_1) / Acc. 126	Resistance to downy mildew and mosaic
73	Bokwan 3 (F_1) / Acc. 126	Resistance to downy mildew and mosaic
75	Bokwan 3 (F_1) / Homei	Resistance to downy mildew and mosaic
78	Jang Cun New (F_1) / Acc. 126	Resistance to downy mildew
80	Jang Cun New (F_1) / Homei	Resistance to downy mildew
93	Tongil 100 (F_1) / Acc. 126	Resistance to downy mildew and mosaic
55	Han Nong 3 (F_1) / Homei	Resistance to downy mildew and soft rot
16	Nonghyep 2 (F_1) / Acc. 126	Resistance to soft rot
17	Nonghyep 2 (F_1) / Hsia Sheng	Resistance to soft rot
19	Nonghyep 2 (F_1) / Acc. 175	Resistance to soft rot

[a] When the varietal name is not known, the parent is identified by its AVRDC accession number.

easily be missed, if only rated at one growth stage. Readings were taken at frequent intervals to avoid this.

The cotyledons of 144 cultivars planted in the greenhouse were inoculated with a spore suspension of the downy mildew pathogen upon emergence. The degree of susceptibility was recorded seven days after inoculation. Four of the *B. chinensis* cultivars (Acc. 93, 95, 98, 99) were resistant, and 37 cultivars were moderately resistant. However, the four resistant cultivars had not been consistent in their reactions to downy mildew in previous screenings and will be tested further to verify these results.

Another experiment was conducted with seedlings inoculated at the 2- to 3-leaf stage. Disease readings were taken at different times after planting. Most of the screened cultivars were more susceptible to downy mildew at 31 days than at 48 days. Seedlings with vigorous growth appeared to be resistant to downy mildew.

Ninety-four cultivars were planted in two plots; one with mulch and one without mulch. Susceptibility to downy mildew was reduced on the plots with mulch *(Tables 8 and 9)*. This could be due to the effect of mulch on the relative humidity at the soil surface, but the exact reason is not known.

The frequency distribution of 42 accessions by their reactions to downy mildew infection at different growth stages indicated that the plants were most susceptible at the cotyledon stage and at the heading or at the bolting stage *(Table 10)*. Disease reactions at the cotyledon stage and 31 days after planting were associated with the reactions at 48 and 26 days after transplanting, respectively. However, if the resistance is only evaluated at the cotyledon stage, a considerable amount of valuable materials with either field resistance or tolerance might be eliminated. Thus,

the pathologists have tentatively concluded that the best time to select for resistance to downy mildew is a week before transplanting to the field (about 20 days after sowing).

The newest additions to our varietal collection were tested for disease resistance during the fall. Nineteen F_1 hybrids from Korea and Japan showed resistance to downy mildew and five had varying degrees of resistance to turnip mosaic virus and soft rot *(Table 11)*.

Forty-nine *B. chinensis* cultivars were also screened. Nine were resistant to downy mildew, and CO Na (Acc. 464) was resistant to soft rot and turnip mosaic virus. The five cultivars with the greatest resistance are listed in *Table 11*.

BACTERIAL DISEASES. Bacterial soft rot, caused by *Erwinia carotovora*, is one of the most destructive diseases attacking Chinese cabbage in the tropics. Initial infection is usually found on the outer petioles that are in contact with soil at the 'wrapping' stage of the plants. The bacterial pathogen is widely distributed in tropical soils. However, studies in the United States and Europe of related pathogens have indicated that the primary inoculum does not originate in the soil, but in plant debris and vegetatively propagated materials.

Several media were tested for soft rot bacteria. Two media (modified Drigalski's and crystal violet pectate) and the plant-tissue method were chosen to grow and study soft rot bacteria populations.

Although the modified Drigalski's medium is not highly selective, it can differentiate between soft rot bacteria and other soil microorganisms by colony morphology. The soft rot bacteria produce golden colonies with halos on this medium. Another type (probably *Pseudomonas* sp.) of bacteria commonly associated with the soft rot bacteria, both in the diseased tissues and in the soil samples, produces small blue circular colonies

Real progress is being made in developing new varieties of Chinese cabbage that produce large heads in the hot summer months. The segregant on the right has a head three times larger than that of its best parent (left).

Table 7. Seven patterns of downy mildew (*Peronospora parasitica*) development represented by cultivars of *B. pekinensis*.

AVRDC acc. no.	Varietal name	Pattern	Growth stage a/			Integrated disease rating a/
			Seedling	Rapid vegetative growth	Head formation	
99		A	R	R	R	R
95	Choy Sun (80 days)	B	R	R	MR	MR
110		C	R	MS	MR	MR
28	Santung	D	R	R	S	MS
82	Choy Sun 3	E	R	MR	S	S
43		F	R	MR	S	S
5	New Autumn	G	MS	MS	S	S

a/ R – less than 25% infection.
MR – 26 to 50% infection.
MS – 51 to 65% infection.
S – more than 75% infection.

Table 8. Reactions of 94 Chinese cabbage cultivars to downy mildew, turnip mosaic virus, and *Alternaria* leaf spot under field conditions. a/

Evaluation time	Percent of 94 cultivars without infection		
	Downy mildew (%)	Turnip mosaic virus (%)	*Alternaria* (%)
26 days after transplanting	4	46	97
48 days after transplanting	0	41	64

a/ 20 seedlings per cultivar were transplanted in the field April 10; data pooled from the plots with and without rice straw mulch.

on the same medium.

The crystal violet pectate (CVP) medium was also used to detect the soft rot bacteria. Using the spot-plate technique, the polypectate hydrolytic activity of the soft rot bacteria was tested on this medium. However, the capacity of the soft rot bacteria to hydrolize polypectate was affected by the presence of other saprophytic bacteria in both the plant tissues and the soil samples. This medium was only selective when the populations of the soft rot bacteria were higher than those of the other soil bacteria. Estimation of the soft rot bacterial population in soil and plant tissues was possible when the CVP medium was combined with the modified Drigalski's medium.

The plant-tissue method was used to test the rotting capacity of the bacteria. Sections of Chinese cabbage petioles were placed in moistened dishes and inoculated with the bacterial pathogen. The rotting capacity of the pathogen was calculated by dividing the number of rotted petiole sections by the total number of sections.

The pathologists conducted a series of experiments to test the ability of the soft rot bacteria to survive as saprophytes and to determine the infection potential of the bacterium as a plant pathogen.

Soil samples contained only traces of soft rot bacteria shortly after plowing under diseased Chinese cabbage plants. Petiole sections of Chinese cabbage were inoculated with bacteria prepared

directly from the diseased tissues and incubated for various lengths of time in the laboratory. The proportions of soft rot bacteria to total bacterial populations in the petiole section (detected by the modified Drigalski's medium) decreased as the incubation time increased *(Table 12)*. In one trial, soft rot bacteria decreased from 93 to 16 percent of the total bacterial population two days after its petiole sections were inoculated and to an undetectable amount four days after inoculation. Other trials demonstrated similar decreases. Apparently, the soft rot bacteria are

Table 9. Reactions of 94 Chinese cabbage cultivars to downy mildew under field conditions as affected by mulching. a/

Reaction to downy mildew b/	Percent of 94 cultivars	
	with mulch (%)	without mulch (%)
R	1	0
MR	14	8
MS	27	15
S	58	77

a/ 20 seedlings per cultivar were transplanted in the field April 10; results were from readings taken May 6 and 29.

b/ R – less then 25% infection.
MR – 26 to 50% infection.
MS – 51 to 75% infection.
S – more than 75% infection.

Table 10. Reactions of 42 Chinese cabbage cultivars to downy mildew infection at different growth stages.

Reaction to downy mildew a/	Percent of 42 cultivars						
	Cotyledon stage b/		Seedling stage c/			Heading stage d/	
	Cotyledon (%)	1st leaf (%)	31 DP (%)	40 DP (%)	49 DP (%)	26 DT (%)	48 DT (%)
R	0	81	40	62	81	38	0
MR	10	7	41	29	14	36	17
MS	7	7	17	10	5	17	12
S	83	0	2	0	0	10	71

a/ R – less than 25% infection.
MR – 26 to 50% infection.
MS – 51 to 75% infection.
S – more than 75% infection.

b/ The 42 cultivars were sown in wooden flats on May 21; the cotyledons were inoculated May 27 and surveyed June 4.

c/ The 42 cultivars were sown in wooden flats March 8. Seedlings were inoculated with a spore suspension of downy mildew, disease readings were taken April 8, 17, and 25. (DP - days after planting).

d/ The 42 cultivars were sown in March and transplanted to the field April 10. Disease readings were taken May 6 and 29. (DT - days after transplanting.)

Table 11. Ten new sources of resistance to downy mildew *(Peronospora parasitica)* and turnip mosaic virus (TuMV) with varying degrees of resistance to soft rot *(Erwinia carotovora)* from a field screening of 154 *B. pekinensis* cultivars and 49 *B. chinensis* cultivars. a/

Brassica pekinensis cultivars						*Brassica chinensis* cultivars					
AVRDC acc. no.	Varietal name	Origin	Reaction to b/			AVRDC acc. no.	Varietal name	Origin	Reaction to b/		
			Downy mildew	TuMV	Soft rot c/				Downy mildew	TuMV	Soft rot
310	Korean hybrid 6 (F_1)	Korea	R	R	R	464	Co Na	Japan	R	R	R
353	Gyokuhai (F_1)	Japan	R	R	R	487	Shinkilina	Japan	R	R	MR
357	Taibyo 65 days (F_1)	Japan	R	R	MR	501	Miyauchina	Japan	R	R	MR
313	Korean Hybrid 9 (F_1)	Korea	R	R	MR	500	Isoko Kyo Mizuna	Japan	R	R	MS
318	BB Chinese cabbage (op)	Korea	R	R	MR	470	Sagami SK	Japan	R	MR	R

a/ Planted Sept. 27; transplanted Oct. 10; disease data taken from 20 plants per cultivar.

b/ R – less than 25% infection.
MR – 26 to 50% infection.
MS – 51 to 75% infection.

c/ When inoculated with soft rot bacteria, only Accessions 310 and 353 remained even moderately resistant.

unable to compete with other saprophytes.

The infection potential was based on the infectivity of an inoculum prepared by grinding a unit weight of diseased tissue, and was estimated by the percentage of petiole sections that rotted when inoculated with a volume (0.01 ml) of freshly prepared inoculum. The population size of soft rot bacteria was determined by placing

Table 12. Mean survival rate of soft rot bacteria, *Erwinia carotovora*, in plant tissue of Chinese cabbage.

Percentage of soft rot bacteria in gram-negative population			
Inoculation	+ 2 days	+ 3 days	+ 4 days
87	16	10	4

the same inoculum on the modified Drigalski's medium. In this study, the infection potential was related to the proportion of soft rot bacteria in the total bacterial population and less associated with the number of soft rot bacteria in the inoculum *(Talbe 13)*.

Table 13. Rotting capacity of pectolytic soft rot bacteria when mixed with other soil bacteria.

Inoculum (0.01 ml)[a]		Reaction on CVP medium[b]	Soft rot infection (%)
Soft rot cells	Soft rot cells as % of total bacterial cells		
1.0×10^4	62	6/32	67
2.5×10^6	14	5/32	31
3.5×10^6	77	21/32	0
1.2×10^7	88	20/32	33
1.0×10^8	91	32/32	90

[a] Inoculum was prepared directly from diseased tissues.
[b] Reaction on crystal violet pectate medium using the spot-plate technique.

The infectivity of this pathogen was high when the inoculum contained only soft rot isolates *(Fig. 3)*. An inoculum dosage containing less than 100 soft rot bacterial cells caused five percent soft rot infection in 24 hours, and 60 percent in 48 hours. The disease can develop rapidly in a short time after initial infection in susceptible Chinese cabbage plants.

The infection potential of the soft rot pathogen was significantly influenced by the presence of other soil saprophytes in the inoculum. As mentioned earlier, a non-soft rot bacterium, probably *Pseudomonas*, was frequently found in soft rot infected cabbage tissues. When the two bacteria were mixed in various combinations of inoculum concentrations, soft rot infection was reduced.

The polypectate hydrolytic activity was also affected by the presence of other bacteria *(Table 14)*. When inoculated with a dosage of 10^6 cells,

Table 14. The rotting capacity of soft rot (SR) bacteria when mixed with non-soft rot (NSR) bacteria.

SR cells : NSR cells ($\log_{10}$)	Soft rot production		Reaction on CVP [a]
	24 hr	48 hr	
6:0	100	100	++
6:5	100	100	++
6:6	100	100	+
6:7	88	100	+
6:8	63	63	+
5:8	0	33	–
4:8	0	0	–
3:8	0	0	–
0:8	0	0	–

[a] CVP–Crystal Violet Pectate

the soft rot bacteria rotted 100 percent of the petiole sections in 24 hours, but only 63 percent when a 10^8-cell dosage of the non-soft rot bacteria was added to the inoculum. When the combination of soft rot and non-soft rot bacteria was 10^4 and 10^8 cells per dosage, respectively, no soft rot infection was noted after 48 hours.

Although it has been reported that the soft rot pathogen of Chinese cabbage has a broad range in the soil, it was difficult to detect the

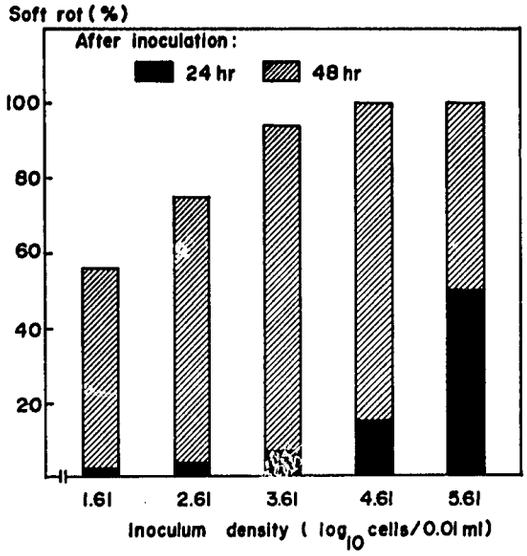


Fig. 3. Infectivity of various inoculum densities of soft rot *(Erwinia carotovora)* at 24 and 48 hours.

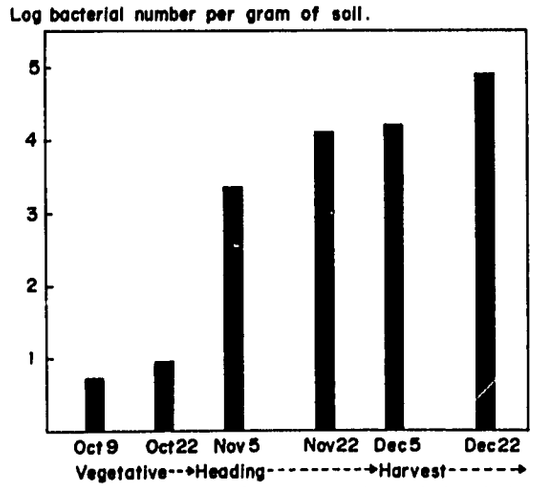


Fig. 4. Increase of the soft rot bacterial population during the life cycle of Chinese cabbage in the field.

bacteria in soil samples. When Chinese cabbage had not been cultivated in a field, no soft rot bacteria were found *(Table 15)*. Soft rot bacteria were also undetected in soil samples from fields where the first crop of Chinese cabbage was only at the seedling stage. However, soft rot bacteria were found in the soil where Chinese cabbage had been planted as the previous crop. In this field, the soft rot bacterial population began increasing at the head-formation stage and remained at 10^5 cells per gram of soil (wet wt) until the end of that cropping season *(Fig. 4)*. In the Lishan mountain area of Taiwan, where Chinese cabbage has been cultivated continually for the last 10 years, only low populations of soft rot bacteria could be detected in soil samples. The maximum soft rot incidence was 10 to 20 percent of the plants in the fields (see *Table 15*).

Once soft rot bacteria are present, the disease develops rapidly. Indentification of resistant cultivars is, therefore, important. However, because the infection of soft rot bacteria is influenced by the presence of other soil microorganisms, repeated evaluations of cultivars with soft rot resistance must be made and the concentration of other soil microorganisms must also be recorded.

Between the fall seasons of 1973 and 1974, 577 Chinese cabbage cultivars were screened in the field. In 1973, 27 cultivars were selected for apparent resistance to soft rot. The following summer, 88 cultivars (including the 27 from 1973) were tested in the field using artificial inoculation. Soft rot infection decreased when mulch was used *(Fig. 5)*. This confirmed previous studies that the incidence of soft rot in the field can be reduced with mulch. From this screening, 10 resistant cultivars were identified; five of them were F_1 hybrids.

Table 15. Occurrence of soft rot bacteria in Chinese cabbage fields.

	Bacterial population[a]	
	Soft rot	Total
	·····(10^4)·····	
No Chinese cabbage for 10 years.	0	140
First crop of Chinese cabbage at seedling stage.	0	250
Second crop of Chinese cabbage at heading stage.	10	540
Continual cropping of Chinese cabbage for 10 years.	3	160

a/ Determined by sampling from the upper 10 cm of the soil.

VIRUS DISEASES. In AVRDC's experimental fields, Chinese cabbage was infected by turnip mosaic virus, which is transmitted mechanically and by aphids. Two other viruses, cauliflower mosaic and cucumber mosaic, were occasionally isolated.

Turnip mosaic virus (TuMV) occurs throughout the year and is most severe during the winter and the early spring in the Shanhua area near AVRDC. This virus has a wide host range and is spread by 40 or more species of aphid vectors.

Diseased samples of Chinese cabbage were collected from AVRDC fields and from Chinese cabbage production areas of Taiwan in order to isolate TuMV. Plants of *Nicotiana glutinosa* were inoculated with the virus from the cabbage plants. In turn, radish or turnip plants were inoculated with the virus; finally, the Chinese cabbage plants were inoculated with the virus from the radish or turnip plants. The plants that produced typical TuMV symptoms were used as sources of inoculum for further study.

The identification of TuMV was further confirmed by testing the isolated virus against TuMV antiserum obtained from J. A. Tomlinson, National Vegetable Research Laboratory (England); by observing the virus particle under the electron microscope; and by transmitting the virus with aphids *(Myzus perusicae* and *Brevicoryne brassicae)* from diseased plants to healthy ones.

The possible mixed infection with cucumber mosaic virus (CMV) cauliflower mosaic virus (CaMV) was further checked with differential hosts, i.e., the common bean *(Phaseolus vulgaris)* for CMV and *Datura stramonium* for CaMV. The separation of the three viruses was achieved as shown in *Figure 6.*

In the fall of 1973, 276 Chinese cabbage

Chinese cabbage protected by rice straw mulch has a better chance of survival from bacterial soft rot infection.

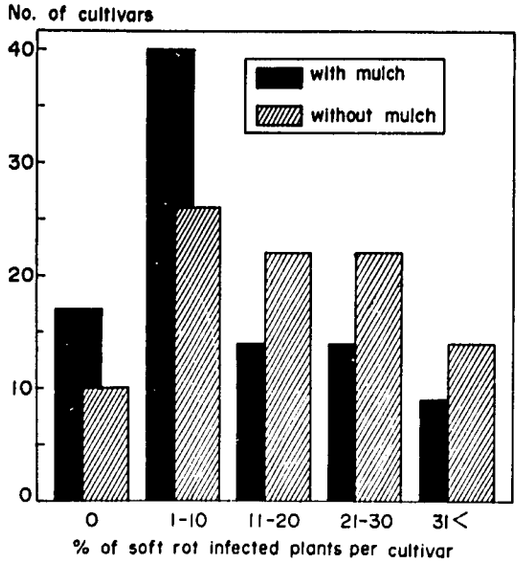


Fig. 5. The effect of rice straw mulching on the incidence of soft rot infection.

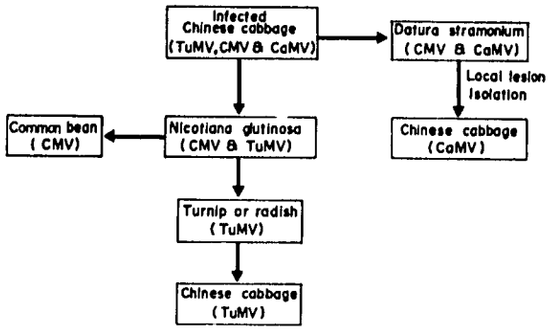


Fig. 6. Flowchart showing the procedure used to separate turnip mosaic virus (TuMV) from cauliflower mosaic (CaMV) and cucumber mosaic (CMV), using differential hosts.

cultivars were tested for resistance to TuMV. In this study, 71 cultivars were rated as resistant under natural infection conditions. These were planted again in the spring of 1974. The same 71 cultivars were also sown in wooden flats in the greenhouse and given the same treatment as those in the field. Accessions 6, 16, and 141 were rated as resistant both in the field and in the greenhouse *(Table 16)*. More accessions were rated as resistant in the greenhouse than in the

Table 16. Partial list of Chinese cabbage cultivars with varying degrees of resistance to turnip mosaic virus (TuMV) in four screenings. a/

AVRDC acc. no. b/	Varietal name	Spring trials c/		Fall trials d/	
		Greenhouse	Field	Inoculated	Not inoculated
144⁻	Feng Lu	R	R	R	R
6⁻	New King	R	R	R	R
16⁻	Uji Hybrid (F_1)	R	R	R	R
181⁻	Michihli	MR	R	R	R
7⁻	Nagaoka Test–8 (F_1)	MR	R	R	R
15⁻	Improved Ping Luh (F_1)	MR	MR	R	R
112⁻	(F_2)	R	MR	MR	R
120⁻	Kinsei R (F_1)	R	MR	MR	R
25⁻	Yue Sham (F_1)	MR	R	MR	R
18⁻	Uji Hybrid 2 (F_1)	MR	R	MR	R
70⁺	Tropical Pride 3	MR	MR	MR	MR
183⁺		R	S	MR	MR
106⁺	Sakata 21 (F_1)	S	MR	MR	MR

a/ 71 cultivars were screened; only the best selections are included here.
b/ Previously identified as either heat tolerant (+) or heat sensitive (–).
c/ Planted March 21; transplanted April 16; inoculated April 26.
d/ Sown directly in the field on Nov. 20; 40 plants per accession were used – 20 plants were inoculated with TuMV on Dec. 17, and 20 served as control.

field, because the plants in the field probably received additional virus inocula from natural infection (transmitted by aphids) in addition to the artificial inoculations. However, Accessions 7, 18, 25, and 181 showed higher degrees of resistance in the field than in the greenhouse.

The cultivars that were rated as either resistant or moderately resistant in both trials were tested again during the winter. To give longer exposure to TuMV during the early stages of growth, the seeds were sown directly in the field on November 20, and 40 plants of each cultivar were inoculated December 27. Accessions 141 and 6 were again resistant in all tests, but Accessions 7 and 16, which had also been rated as resistant, suffered some infection (less than 10%).

When *Chenopodium aramanticola* (a local lesion host of TuMV), was inoculated with the plant sap of Accessions 6, 16, 141, and 181 separately, lesions resulted from all except Accession 141. Thus, we concluded that Accession 141 is truly resistant, whereas Accessions 6, 16, and 181 are only field resistant.

ENTOMOLOGY

All the commercially important *Brassicae*, including Chinese cabbage, are severely attacked by insect pests. The diamond-back moth, *Plutella xylostella*, is among the most damaging of the cabbage pests and is common throughout the world. Its reproductive potential is high with each female capable of producing 200 to 300 eggs and the number of generations may reach 20 per year in the tropics. Insecticide resistance has been alleged or proven for at least 10 of the insecticides commonly used for control of *P. xylostella*.

Two other major insect pests of cruciferous crops are the cabbage butterfly, *Pieris rapae*, and cabbage loopers, *Trichoplusia ni*. In addition, turnip aphids, *Rhopalosphium pseudobrassicae*, and the striped flea beetle, *Phyllotreta striolata*, occasionally cause considerable damage in Southeast Asia.

VARIETAL RESISTANCE. Because of the low threshold of insect damage tolerated on

Table 17. Selected Chinese cabbage cultivars with the lowest insect damage ratings in two trials. a/

AVRDC acc. no.	Varietal name	Overall damage rating b/ Spring	Fall	Comments
203	Bokean 70 days (F_1)	L	M	No *P. xylostella* present
205	Konong 3 (F_1)	L	M	
30	Dark leaf late Chinese cabbage		L	No *T. ni* present
207	Victoria (F_1)	H	L	*P. rapae* present in the spring
286	Kang Reuk (F_1)		M	
86	Wong Bok		M	No *T. ni* present
167	Yung Ching (30 days)		M	No *T. ni* present
166	Chin Lu		M	
192			M	No *P. xylostella* present
202	Deahyeng Karak	L	M	

a/ Spring trial planted March 5 and sampled April 11 and 12. Fall trial planted Oct. 3 and 4 and sampled Nov. 11,12, and 13. 20 plants per plot and 3 replications.

b/ Damage rating:

L – Light

M – Moderate

H – Heavy

vegetable crops, the appearance of these insect pests usually cause farmers to apply insecticides as frequently as every three or four days.

Field screening of Chinese cabbage *(B. pekinensis)* and common cabbage *(B. oleracea* var. *capitata)* was initiated in the spring. The first field trial was so rapidly attacked by insects that the common cabbage entries were eliminated before evaluation could take place. However, some Chinese cabbage cultivars did suffer less damage from insect attack *(Table 17)*.

The spring population of *P. xylostella* at AVRDC was much lower than in the fall. Therefore, the fall trial was more significant for evaluating field preference of the *P. xylostella* larvae (see *Table 17*). The mean number of moth larvae in the fall trial ranged from zero in 13 cultivars to 20 in 3 cultivars. Cabbage worm *(P. rapae)* populations were low in the fall trial, but a variation of means from 1.5 to 3.7 larvae per sample was obtained in the spring. Although not present in measurable numbers in the spring, cabbage loopers *(T. ni)* had mean populations ranging from zero to eight per 10-plant sample in the fall trial.

The majority of the tested cultivars were resistant to one pest and suceptible to the others. Some varietal resistance to the major cabbage pests in Southeast Asia exists and can be developed for use in integrated pest control systems, minimizing insecticide applications.

BIOLOGICAL CONTROL. Research has progressed on the practical applicability of using specific insect-pathogenic viral agents for the biological control of the major lepidopterous cabbage pests. Granulosis viruses of *P. xylostella* and *P. rapae* were field tested on Chinese cabbage and compared with Bayrusil, an effective insecticide,

Table 18. Evaluation of granulosis viruses (GV) for the control of the diamond-back moth *(P. xylostella)* in Chinese cabbage.a/

Treatment b/	No. of *P. xylostella* larvae				GV effectiveness as % of Bayrusil c/		Mean damage rating d/	Mean head weight e/ (g)	Marketable heads f/ (%)
	Oct.28		Nov.4						
	Healthy	Infected	Healthy	Infected	Oct.28	Nov.4			
	(Mean no. / plant)				-------(%)------				
A. Plutella GV (granules/ha)									
5.6×10^{10}	8.6	2.0	2.3	1.4	0	38	moderate	780	91
2.8×10^{11}	4.7	2.5	2.0	1.0	30	51	moderate	890	96
5.6×10^{11}	2.7	2.8	1.8	1.8	48	40	moderate	750	94
2.8×10^{12}	2.1	3.5	1.0	0.9	47	70	slight	870	96
B. Bayrusil (g/ha)									
250	0.5	0	0.3	0	100	100	moderate	1,080	99
C. Control	10.1	0.1	5.8	0.9	0	0	heavy	850	91

a/ Cultivar KY 60 was transplanted in the field on Sept. 12.
b/ The plants were sprayed Oct. 14, 21, 29 and Nov. 15 except for those in the control plot.
c/ An effective insecticide for *P. xylostella* control.
d/ Field observation.
e/ LSD at 5% level of significance was 0.145.
f/ Not sufficiently damaged to keep it from being sold.

The viruses were isolated in Taiwan and identified through pathological changes in infected insects and by light phase and electron microscopy techniques.

The insects *(P. xylostella* and *P. rapae)* were grown as hosts for the viruses both in the greenhouse and in the field on Chinese cabbage, common cabbage, and mustard *(B. juncea)* foliage. Larvae were periodically collected and sprayed with virus suspensions. After the larvae died, their bodies were used to prepare more virus suspension. The procedure is described in *Chart 1.*

The effects of the various treatments were assessed twice before harvest by counting both healthy and infected insects on all plants *(Table 18.)* Damage ratings, average head weights, and percentage of marketable (i.e., undamaged) heads were recorded at harvest (also in *Table 18*).

Application of the granulosis virus reduced the numbers of *P. xylostella* larvae considerably, especially with the higher virus concentrations. Although none of the virus treatments were as effective as the insecticide, the two field counts of healthy insects showed approximately a five-fold reduction in larvae numbers for the highest virus concentration compared to the mean populations on the control plants. In general, the virus treatments resulted in reduced insect damage and slightly increased the percentage of marketable heads (see *Table 18*).

Chart 1. Procedure for preparing granulosis virus suspensions for the biological control of *P. xylostella.*

1) Collection of infected larvae.
2) Mix with tap water in a blender.
3) Filter through four layers of cheesecloth.
4) Centrifuge at 5000 rpm for 30 minutes.
5) Decant and resuspend in tap water.
6) Centrifuge at 1000 rpm for 10 minutes.
7) Collect supernatent as stock suspension.
8) Determine concentration with hemocytometer.
9) Refrigerate at 5°C.
10) Mix with water and a spreader-sticker to apply in the field.

The approximate number of *P. xylostella* virus granules applied per 1000 liter of spray/ha was calculated by hemocytometer counts to the following larval equivalents per liter.

Granules/ha	Equivalent no. of larvae / liter
2.8×10^{12}	10.0
5.6×10^{11}	2.0
2.8×10^{11}	1.0
5.6×10^{10}	0.2

Table 19. Effects of temperature on the infectivity of the *Plutella* granulosis virus (GV). [a]

Rearing temp (°C)	Total no. of larvae		No. of larvae that pupated		Percent infected (%)	
	with GV	without GV	with GV	without GV	with GV	without GV
20	90	30	4	25	91	0
25	30	45	3	26	90	5
35	75	30	43	18	27	0
37	33		17		18	
39	90	45	69	38	0	0

[a] 15 to 20 second-instar *P. xylostella* larvae per potted cabbage plant were used. The virus spray treatment consisted of one-fourth instar diseased larvae per 10 ml of water; concentration of virus granules was 2.8×10^{10} granules per liter.

This experiment demonstrated that the diamond-back moth could be partially controlled with a virus disease, which is relatively simple to produce. Further experiments will be conducted to determine the applicability of this technique on a large scale. In addition, the effect of the environment on the infectivity of the virus must be known before such techniques can be recommended to farmers.

Experiments were conducted to determine the effect of temperature on the pathogenicity of the granulosis virus. Second-instar larave of *P. xylostella* were fed cabbage leaves that had been sprayed with a concentration of 2.8 x 10^{10} granules per liter and then placed in growth chambers set at different temperatures. Similar tests were made without the virus to establish normal mortality rates at the different temperatures. As the temperatures increased from 20° to 40°C, the percent of infection rapidly decreased from 91 percent to zero *(Table 19)*. Temperatures in this range had no harmful effect on the untreated larvae that pupated.

CHEMICAL CONTROL. Insecticides are the major means used to achieve insect control on cruciferous crops. A wide variety of insecticides are generally available near population centers throughout Southeast Asia where *Brassica* production is concentrated. Insecticides selected for testing were those generally recommended for cruciferous crops or because of related recommendations, which might satisfy the specific pest-control requirements.

Table 20. Evaluation of insecticides on common cabbage (*B. oleracea* var. *capitata*) for *P. xylostella* control a/.

Insecticide b/	Active ingredient (kg/ha)	No. of *P. xylostella* larave and pupae per 10 plant sample c/	Yield (ton/ha) c/
S–2539	1.5	2	34
Hostathion	1.0	3	34
Diazinon	0.5	12	34
Salithion	0.5	23	30
DDT	1.0	34	32
Gardona	1.0	52	27
Control		52	26
Ethyl Parathion	0.5	102	30
Azodrin	0.5	156	36
Sevin	1.5	157	31

a/ Cultivar KY Cross was transplanted Aug. 20.
b/ Insecticides applied Aug. 29, Sept. 6, 13, 19, 26 Oct. 4, 11, 18, and 24.
c/ Data are mean sample data from 4 replicated 10-m^2 plots.

Table 21. Evaluation of insecticides on cauliflower (*B. oleracea* var. *botrytis*) for control of *P. xylostella* and *T. ni*. a/

Insecticide b/	Active ingredient (kg/ha)	Yield c/ (tons/ha)	No. of marketable heads per plot c/	No. per 10 plant sample c/	
				P. xylostella	*T. ni*
Surecide	0.5	18	30	5	12
Spanone	0.5	22	30	20	9
Dipel	0.5	19	29	90	24
Padan	0.5	19	29	100	38
DDVP	0.5	12	25	140	14
Nexion	1.0	12	31	146	29
Dursban	0.5	15	31	160	10
Control		12	23	177	33
Lannate	0.5	20	30	199	17
Sumithion	0.5	11	29	251	266

a/ Cultivar Nan Tze Super Early transplanted Sept. 11.
b/ Insecticides applied Sept. 18, 25, Oct. 4, 11, 18, 24, and Nov. 1.
c/ Harvested and evaluated Nov. 7,8,14,15, and 16. Data are mean sample data from 4 replicated 10-m^2 plots.

Effective control of the diamond-back moth was achieved with Sumitoma S-2539 (a synthetic pyrethroid) and Hostathion in a fall trial using common cabbage *(Table 20)*. Cabbage looper *(T. ni)* and diamond-back moth larvae *(P. xylostella)* were the major cruciferous pests encountered in a third test of insecticides on cauliflower, *B. oleracea* var. *botrytis (Table 21)*. The plot sprayed with Spanone had the highest average head weight and the lowest number of loopers. Both Surecide and Spanone controlled the diamond-back moth and the cabbage looper. Of nine insecticides tested in the summer, six provided good aphid control, and the yields in the plots treated with insecticide were more than twice that of the control plot *(Table 22)*.

PLANT PHYSIOLOGY

The conductivity–measurement technique applied to sorghum in studies on heat tolerance was tested as a simple mass-screening technique for Chinese cabbage. An experiment was conducted to determine the relationship of leaf-cell injury to temperature as associated with conductivity.

Washed leaf discs were placed in a series of test tubes. After adding distilled water, the test tubes were submerged in water baths for one hour at various temperatures, and then placed overnight in cold storage. Electrolytes diffusing from the tissue were measured the next day with a conductivity bridge. Then the total conductivity was measured again after submerging the tubes in a boiling water bath for 10 minutes. The ratio of these two conductivity measurements was used as an index to express the degree of injury under a particular temperature.

Six cultivars were planted under two different conditions (with and without water stress). The degree of injury to the leaves and the number of stomata were determined weekly for six weeks. A varietal difference in leaf-cell injury was not observed, nor did water stress affect the response of leaf cells to temperature. There was no significant difference in the number of stomata between heat-tolerant heat-sensitive cultivars. Apparently, the physiological basis for head formation is independent of the heat resistance of the leaf cells. Field observarions confirmed this; heat-sensitive cultivars grow well, but do not form heads under high temperatures.

The heat-tolerant cultivars had a much higher total conductivity than did the heat-sensitive cultivars. This means that the heat-tolerant

Table 22. List of insecticides, which reduced turnip aphid *(Rhopalosphium pseudobrassicae)* populations, and their effect on Chinese cabbage yields. a/

Insecticide b/	Active ingredients (kg/ha)	Percent of plants with more than 100 aphids c/	No. of marketable heads d/	Yield (tons/ha)	Yield as % of control
Phosvel	1.0	5	24	11.8	295
Actellic	0.5	5	25	10.8	270
Tameron	0.5	10	20	10.4	260
Reldan	0.5	0	22	10.4	360
Bayrusil	0.5	2	25	9.8	245
Folithion	0.5	5	24	8.9	223
Mean of treatments		6	23	10.3	257
Control		65	12	4	100

a/ Cultivar Formosa 45 was planted June 25, transplanted July 23, and harvested Sept. 13.
b/ Insecticides were applied July 29, Aug. 6, 13, 23, and Sept. 6.
c/ The number of aphids were counted at harvest.
d/ 28 plants were planted per 10-m^2 plot.

plants contained more electrolytes than the heat sensitive. The total conductivity of the six cultivars at various growth stages was determined *(Fig. 7)*. When the .ata for the cultivars were averaged, the conductivity of the heat-tolerant cultivars was greater in all cases than the conductivity of the heat-sensitive ones. There was a tendency for this difference to increase with time. The technique of total conductivity determination is simple. Hence, it might be used as a mass-screening technique at early growth stages.

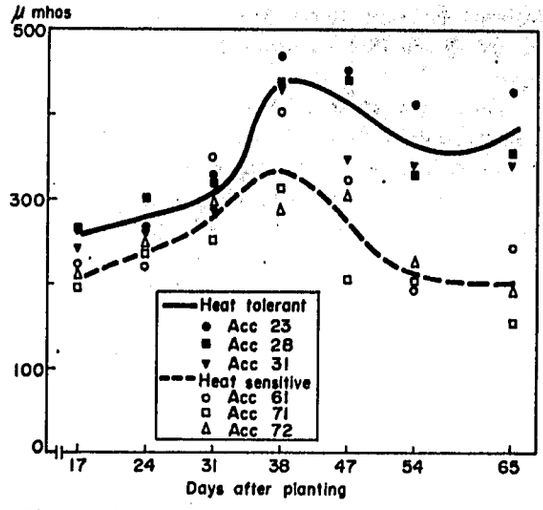


Fig. 7. Comparison of heat-tolerant and heat-sensitive Chinese cabbage cultivars by total conductivity (μ mhos) of the leaves at various stages of growth.

AGRICULTURAL CHEMISTRY

An experiment was conducted to study the effect of temperature on both the chewing quality and the vitamin C content of Chinese cabbage leaves. The crude fiber and vitamin C contents of the winter crop were determined and compared with those of the summer crop.. The frequency distribution of crude fiber content was basically the same in both summer and winter seasons *(Fig. 8)*. However, the vitamin C content of Chinese cabbage leaves grown in the summer was generally higher than that of the winter crop *(Fig. 9)*. Production of *B. pekinensis* in the summer will not decrease the crude fiber content, but may increase the vitamin C content as compared to winter production.

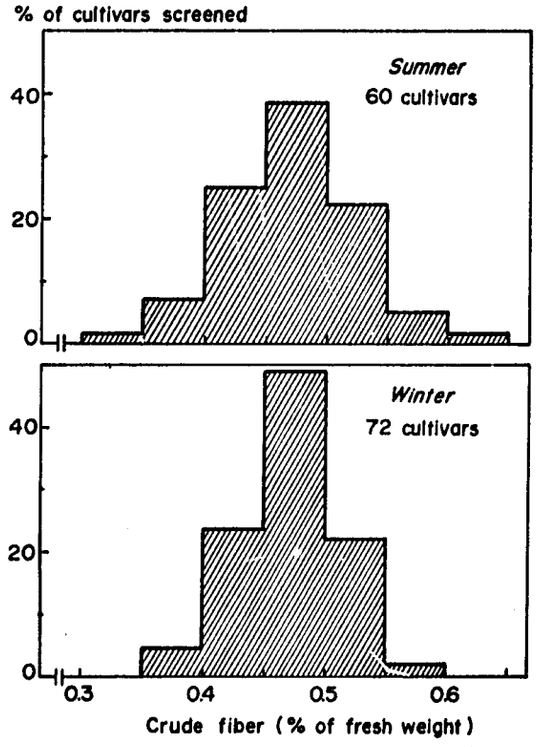


Fig. 8. Distribution of Chinese cabbage cultivars by crude fiber content when grown in the summer (top) and in the winter (bottom).

SOIL SCIENCE

The response of Chinese cabbage grown in calcareous soils to the addition of humic materials was determined. Preliminary tests indicated that the application of 600 kg/ha of Azumin, a commercial organic fertilizer containing humic acid, increased the yield potential of Chinese cabbage by as much as 30 percent over the control. Further studies on the fertility requirements for Chinese cabbage production are under way.

AGRICULTURAL ECONOMICS

Initial studies on the economics of Chinese cabbage *(B. pekinensis)* production in Southeast Asia were limited to Taiwan. Assuming that production costs for common cabbage *(B. oleracea* var. *capitata)* are similar to those of Chinese

cabbage, the economists examined available data on the production of common cabbage in the region.

Thus, production costs were determined for Chinese cabbage in Taiwan and common cabbage in the Philippines. The major cost for winter cultivation in Taiwan was labor (40%) closely followed by fertilizer, i.e., both chemical and organic, (31%). In the Philippines, the purchase of fertilizers was more than half (52%) the total production costs.

In 1973, Chinese cabbage *(B. pekinensis)* ranked fifth among vegetable crops grown in Taiwan. This included planted area (5,335 ha), total production (75,998 tons), and total value (US$ 5,472)+. However, this crop is primarily produced during the cooler seasons. During the hot summer months of 1972, for example, the production was limited to the highlands. The supply was considerably reduced resulting in scarcity and higher prices (*Fig. 10*).

The more tropical Asian countries, e.g., Thailand and the Philippines, had the lowest yields of common cabbage *(Table 23)*. even though commercial varieties that are reasonably heat tolerant are available.

INTERNATIONAL ACTIVITIES

In 1974, seed samples of several cultivars of Chinese cabbage were sent to various countries in Southeast Asia. These included both cultivars and hybrids. They were generally heat-tolerant types for testing under the summer conditions of the recipient country.

In the heat-tolerance screening trial conducted by Mrs. Manee and her colleagues at Chiang Mai University in Thailand during the summer, six of the 10 cultivars from AVRDC yielded significantly more than the local cultivar, Thai Early. However, only Accessions 140 and 189 produced heads of good cooking quality. All the cultivars proved to be heat tolerant in this trial, as they had earlier at AVRDC.

+ NT$ 207,382 at the official exchange rate of US$ 1:NT$ 37.90.

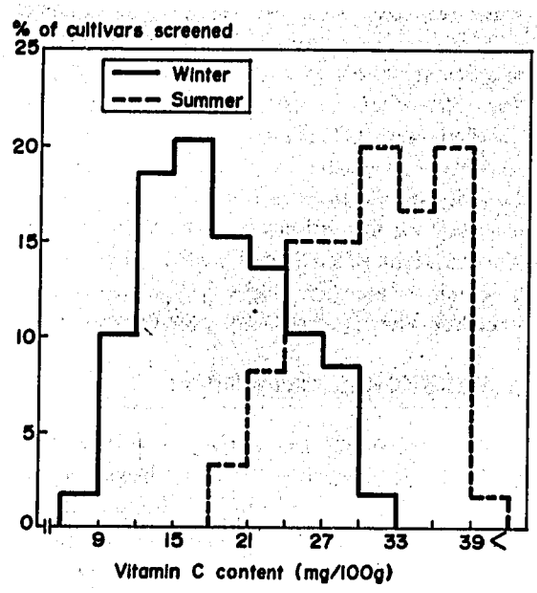


Fig. 9. Distribution of Chinese cabbage cultivars by vitamin C content when grown in the summer and in the winter.

Table 23. Common cabbage (*B. oleracea* var. *capitata*) production, area, and yields in selected Asian countries, 1972.[a]

Country	Production (1,000 tons)	Area (1,000 ha)	Yield (tons/ha)
Japan	3,019	91	33.3
World average	*15,348*	*778*	*19.7*
Taiwan, R.O.C.[b]	430[	32	13.4
Korea	900	80	11.2
Philippines	55	8	7.3
Thailand	180	32	5.6

However, from Korea, Dr. Choi, Director of the AVRDC Sub-Center, reported that most of the 48 heat-tolerant cultivars obtained from AVRDC flowered profusely in the field during their summer planting. The summer conditions in Korea require cultivars that are resistant to bolting, but possess sufficient heat tolerance to yield economically. This particular problem might be partly resolved by a cultivar such as Tropicana, which is relatively resistant to bolting, but has only moderate heat tolerance.

The distribution of segregating populations of

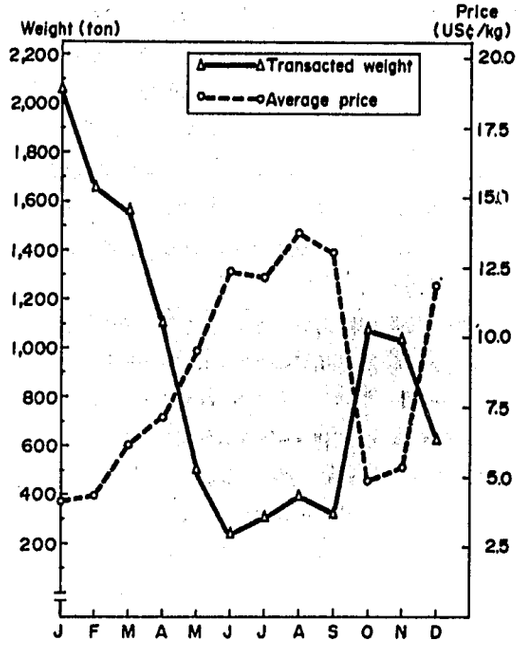


Fig. 10. Monthly transactions of headed Chinese cabbage at the Taipei City Wholesale Market (1972).

Chinese cabbage throughout Southeast Asia does not appear to be immediately feasible, because the methods for seed production from such populations must first be developed. Furthermore, facilities to carry out this operation must be present in the recipient country.

In 1974, a few segregating populations were distributed to two institutions with such facilities. These were Chiang Mai University located in the highlands of Thailand and the AVRDC Sub-Center in Suweon, Korea.

Sweet potato

More people can be fed from a hectare of sweet potato than from a hectare of rice. At AVRDC, we are developing varieties that produce roots containing high amounts of protein and β-carotene. Three hundred successful crosses were made in 1974. Thirteen selections produced computed yields greater than 20 tons/ha in about 100 days. In small experimental plots one selection had a yield of 63 tons/ha, and nine had yields of 46 tons/ha or more 145 days after planting.

Eight of these high yielding selections also ranked high in both protein and β-carotene content. Cultivars with high yield potential and early maturity are being screened under minimum input conditions. Seven selections produced computed yields of 30 tons/ha or more when grown without fertilizer, pesticides, or irrigation. Fourteen cultivars were identified with field resistance to the witches' broom disease. Varietal differences in susceptibility to sweet potato weevil infestation were also found. Experiments showed potassium to be more important in root enlargement than either nitrogen or phosphorus.

IPOMOEA SP. GERMPLASM COLLECTION:

Ipomoea batatas

Cultivars	230
Open-pollinated seed	19,300

PLANT BREEDING

THE WORLD COLLECTION. In 1974, we received 39 cultivars and breeding materials mostly from Dr. Azucena L. Carpena of the UPLB College of Agriculture in the Philippines. In June, a large seed collection of crosses and improved populations was received from Dr. S. K. Hahn of the International Institute of Tropical Agriculture (IITA) in Nigeria. Some were sown in October and the rest will be planted in 1975.

THE CROSSING PROGRAM. The breeders made 300 crosses, which produced, 3,504 seeds. In addition, 10,253 open-pollinated seeds were gathered from the nursery, whose parents had been selected for various desirable characters.

These seeds together with 2,500 from Dr. Teme Hernandez of Louisiana State University and 300 from Mr. Keun-Yong Park of the Crop Experiment Station in Korea were sown. After 11 weeks, plants that had roots with orange-colored flesh as well as vigorous and disease-free vegetative growth were selected *(Table 1)*.

With such low selection rates (1.5 to 7.3% of the population), it is probable that some desirable genotypes were lost. The more vigorous seedlings tended to crowd out the slower-growing plants. However, it is likely that the more competitive genotypes were not always the best. In future screenings, the seeds will be planted separately in pots to eliminate competition.

While the soil scientists were investigating ways to increase the efficiency of fertilizer utilization by plants, the breeders screened the sweet potato germplasm for selections that could yield well under low levels of management and that had some resistance to insect pests and diseases. Since sweet potato is mostly grown under rainfed conditions in Southeast Asia, we are seeking varieties that can withstand water stress.

Four plantings of the 480 selections noted in *Table 1* were made at AVRDC in 1974. The results for the highest yielding selections harvested at 100 to 107 days after planting are presented in *Table 2*. The data indicate that early maturing, high-yielding sweet potato cultivars can be developed for intensive cropping systems.

Some of the selections were not harvested until 139 to 144 days after planting. The results for the best selections are summarized in *Table 3*. As would be expected, the orange-fleshed selections were high in β-carotene; fortunately, they also ranked high in protein *(Table 4)*. An open-pollinated selection from Centennial contained the most protein (8%), and Selection 200-3 had the highest amount of β-carotene (15 mg/100 g). The parental cultivars that produced the highest yielding progeny are listed in *Table 5*.

In August, a yield trial was planted to evaluate the fresh market (orange-fleshed) and industrial (yellow- and white-fleshed) cultivars. The results for the highest yielding cultivars are shown in *Table 6*.

Yields varied from one or two tons/ha to those recorded in *Table 6*. The preponderance of low yields was thought to be partially due to the late maturity of the cultivars; they should have been left in the ground longer. To test this idea, four sets of 180 cultivars (5 cuttings each) were planted June 28. One set was harvested after 90 days,

Table 1. Summary of information on segregating populations; 1974.

Population	Number of		Selection rate (%)
	Seeds sown	Selections	
Cross combinations	3.504	239	6.8
Open-pollinated seeds:			
AVRDC	10,253	151	1.5
Louisiana State University	2,500	688	2.7
Crop Experiment station (Korea)	300	22	6.3
Total	16,557	480	2.9(mean)

Table 2. Selections with the highest yields when harvested 100 to 107 days after planting.

AVRDC selection no.	Pedigree	Marketable yield (tons/ha)	Yield production rate (kg/ha per day)	Flesh colo
35-1	HDK 6 / B 6708	45 a/	421	orange
030-6	Centennial (op)	41 a/	383	orange
61	Allgood / Tainung 63	32 b/	320	orange
010-2	HDK 8 (op)	29 a/ & 24 b/	271-240	yellow
01-2	BNAS- white (op)	28 a/	262	yellow
128	PI 313545 / Acadian	24 b/	240	orange
259-4	HM 16 / B 6733	24 b/+	240	orange
294-1	Polycross 2	23 b/+	230	orange
2-5	BNAS-white / HDK 12	23 b/	230	orange
37-1	HDK 6 / Tainung 63	23 b/	230	orange
31-3	Rose Centenial (op)	22 a/	206	yellow
28-1	HDK 8 / OK-9-3	21 a/	196	orange
021-1	Hom Kao (op)	20 b/	200	yellow

a/ Planted May 23; harvested Sept. 7 (107 days); yield computed from that of a single hill; the check cultivars failed to develop enlarged roots.

b/ Planted August 9; harvested Nov. 17 (100 days); yield computed from that of 3 to 5 hills; 6 check cultivars had a mean computed yield of only 3 tons/ha.

+ Also ranked high in yield when harvested at 139 to 144 days.

(op) – open pollinated

and the other sets were harvested at 120, 140, and 160 days after planting.

After 90 days, only two percent of the cultivars produced enlarged roots, ranging from 2.0 to 2.8 tons/ha (*Fig. 1*). About 14 percent matured in the 120-day group with a yield range of 1 to 14 tons/ha. The maximum yield of 20 tons/ha was attained at 140 days. Leaving them in the ground longer than 140 days did not increase yields any further.

The generally low yield levels in this experiment can be attributed largely to the heavy rainfall and the intermittent flooding of the experimental field. The experiment proved that at least a 140-day growth period is needed for maximum yield and that during the rainy season respectable yields could not be obtained in 90 days with these cultivars.

The best selections were grown under low-level management conditions (no fertilizer, no irrigation, no pesticides). The best seven yields ranged from 30 to 39 tons/ha when harvested at 127 days (*Table 7*). Natural precipitation totaled 162 mm for the entire cropping season, whereas from 530 to 600 mm of precipitation is considered to be optimum. This supports the contention that sweet potato can produce relatively large amount of food under low-level management conditions.

An experiment was conducted to determine the environmental constraints (i.e., spacing, season, fertilizer application) on root yield and protein content of roots and tips, using two sweet potato cultivars (Red Tuber Tail, Puerto Rico). Three row spacings (20, 30, 40 cm) and three fertilizer applications (no nitrogen, basal, split) were used. Each entry occupied a row, five meters long and one meter wide. The split-split-plot design was used with fertilizer as the main plot, spacing as the sub plot, and variety as the sub-sub

Table 3. Selections with the highest yields when harvested 139 to 144 days after planting.

AVRDC selection no.	Pedigree	Marketable yield (tons/ha)	Yield production rate (kg/ha per day)	Flesh color
209-3	B 6708 / OK-0-3	63 a/	453	orange
294-1	Polycross 2	59 b/	410	orange
259-4	HM 16 / B 6733	57 b/+	396	orange
200-3	B 6708 / Centennial	54 a/	375	orange
41	Yod Daeng / Old Goldrush	53 b/	368	yellow
204-2	B 6708 / Hopi	51 b/	354	orange
016-1	HDK 12 (op)	50 b/	347	orange
272-9	Red Tuber Tail / Allgood	46 b/	319	yellow
02-1	BNAS-red (op)	46 b/	319	yellow

a/ Planted May 23; harvested Oct. 9 (139 days); yield computed from that of five hills.

b/ Planted August 9; harvested Dec. 31(144 days); yield computed from that of 3 to 5 hills; six check cultivars had a mean computed yield of 17 tons/ha.

\+ Also ranked high in yield when harvested at 100 days.
(op) – open pollinated

Table 4. Composition of the roots of some high yielding, orange-fleshed selections.

AVRDC selection no.	Pedigree	Protein (% dry wt)	β-carotene (mg/100g of fresh wt)	Starch (%)
030-6	Centennial (op)	8	12	58
200-3	B 6708 / Centennial	7	15	53
35-1	HDK 6 / B 6708	7	10	55
61	Allgood / Tainung 63	6	13	60
37-1	HDK 6 / Tainung 63	6	2	50
010-2	HDK 8 (op)	6	5	56
209-3	B 6708 / OK-9-3	5	11	52
128	PI 315345 / Acadian	5	9	50

(op) – open pollinated

plot. The experiment was replicated four times.

The yield was influenced by both spacing and variety *(Table 8)*. Both the 20- and 30-cm spacings gave higher yields than the 40-cm spacing, and Red Tuber Tail was definitely a higher yielder than Puerto Rico.

The significant mean squares for the interactions of variety and spacing (0.77**) and variety and fertilizer (2.02**) on the protein content of the tips suggest that caution should be exercised in interpreting protein analyses, because they can be influenced by both spacing and fertilizer.

Although the sweet potato program is still in its initial stages, we conducted two organoleptic evaluations to examine the acceptability of some of our best selections and to gain experience in conducting such evaluations.

At AVRDC, 20 selections plus three check

Table 5. The parental cultivars and genetic lines used in the AVRDC sweet potato hybridization program that produced the highest yielding progeny, 1974.

AVRDC acc. no.	Varietal name	Origin	No. of cross combinations	Flesh color
10	HDK 8	Laos	30	orange
16	HDK 12	Laos	12	orange
1	BNAS-white	Philippines	4	yellow
2	BNAS-red	Philippines	5	yellow
171	Tainung 63	Taiwan	18	orange
152	Red Tuber Tail	Taiwan	8	yellow
19	Yod Daeng	Thailand	8	white
21	Hom Kao	Thailand	6	white
122	B 6708	U.S.A.	33	orange
30	Centennial	U.S.A.	31	orange
25	Acadian	U.S.A.	29	orange
26	Allgood	U.S.A.	25	orange
124	B 6733	U.S.A.	13	orange
61	Hopi	U.S.A.	14	orange
151	OK-9-3	U.S.A.	13	orange

a/ The cultivars from Southeast Asia were used because they are already adapted to the region and acceptable locally. The majority of the crosses were between the Asian and the U.S. cultivars; the later generally yield well and are high in both protein and β-carotene content.

cultivars were evaluated by 56 participants, who were mostly Asians. Each entry consisted of two to three roots and was boiled separately for 25 minutes. The boiled roots were sliced and offered to the panel members, who sampled them and recorded their preferences. Afterwards, each taster was requested to rank the best five *(Table 9)*.

To get an idea of the relative preference of the taste panel, each ranking was multipled by 5, 4, 3, 2, and 1 in the descending order of preference. For example, if all of the 56 tasters ranked Selection 209-2 as 1, then it would have a perfect score 280 (56 x 5 = 280).

Selection 209-2 was ranked first by 15 of the tasters. This selection (B 6708 / OK 9-3) is orange-fleshed and had a computed yield of 26 tons/ha under minimum input conditions.

In August, the breeders planted 25 selections at the UPLB La Granja Research and Training Station (La Carlota City, Philippines). The selec-

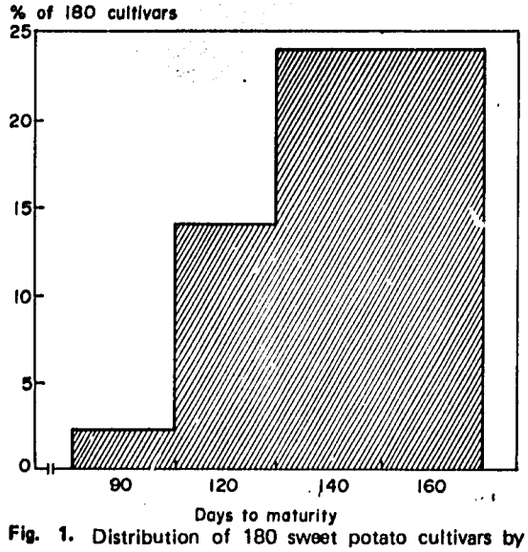


Fig. 1. Distribution of 180 sweet potato cultivars by number of days to maturity.

Table 6. Marketable yield and relative weevil (*Cylas* sp) resistance of the highest yielding sweet potato cultivars. a/

Fresh market use (orange-fleshed)				Industrial use (yellow and white flesh)			
AVRDC acc. no.	Varietal name	Marketable yield b/ (tons/ha)	Weevil resistance index c/	AVRDC acc. no.	Varietal name	Marketable Yield (tons/ha)	Weevil resistance index c/
36	Copper Skin Goldrush	24		110	PI 344138	22	S
29	Carogold	22	S	114	PI 344122	20	S
26	Allgood	20		89	PI 308196	19	MS
134	HM 606	19	S	52	PI 153908	19	
169	Tainung 62	17	S	8	Daja 380	17	
122	B 6708	15	MS	162	Tainung 53	16	MR
				122	PI 344120	16	R

a/ Planted August 9; harvested after 140 days.
b/ Means of three replications.
c/ See Entomology section for an explanation of weevil resistance index.

The results of a sweet potato yield trial are being recorded in this experimental field at AVRDC

Table 7. Performance of the best seven sweet potato selections under minimum input conditions. a/

AVRDC selection no.	Pedigree	Marketable yield b/ (tons/ha)	Flesh color	Weevil infestation c/
466	K 63002-6	39	white	mild
0157-3	Tainung 27 (op)	37	orange	mild
272-6	Red Tuber Tail / Allgood	37	orange	mild
407	L9-192-17	35	orange	mild
0122-2	B 6708 (op)	33	orange	moderate
39-1	Yod Daeng / Acadian	30	yellow	severe
2-5	HM 16 / Acadian	30	orange	moderate

a/ Planted Sept. 18; harvested Jan. 13, 1975 (117 days); 3 check cultivars ranged in yield from 0 to 17 tons/ha. No fertilizer, pesticides, or irrigation were supplied, and natural precipitation totaled 162 mm.

b/ Based on yield from 4 to 5 hills.

c/ Field observation.

Table 8. Effect of spacing on the yield of two cultivars of sweet potato.

Spacing b/			Variety c/		
	Row spacing	Yield (tons/ha)		Varietal name	Yield (tons/ha)
	20	9.6		Red Tuber Tail	12.2
	30	9.4		Puerto Rico	6.0
	40	8.2			
HSD	.05	1.1	LSD	.05	1.1
	.01	1.5		.01	1.6
CV (%)		11.3	CV (%)		29.8

a/ Data are means of 4 replications.

b/ Mean square of root yield (tons/ha) was 12.66 and highly significant at 1% level.

c/ Mean squares of root yield (tons/ha), root protein, and protein in the tips were 691.28, 170.17, and 2.79, respectively, and all were highly significant at the 1% level.

tions were harvested in December, 104 days later. We grated and dried a 20-gram sample of each selection for protein, starch, and sugar content analysis at AVRDC *(Table 10)*. The higher yield of BNAS over Selection 140 was attributed to the fact that fresher cuttings were used as planting material in the case of BNAS.

The nine highest yielding selections and two check cultivars were organoleptically evaluated at La Granja. The boiled samples were sliced, tasted, and rated for preference. Our Selection 140 received the highest rating by this Filipino taste panel *(see Table 10)*.

The breeders initiated a program to develop varieties with more palatable and nutritious greens. Earlier studies on the human consumption of sweet potato tips+ revealed that acceptable tips should be tender, without hairs, and somewhat purple in color. The purplish tips add color to the meal, and it is common to see bundles of sweet potato tips with a tinge of purple for sale in the Filipino market.

The distribution of 177 cultivars by stem and leaf characters is shown in *Table 11*. The color of the stem, leaves, and veins contribute to the general appearance of the tips.

In examining 451 selections, the breeders found 154 without hairs, 144 with purple leaves, and 108 whose leaves were green with purplee edges. Thus, a large number of both cultivars and selections are available from which selections can be made for palatability, tenderness, flavor, and nutritional quality.

The same selections plus 177 cultivars were examined to identify those that had more young leaves, with less than a 1-cm petiole. Ten samples per selection were measured. Leaves with

+ The term 'tip' refers to that portion of the sweet potato top used for human consumption. The term 'top', of course, is used to denote the entire above-ground part of the plant.

Table 9. The most acceptable selections from an organoleptic evaluation of sweet potato roots. a/

AVRDC selection no.	Pedigree	Preference score (0-280)	Preference %	Flesh color
209-2	B 6708 / OK-9-13	101	34	orange
377-2	LO 3-77	72	24	orange
026-3	Allgood (op)	66	24	orange
290-1	Centennial / Allgood	63	23	orange
39-1	Yod Daeng / Acadian	61	22	orange
196-8	B 6708 / HDK 8	60	21	orange
196-1	B 6708 / HDK 8	54	19	orange

a/ Planted Sept. 18; harvested Jan. 13, 1975 (117 days); from the minimum input trial (see *Table 7*).

Table 10. Preference scores, nutritional components, and yields for nine AVRDC sweet potato selections compared with two popular cultivars in the Philippines.

AVRDC selection no.	Pedigree or varietal name	Preference score (1-145)	Preference (%)	Protein (%)	Starch (%)	Sugar (%)	Flesh color	Yield a/ (tons/ha)
140	Tainung 57 / Hopi	82	57	6	79	13	orange	22
	Karja b/	61	42	5	72	10	yellow	21
203	B 6708 / Tainung 61	54	37	3	83	9	orange	11
	BNAS b/	47	32	4	77	10	yellow	28
26-1	Sweet Potato 45 / Allgood	46	32	7	58	12	orange	6
122-4	Southern Queen / OK-3-106	39	27	6	52	15	orange	4
137-2	Tainung 57 / Acadian	23	16	5	82	11	orange	7
225-2	HM 16 / Julian	21	15	3	71	15	orange	7
2-1	BNAS–white / HDK 12	19	13	3	67	13	orange	3
150-1	Georgia Red / Acadian	13	9	3	72	13	purplish-orange	9
01-1	BNAS–white (op)	1	1	1	65	20	orange	4

a/ Planted Aug. 21 UPLB La Granja Research and Training Station in La Carlota City (Philippines); harvested Dec. 4; yield computed from that of 4 to 5 hills.

b/ Cultivar popular in the Philippines.

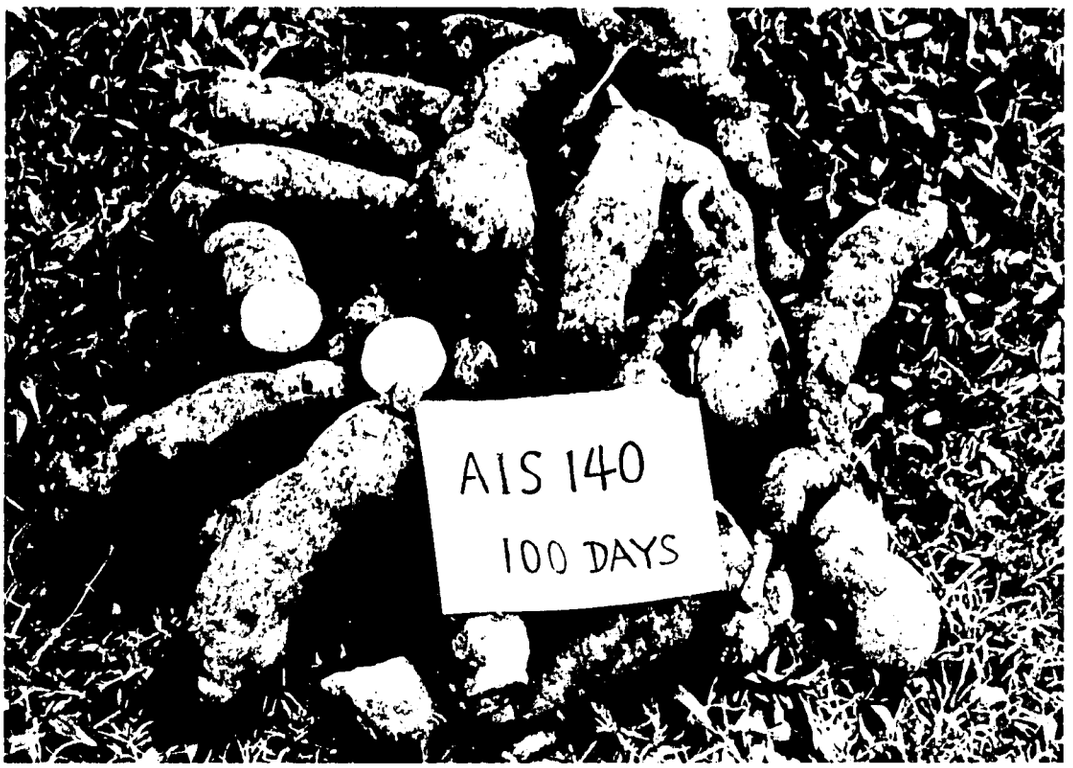
more than 1-cm petioles are tougher. Usually, only the 10-cm tips are generally used as greens, and those having short petioles are preferred *(Fig. 2)*.

The results of the study are shown graphically in *Figure 3*. The number of leaves per 10-cm tip ranged from 2 to 10, and the average tip weight varied from 2 to 14 grams. Naturally, we are interested in both large and tender tips.

In the summer (July 30), an experiment to evaluate the yield of the tips of three cultivars under four levels of nitrogen (0, 60, 120, 180 kg/ha) and two topping frequencies (once and twice a week) was conducted. Fertilizer at the rate of 20 kg/ha N, 35 kg/ha P, and 50 kg/ha K was applied three weeks after planting and additional nitrogen was applied periodically during the experiment. A split-split-plot design with fertilizer as the main plot, topping as the sub plot, and variety as the sub-sub plot was used. The treatments were replicated three times.

Harvesting of 15-cm long tips was initiated six weeks after planting. Five and eight harvestings were made for the twice-a-week and once-a-week toppings, respectively. Our data indicated that nitrogen application and frequency of harvesting

Fig. 2. Drawings depicting the type of sweet potato tips preferred as greens.



This sweet potato selection (AIS 140) produced high yields in two Filipino yield trials and was the most preferred entry in an organoleptic test in the Philippines.

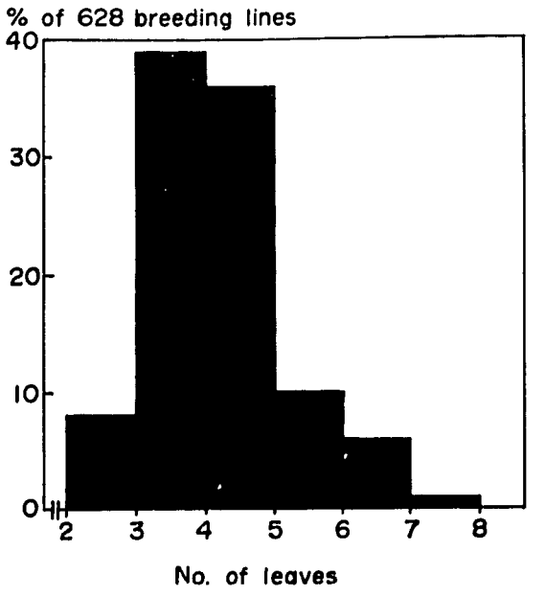


Fig. 3. Distribution of both sweet potato cultivars and selections by number of leaves per 10-cm tip.

did not influence the yield or protein content of the tips; therefore, the data were pooled and the results are presented in *Table 12*. Both BNAS-white, a broad-leafed cultivar, and HDK 8, a medium-leafed cultivar, had higher tip yields than PI 324889, a fine-leafed cultivar.

PLANT PATHOLOGY

In 1974, the pathologists continued to screen for resistance to witches' broom, a mycoplasma-like disease of sweet potato transmitted by leafhoppers *(Orosius ryukyuensis)*. An epidemiological survey was also conducted.

Plants infected with witches' broom usually produced bushy branches or elongated auxillary buds with small leaves and green flowers. The enlarged roots are fewer and of poorer quality. It is difficult to control this disease by chemicals, only tetracycline and its derivatives can inhibit

Table 11. Stem and leaf color and morphological characteristics of leaves of 177 sweet potato accessions.

Color	Stems	Veins	Leaves
	(no. of accessions)		
Purple	24	56	2
Greenish-purple	76	5	52+
Green	77	116	123
	177	177	177
Hairs			
Without			57
With			120
			177
Leaf shape (no. of points/leaf)			
One (entire)			123
Three (trifoliate)			21
Five (palmate)			23
			177

+ Green with purple edges.

Table 12. Comparison of yield and protein content of sweet potato tips between 3 cultivars with different leaf types.

Varietal name	Type of leaf	Tip yield[a] (tons/ha)	Protein content[a] (%)
BNAS-white	broad	17.7	25.3
HDK 8	medium	15.9	24.6
PI 324889	fine	13.9	23.4
HSD .05		1.8	
HSD .01		2.4	
CV (%)		17.24	

[a] Means of replications were not significant (arcsin transformation was used to normalize the data for statistical analysis.

the development of witches' broom.

Screening for resistance to witches' broom was conducted in cooperation with Mr. I-Lang Yang of the Chiayi Agricultural Experiment Station (Taiwan) who has a large varietal collection of sweet potato. Trials were established at Chidin in northern Taiwan and at Nanliao and Tungweh on Penghu Island. Sweet potato cuttings of 365 cultivars were planted in early June. Of these 365 cultivars, 148 were planted at all three locations, 153 at both Chidin and Nanliao, and 64 at only one site. Infected cuttings were planted in every other row of the screening fields.

Symptoms of witches' broom were evident in late July, August, and September. However, no new symptoms were observed in October as the temperatures became cooler. Of the 148 cultivars screened at all three sites, 14 did not show any symptoms of witches' broom and were considered to be field resistant *(Table 13)*. Because natural infection is controlled by the host-vector relationship, infectivity, and amount of inoculum available;

Table 13. List of sweet potato cultivars that are field resistant to witches' broom.[a]

AVRDC acc. no.	Varietal name	Origin
7	Karja 381J	Indonesia
8	Daja 380	Indonesia
10	HDK 8	Laos
12	HKD 3	Laos
20	Yod Kao	Thailand
73	PI 208029	U. S. A.
90	PI 308201	U. S. A.
104	PI 318856	U. S. A.
115	PI 344123	U.S. A.
117	PI 344129	U. S. A.
119	PI 344138	U. S. A.
132	HM 288	U. S. A.
151	OK-9-3	U. S. A.
172	American Yellow Skin	Taiwan

[a] 40 plants of each cultivar were planted at 3 locations; Chidin, Nanliao, and Tungweh in early June. 365 cultivars and breeding lines were screened. The 14 cultivars listed had no infection.

further testing of these field-resistant cultivars is necessary. Graft-inoculation and vector transmission will be used to ensure their resistance.

The inoculum sources, vectors, and host plants were also studied at the three screening sites. Note in *Table 14* that the percentage of infected plants in the nurseries (source of cuttings) were (55 to 92%) in Nanliao and Tungweh and lower (20

to 40%) in Chidin. The nurseries in Chidin were replanted more frequently. In the Chidin area, the host plants *(Ipomoea sp.)* were abundant. The spread of this disease might be prevented by eradicating diseased sweet potatoes and other host plants and planting only healthy cuttings.

Table 14. Survey results on source of inoculum, vector, and host plants of sweet potato witches' broom.

Location	Percentage of infected plants		Number of leafhoppers[b]	Host plants
	Nurseries[a]	Field		
	------%-------			
Chidin	22to35	20to35	27	*Ipomoea sp.*
Nanliao	55to85	26to45	32	
Tungweh	60to92	28to50	30	

[a] Surveys of the nurseries were made in June, and the fields were surveyed in September.

[b] Leafhoppers were caught by swinging an insect net, 100 passes per count.

ENTOMOLOGY

The most serious pest of sweet potato in Southeast Asia is the sweet potato weevil, *Cylas formicarius.* Other insect pests of occasional importance include a leaf folder, *Brachmia macroscopa,* leaf miners of the genus *Bedellia,* and tetranychid mites. Elaterid wireworms, chrysmelid rootworms, and flea beetles *(Phyllotreta* sp.) attack the sweet potato in other countries, but throughout much of the world where sweet potato is a major crop, the weevil is generally the most damaging pest.

One practical method of controlling the weevil is through crop rotation. If no heavy infestation sources are in the immediate vicinity, it usually takes at least one growing season for populations to build up. Thus, earlier maturing varieties might offer a way of reducing weevil attack where rotation is practiced.

Soil insecticides can also be used to control the weevil. Broad spectrum, long-lasting residual compounds such as hepatchlor and dieldrin are effective, but current concern over residue problems has caused many countries to pass legislation prohibiting their use.

Because of the declining use of chlorinated hydrocarbon insecticides for the control of the weevil, organophosphate and carbamate soil insecticides are being used more frequently. However, they are more costly than the chlorinated hydrocarbons, more hazardous to handle in concentrated forms, and more quickly inactivated in the soil.

Sweet potato is often grown because it requires minimal capital inputs. A small farner cannot usually afford to use costly insecticides. Thus, the identification and development of varietal resistance offers a practical solution. Even if immunity is not achieved, relative resistance is highly desirable if it will result in varieties with lower rates of infestation.

Field screening for varietal resistance to the sweet potato weevil began at AVRDC in 1974. The cultivars were planted on July 23 and subjected to naturally occurring infestations. The amount of infestation was determined by the mean number of weevils per 30 cm of stem for five samples of each cultivar, the yields of 5-m^2 plots (approx 1/2000 ha); and the total number of weevil larvae, pupae, and adults per one kilogram of roots.

Relative resistance to weevil infestation was measured as a function of the mean infestation of the entire population being screened. Resistance (R) was defined as infestation of less than the mean ($\bar{x}$) divided by four ($\bar{x}/4$); moderate resistance (MR), as between $\bar{x}/4$ and $\bar{x}/3$; moderate susceptibility (MS), as between $\bar{x}/3$ and $\bar{x}/2$; and susceptibility (S) was defined as infestation higher than $\bar{x}/2$.

The mean infestation rate for the screened cultivars was 22.5 weevils per kilogram of root, and the infestation level below which the cultivars were considered to be resistant was 5.62 weevils per kilogram or $\bar{x}/4$. Thirty of the 90 cultivars examined were resistant under this measure. The most promising of these resistant cultivars are listed in *Table 15.* The number of weevils for five 30-cm stem samples ranged from 0 to 16 for the 90 cultivars, with a mean of 3.4 weevils per stem.

The yield varied considerably from less than 0.2 ton/ha to more than 20 tons/ha. The mean yield was 5.6 tons/ha. The entomologists found

that as the yield increased to 6 tons/ha, the number of weevils also increased (*Fig. 4*).

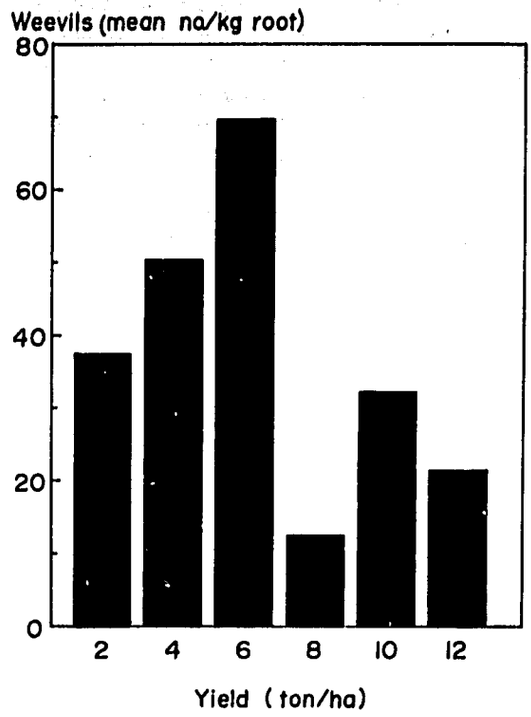


Fig. 4. Variation in sweet potato weevil (*Cylas formicarius*) populations by yield.

However, in the yield range from 6 to 12 tons/ha, the mean number of weevils declined. The apparent increase in infestation corresponding to yield increases up to 6 tons/ha might have been because this yield level offered the weevils an optimum amount of food and habitat. On the other hand, the higher yielding cultivars (more than 6 tons/ha) possibly provided more food than could be effectively consumed by the existing populations of weevils at the time of evaluation.

Additional replicated field experiments are currently in progress for the verification of resistance and to identify additional resistant lines. Studies of varietal resistance to weevil infestation under storage conditions have been initiated.

Because different insect species, biotypes, or speciation can be expected in geographically isolated areas, locally identified resistant cultivars will be field-screened in various Southeast Asian countries.

AGRICULTURAL CHEMISTRY

One of our objectives is to improve the protein and β-carotene content of sweet potato roots. The variability of these two nutrients in our varietal collection was demonstrated in 1973(*72-73 Annual Report*). Comparisons made between the same cultivars planted in the spring and in the summer determined that both protein and β-carotene contents were reasonably stable.

The initial cultivars selected by the breeders were analyzed for dry matter, protein, starch, sugar, and β-carotene (*Figs. 5 to 9*). Note that there was a wide range for each component among these cultivars.

The nutritional components were also analyzed at different growth stages. The cultivar Tainung 63 was planted in the field during the fall season (*Table 16*). The starch to sugar ratio sometimes varied, but the total carbohydrate content (starch

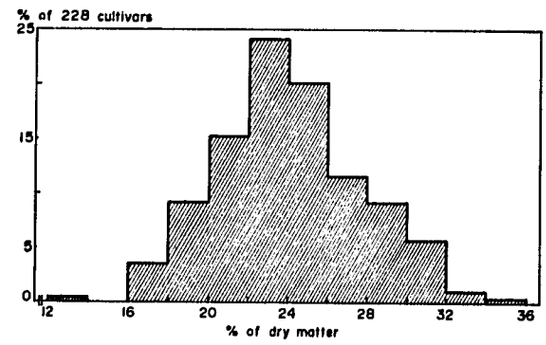


Fig. 5. Distribution of 228 sweet potato cultivars by dry matter content.

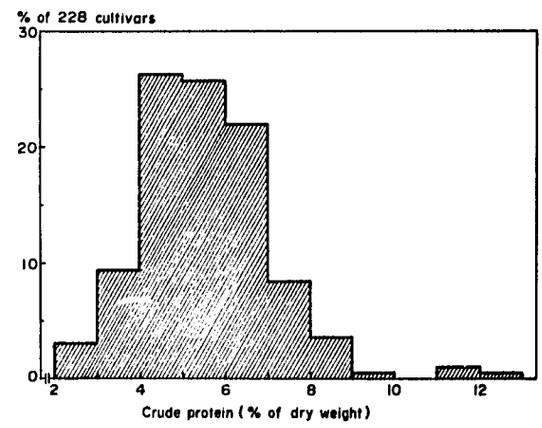


Fig. 6. Distribution of 228 sweet potato cultivars by crude protein content (N x 6.25).

Table 15. List of resistant cultivars with the lowest infestations of sweet potato weevil, *Cylas formicarius*. [a-c]

AVRDC acc. no.	Varietal name	No. of weevils per kg of root	Total yield [d] (tons/ha)	Mean no. of weevils per 30 cm of stem	Damage rating [e]
82	PI 288621	0	5.9	5	0.7
163	Tainung 54	0	5.4	5	0.3
127	HM 16	0	3.8	3	1.3
93	PI 315342	0	2.2	2	0
116	PI 344124	0	1.6	2	1.0
125	B 7078	0	1.6	1	0.6
159	Tainung 44	0	1.4	4	1.0
37	Heartagold	0	1.2	3	1.0
112	PI 344120	0	1.2	4	0
113	PI 343721	0	1.2	3	0.6
172	American Yellow Skin	0	1.0	4	0
138	OK-8-20	0.6	9.4	1	1.2
167	Tainung 60	1.0	17.2	2	1.7
141	OK-8-29	1.6	12.6	1	1.3
115	PI 344123	2.6	4.6	4	1.3

[a] Planted July 23 and harvested Jan. 14, 1975.
[b] 90 cultivars screened; 30 rated as relatively resistant to the sweet potato weevil.
[c] The relative weevil resistance index for this screening was as follows:
The mean ($\bar{x}$) infestation rate was 22.5 weevils/kg of root.
Thus; $R = \leq \bar{X}/4$ or ≤ 5.62
$MR = \bar{X}/4 < \bar{X}/3$ or 5.62 to 7.50
$MS = \bar{X}/3 < \bar{X}/2$ or 7.50 to 11.25
$S = > \bar{X}/2$ or > 11.25
[d] Yield computed from that of a 5-m^2 plot.
[e] Damage rating determined as follows:
for each adult present in roots = 4
for each pupae present in roots = 3
for each larvae present in roots = 2
for only damage without insect = 1
This sum was divided by the number of roots to give the damage rating.

+ sugar) remained fairly constant through the various growth stages.

Sweet potato tips from the same trials were analyzed for their protein content. No significant correlation was observed between the protein (N x 6.25) contents of the roots and the tips (r = 0.2775). This indicates the possiblity of producing lines containing high protein in both tips and roots. It is also possible that high variability in total nitrogen absorption exists among the different varieties.

The chemists conducted a nitrogen-fractionation experiment to determine the forms of nitrogen present in sweet potato roots. The Bernstein method was used to determine the fraction of true protein nitrogen content in the roots. The true protein content (expressed as a % of crude protein) among 10 sweet potato selections varied from 62 to 84 percent *(Fig. 10)*. The Udy-dye-binding method was applied to these selections, and a high correlation coefficient between the Udy reading and true protein content

was obtained (r = -0.9828). This method was then used to analyze the true protein content of sweet potato roots.

The distribution of the protein, starch, sugar, and moisture contents of the sweet potato root were also investigated in six selections. The sweet potato root samples were separated into four layers (inner to outer). Although there were some difference among layers, most of the selections had a higher moisture content in the outer layers than in the core. The distribution of protein content of two sweet potato roots (Selection 040-6 with light yellow flesh and Selection 200-2 with orange flesh) is shown in *Figure 11.*

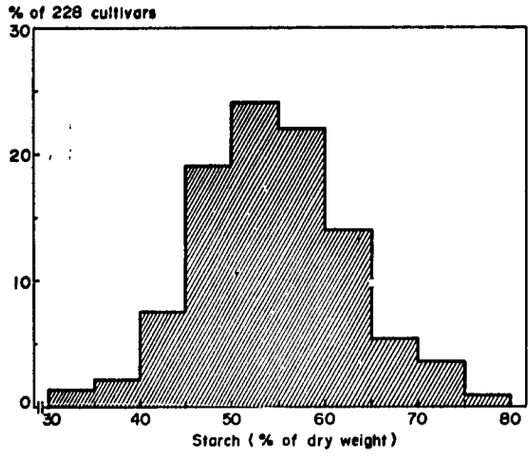


Fig. 7. Distribution of 228 sweet potato cultivars by starch content.

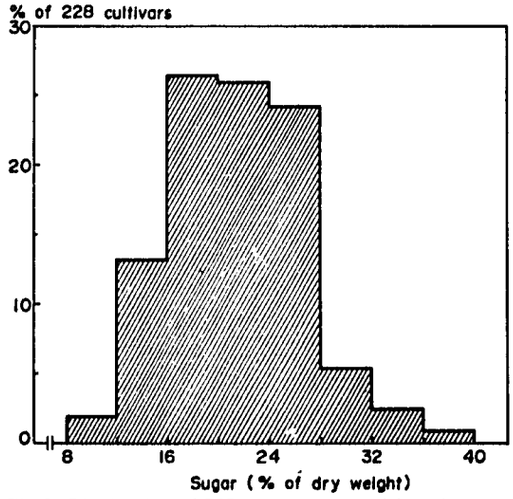


Fig. 8. Distribution of 228 sweet potato cultivars by sugar content.

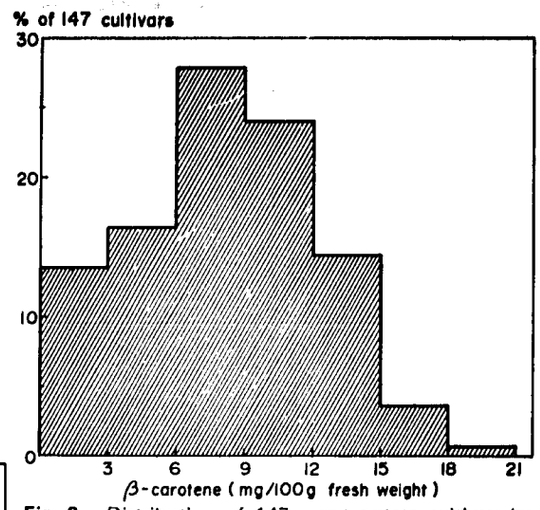


Fig. 9. Distribution of 147 sweet potato cultivars by β-carotene content.

Table 16. The nutritional components of sweet potato measured at two growth stages. a/

Nutritional component	Growth stages	
	62 days b/	117 days b/
Dry matter content (% at 100°C)	21	29
Crude protein (% dry wt)	9	7
Starch (% dry wt)	59	67
Sugar (% dry wt)	19	13
Starch (as % of sugar)	3	5
Total carbohydrates (% dry wt)	78	80
β-carotene (mg/100 g at fresh wt)	9	15

a/ The cultivar Tainung 63 was planted during the fall season.

b/ Days after planting.

Note that the protein content is highest at the stem end in both cultivars. A similar experiment determined that the β-carotene content was also higher in the stem end of the sweet potato root.

The relationship between protein content and dry matter yield was studied in a yield trial of 17 cultivars. The yield at 140 days after planting and the protein content of these cultivars are

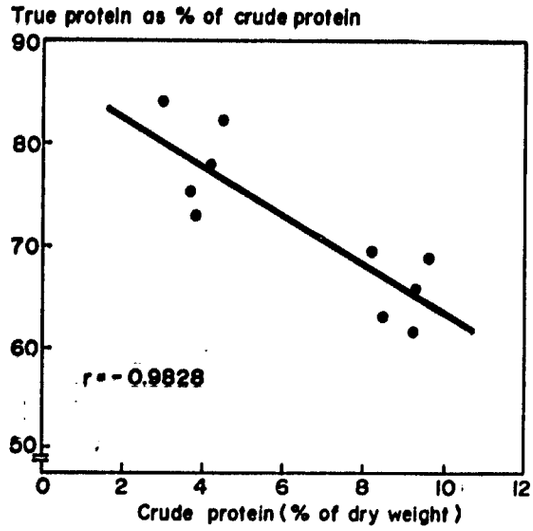


Fig. 10. Correlation between the true protein (expressed as a % of crude protein) and crude protein contents of 10 sweet potato selections.

plotted in *Figure 12.* A very low correlation was found between the dry matter yield and the protein content. Therefore, plant breeders should have no difficulty in developing high protein varieties that yield well.

SOIL SCIENCE

Sweet potato requires more potassium than nitrogen or phosphorus. For example, to produce 30 tons/ha of top and 22 tons/ha of roots; 80 kg/ha N, 29 kg/ha P, and 185 kg/ha K must be supplied. Our studies determined that even when excessive top growth did not occur, the requirements were basically the same.

Although the sweet potato requires a high quantity of K, the plant is not able to efficiently absorb potassium from the soil. Our sweet potato germplasm collection will be screened to identify cultivars that are able to absorb mineral potassium more readily. Meanwhile, the concentration of the potassium ion in the soil must be adequately maintained if high yields are to be obtained.

It is also important to maintain a high concentration of potassium in the leaves for a high rate of photosynthesis. The soil scientists observed that the best root enlargement occurred when the potassium to nitrogen ratio was the highest.

The sweet potato has little difficulty in obtaining sufficient nitrogen from the soil, especially when compost is used. In addition, the application of compost (more than 10 tons/ha) can often increase the yield by more than 30 percent because the potassium in the compost is not fixed. The amount of N should be less than one-third the amount of K to avoid excessive vine growth.

AGRICULTURAL ECONOMICS

We have only initiated our studies into the economic importance of sweet potato in Southeast Asia. Because the crop is bound to play an increasing role in food production in Asia, it will receive considerable attention in the future. Data on production, area, and yields for various Asian countries are presented in *Table 17.*

INTERNATIONAL ACTIVITIES

The testing of AVRDC sweet potato selections in the Philippines and Thailand was accomplished through scientist-to-scientist contacts. Generally 10 severely pruned cuttings of each selection are handcarried to the various cooperators. Asexually

Table 17. Production, area, and yields of sweet potato *(Ipomoea batatas)* and yams *(Dioscorea rotundata)* in selected Asian countries; 1972. a/

Country	Production (1,000 tons)	Area (1,000 ha)	Yield (tons/ha)
Japan	2,107	97	21.8
Korea	1,877	110	17.1
Malaysia (Western)	72	5	16.0
Taiwan, R.O.C. b/	3,391	210	13.9
World average	*124,903*	*14,950*	*8.3*
India	1,550	215	7.2
Thailand	270	42	6.4
Malyasia (Sabah)	5	1	5.9
Indonesia	1,944	350	5.6
Philippines	680	129	5.3

a/ Adapted from *The FAO Production Yearbook,* 1972 (Vol. 26, Rome). All estimates by FAO unless noted otherwise.

b/ *Taiwan Agricultural Yearbook,* 1973 Edition. Provincial Department of Agriculture and Forestry, Taiwan. July 1973.

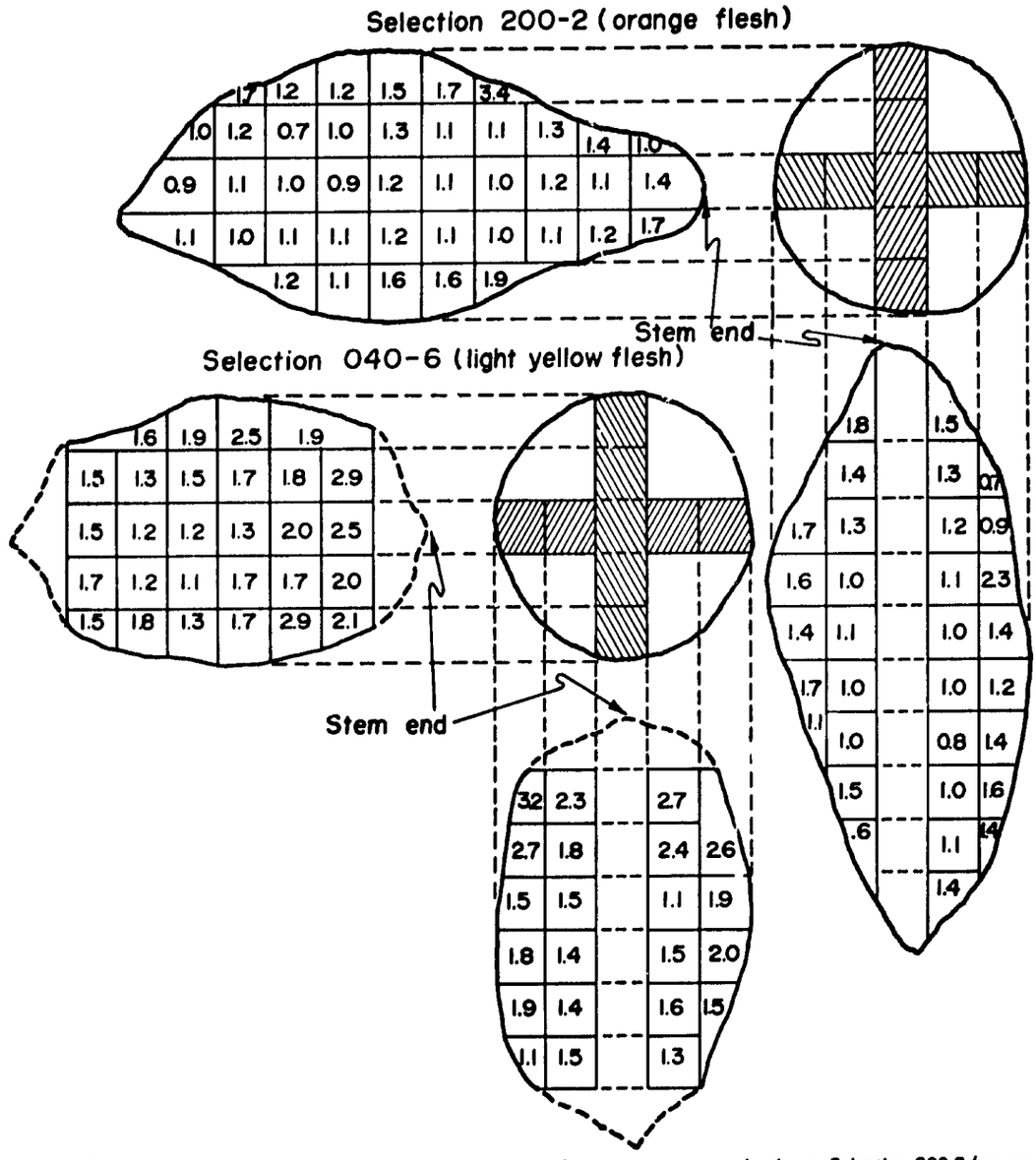


Fig. 11. Distribution of protein content throughout the roots of two sweet potato selections: Selection 200-2 (orange flesh) and Selection 040-6 (light yellow flesh).

propagated materials introduced in this manner can give a high percentage of survival for about a week. Compared with freshly cut vines, however, their rate of recovery is much slower.

In Thailand, our cooperator is Mrs. Sutevee Sukprakarn of Kasetsart University, who grew 20 selections made during the summer season at AVRDC.

In the Philippines, we are cooperating with two institutions: The University of the Philippines at Los Baños (UPLB) La Granja Research and Training Station in La Carlota City and the Multiple Cropping Program of the International Rice Research Institute (IRRI). Mr. Servillano R. Gumasing and Mr. Fransisco C. Cruz of UPLB and IRRI, respectively, are the primary cooperating

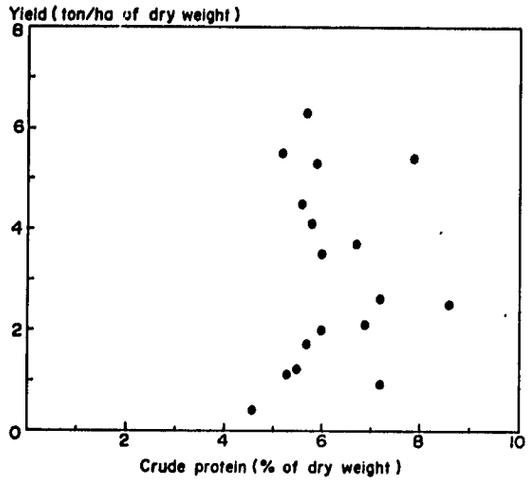
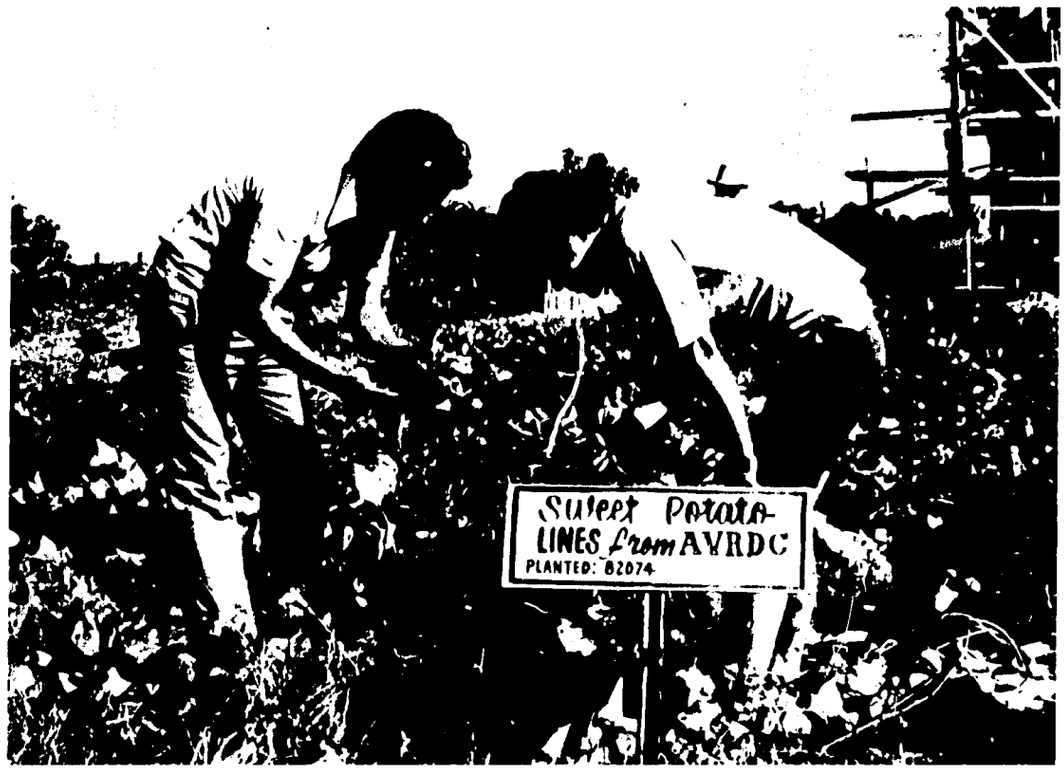


Fig. 12. Relationship between the yield and crude protein content of 17 sweet potato cultivars.

scientists.

Thirty selections were taken to IRRI in September. These, together with six check cultivars, were planted September 11 and harvested 89 days later. The yields ranged from 0 to 12 tons/ha and our Selection 140 had the highest yield. Of the check cultivars, which included BNAS, Bulacan, Centennial Julian, Ceylon, etc.; only Centennial yielded more than three tons. Another yield trial of 36 entries was planted at IRRI for digging in March 1975.

Another 50 selections were planted at UPLB La Granja. In addition, the original 30 selections grown at IRRI were also planted at La Granja, and the initial 25 selections planted at La Granja in August were later planted at IRRI. Thus, UPLB La Granja has about 105 of our selections and IRRI has 55.



AVRDC's sweet potato lines were planted at the UPLB La Granja Research and Training Station (La Carlota City, Philippines). Mr. Servillano Gumasing of UPLB and Mr. Soh-Har Wong of AVRDC examine their performance.

White potato

The primary objective of AVRDC's white potato improvement program continued to be the development of varieties that will yield well in the humid lowland tropics. Thirty cultivars produced marketable tubers under high temperatures in summer trials.

One selection produced, in a single hill, eight marketable tubers with a total weight of 400 grams. New populations were received as true seed from other breeding programs and are being transformed into clones for future screening.

SOLANUM SP. GERMPLASM COLLECTION

Solanum tuberosum		
	Cultivated tetraploids	1,282
	wild diploids	123
	derived haploids	9
Solanum andigena		58
Solanum phureja		21
Solanum stenotomum		4

PLANT BREEDING

THE WORLD COLLECTION. Nineteen accessions were added to the white potato germplasm collection during 1974. These cultivars came from the Wageningen Potato Collection (WAC) in the Netherlands.

A revised list *(Table 1)* of the tuber-bearing species of the genus Solanum shows a reduction in the number of accessions from the 1,501 reported in the *72-73 Annual Report.* The reason is that the 25 intervarietal crosses (Katahdin background) are classified as part of the collection of segregating populations rather than as accessions. Furthermore, the accessions of *Solanum phureja* and *Solanum stenotomum* have been separated from the wild diploid complex because both are now considered to be cultivated diploids.

Table 1. Revised list of AVRDC's tuber-bearing *Solanum* collections.

Collections	*Source*	*Number of accessions*
Cultivated tetraploids a/	Mexico	1,282
27 wild diploid species b/	USDA d/	123
S. andigena c/	USDA,WAC e/	58
S. phureja c/	USDA,WAC	21
S. stenotomum c/	USDA,WAC	4
Derived *S. tuberosum* haploids a/	USDA	9
Total		1,497

a/ Received as clones.
b/ 18 species received in both clonal and true seed forms; 9 species, as seed.
c/ Recieved as seed.
d/ USDA - U.S. Department of Agriculture.
e/ WAC - Wageningen Potato collection, the Netherlands.

The cultivated tetraploids were planted during the 73-74 winter season to propagate the various cultivated clones in the collection and to provide the breeders with data concerning maturity and various vine and tuber characteristics.

Most of the wild diploid species were grown in small clay pots during the winter season to transform the accessions into clones from true seed. Subsequently, these clones were screened for heat tolerance during the summer.

Additional accessions were transformed from true seeds into tubers during the 73-74 winter season. Included in this were accessions belonging to *S. andigena, S. phureja, S. stenotomum,* and some of the wild diploid species. The resulting clones will be observed in the 1975 heat-tolerance nursery.

CROSSES AND OPEN–POLLINATED POPULATIONS. In 1974, 114 segregating populations were received from other breeding programs as true seeds. Their backgrounds, source, and the number of families composing each population are shown in *Table 2.*

Table 2. List of various segregating populations of white potato acquired by AVRDC in 1974 from other breeding programs.

Segregating populations	*Source*	*No. of families*
S. phureja-S. stenotomum mass-selected populations a/	North Carolina Univ.	74
Neotuberosum populations	CPC b/	2
Intervarietal crossea	CIP c/	7
S. tuberosum LBR d/ cultivars; Bulk pollen of other LBR cultivars	CIP	10
S. andigena / S. tuberosum crosses	Cornell Univ.	6
Open-pollinated *S. andigena*	Cornell Univ.	2
S. andigena clones; Bulk *S. andigena pollen*	Cornell Univ.	13
Total		114

a/ These materials vary in number of mass-selection cycles.
b/ CPC – Commonwealth Potato Collection, Scotland.
c/ CIP – International Potato Center, Peru.
d/ LBR – Late blight resistant.

These new segregating populations were planted in small pots to transform the seedlings into clones. The harvested tubers will also be entered in the 1975 heat-tolerance nursery.

The AVRDC white potato program is now based on a total of 163 segregating populations, in addition to the genetic variability existing in the cultivated tetraploids and diploids and in the

wild diploid accessions. From the first 24 segregating populations, the breeders have screened 2,996 seedlings ranging from 28 to 566 seedlings per population.

SCREENING FOR HEAT TOLERANCE. During the 1974 summer season, three types of materials were screened for possible adaptability to high temperature and high humidity. These materials were: (i) the Mexican collection of cultivated tetraploids, (ii) the wild diploid species, and (iii) the segregating populations from crosses with diverse parental background.

(i) The Mexican collection. This collection had been screened for heat tolerance in 1973 *(72-73 Annual Report)* but was reevaluated because some of the entries had not survived long enough to be appraised in the 1973 trial. Furthermore, sample size in the previous screening was limited to a single plant per accession.

In the 1974 heat-tolerance nursery, the breeders planted five or more plants per accession. Occasionally, less than five plants were available for a given accession.

The nursery was planted May 20 on beds spaced one meter apart. Torrential rains and heavy flooding destroyed the entire trial two weeks after planting.

+ For Asia, we define a marketable tuber as one weighing at least 50 grams, or with a minimum diameter of four centimeters.

A second nursery was planted July 29. Again, five plants per accession were used in most cases. The beds were raised higher than usual and covered with straw mulch after planting to preserve the bed structure.

Only 594 of the 853 accessions planted survived until they could be evaluated 3 months later (last week of October). All plants were scored for tuber production. Data on the vegetative growth and vine characteristics were also recorded. This evaluation was premature for some of the late-maturing types. However, the arrival of the cold season made the early harvest necessary.

A list of the accessions that produced marketable+ tubers under high temperatures is given in *Table 3.* This list composed only 1.5 percent of the total number screened. Although other breeding lines in the collection initiated tubers, most of them were not of marketable size and, therefore, were not included in the list.

Accession 869 (AXL 69-1) ranked highest for total yield (470 g), marketable yield (390 g), and number of marketable tubers (6). Although Accession 877 (BUU 69-1) produced the highest total number of tubers (15), its tuber-bulking efficiency was the lowest (0.2) in the group.

(ii) Wild diploid species. In 1973, eight wild diploid species tuberized in a summer trial under pot culture conditions. This gave us hope that from these species, we might obtain valuable

Table 3. Summary of horticultural characteristics of accessions from the Mexican collection that produced marketable tubers; 1974 heat-tolerance nursery.

AVRDC acc. no.	Line or variety designation	Total yield (g)	Total tuber no.	Marketable yield (g)	Marketable tuber no.	Tuber-bulking efficiency a/	Top growth
869	AXL 69-1	470	10	390	6	0.6	luxuriant
877	BUU 69-1	370	15	150	3	0.2	good
579	AMZ 69-1	320	5	220	3	0.6	luxuriant
432	India 837	310	7	265	5	0.7	good
72	ADQ 69-1	300	5	170	3	0.6	good
401	H 65-6 / Libertas	300	8	250	5	0.6	good
18	Juanita / J-178-10(107)	250	10	190	4	0.4	luxuriant
893	BXD 69-1	230	3	160	2	0.7	good
977	USDA B 6139-11	230	4	230	4	0.1	good

a/ Tuber-bulking efficiency is the ratio of the number of marketable tubers to the total number of tubers produced.

White potato Accession 869 (AXL 69-1) produced the highest marketable yield (390 g) of the Mexican collection in the 1974 heat-tolerance nursery.

genetic material to use in breeding for heat tolerance.

However, the biggest constraint in screening wild species for heat tolerance is the lack of a reference point to judge the performance of a specific species. In the cultivated tetraploids, the marketability of a tuber serves as a standard in evaluating a particular clone. However, most of the wild species do not produce tubers of sufficient size, as compared with the cultivated types.

To resolve this problem, the breeders attempted to provide the wild species with optimum night conditions. Clonal samples (2 to 4 plants per accession) of four accessions were divided into two groups (warm night treatment and cool night treatment) with all other cultural practices constant (e.g., light duration and soil fertility). Both groups were planted in small clay pots July 31.

The cool night temperature treatment (15°C) began August 20. These plants were moved inside the cold chamber at 5:00 PM and removed at 8:00 AM. Artificial lighting was provided inside the cold chamber equal to the natural (12-hour) day length received by the plants that remained outside. A *S. tuberosum* cultivar (Nohrin 1) was included for comparison.

The plants of only two species performed better under the warm night treatment than those that were grown under the cooler night temperatures *(Table 4)*. These were *S. vernii* (Acc. 1475-1) and *S. pinnatisectum* (Acc. 1406-4),

Table 4. Comparative growth and tuber production in some diploid *Solanum* species. Nohrin 1 served as a *S. tuberosum* check.

Species	Night temp treatment[a/]	AVRDC selection no.	Vegetative growth			Tuber production				Heat-tolerance indexb/
			plant height	internode length	top growth	total yield	total tuber no.	largest tuber diameter	largest tuber weight	
			(cm)	(cm)	(g)	(g)		(cm)	(g)	
S. vernii	Warm	1475-1	29	1.7	13	55	26	1.7	5.0	1.3
	Cool	1475-1	20	2.5	15	39	20	1.5	3.5	
S. vernii	Warm	1475-4	26	1.1	37	8	16	1.3	2.0	0.6
	Cool	1475-4	23	1.5	37	40	16	2.0	5.4	
S. pinnatisectum	Warm	1406-4	51	2.6	20	59	28	1.7	4.7	1.2
	Cool	1406-4	35	1.8	17	48	23	1.6	3.7	
S. tuberosum (Nohrin 1)	Warm	1527	29	3.5	32	12	2	1.7	6.1	0.3
	Cool	1527	24	3.0	21	117	8	3.2	27.8	

a/ Plants receiving the cool night treatment were grown outside during the daytime and transferred at night inside a large cooler with a mean temperature of 15°C. The plants treated with warm night temperatures remained outside under natural summer conditions.

b/ Heat-tolerance index is the average of the ratios obtained between the two treatments in total yield and total tuber number.

which had also formed tubers in the 1973 heat-tolerance nursery.

Another clone of *S. vernii* (Acc. 1475-4) did not perform as well, which indicated that substantial heterozygosity exists within this true seed accession.

The heat-tolerance index was determined by averaging the ratios of the number of tubers and total tuber weight between the two treatments and was slightly higher for *S. vernii* (Acc. 1475-1) than for *S. pinnatisectum* (Acc. 1406-4). These values were 1.3 and 1.2, respectively. Whether this index had any significance is not known. However, the breeders used it as a rough gauge of clonal differences.

The cultivar Nohrin 1 had the lowest value (0.3). As would be expected, this Japanese cultivar is heat-sensitive (see *Table 4*). The yield of the cool-temperature-treated Nohrin 1 would have been greater, had it not been prematurely harvested to match the growth duration of the plants that died early under natural summer conditions.

Intra-clonal frequency distributions of tuber weight and diameter at the warm and cool night temperature treatments were plotted for both species (*Fig. 1*). These distributions were non-genetic and only indicated the comparative differences between plants of each accession grown under the two treatments.

These intra-clonal distributions compared the two treatments by tuber weight and diameter (see *Fig. 1*). Except for the tuber weight of Accession 1475-1, the distributions were identical for both treatments. This indicated that the higher yields of the plants grown under the warmer night temperatures cannot be attributed to a greater number of small tubers. This was especially true for the *S. pinnatisectum* accession.

If the *S. vernii* species is indeed heat tolerant, we should be able to use it in our breeding program because of its proven cross compatibility with *S. tuberosum*. However, we are not aware of any successful crosses between *S. pinnatisectum* and the cultivated potato.

(iii) Segregating populations. Three segregating populations (the University of Guelph collection, the *S. andigena* / *S. tuberosum crosses*, and the intervarietal crosses with Katahdin background) were successfully converted into clones in the 73-74 winter season. These populations were planted July 22, and straw mulch was placed on top of each bed.

An evaluation of selections obtained from the

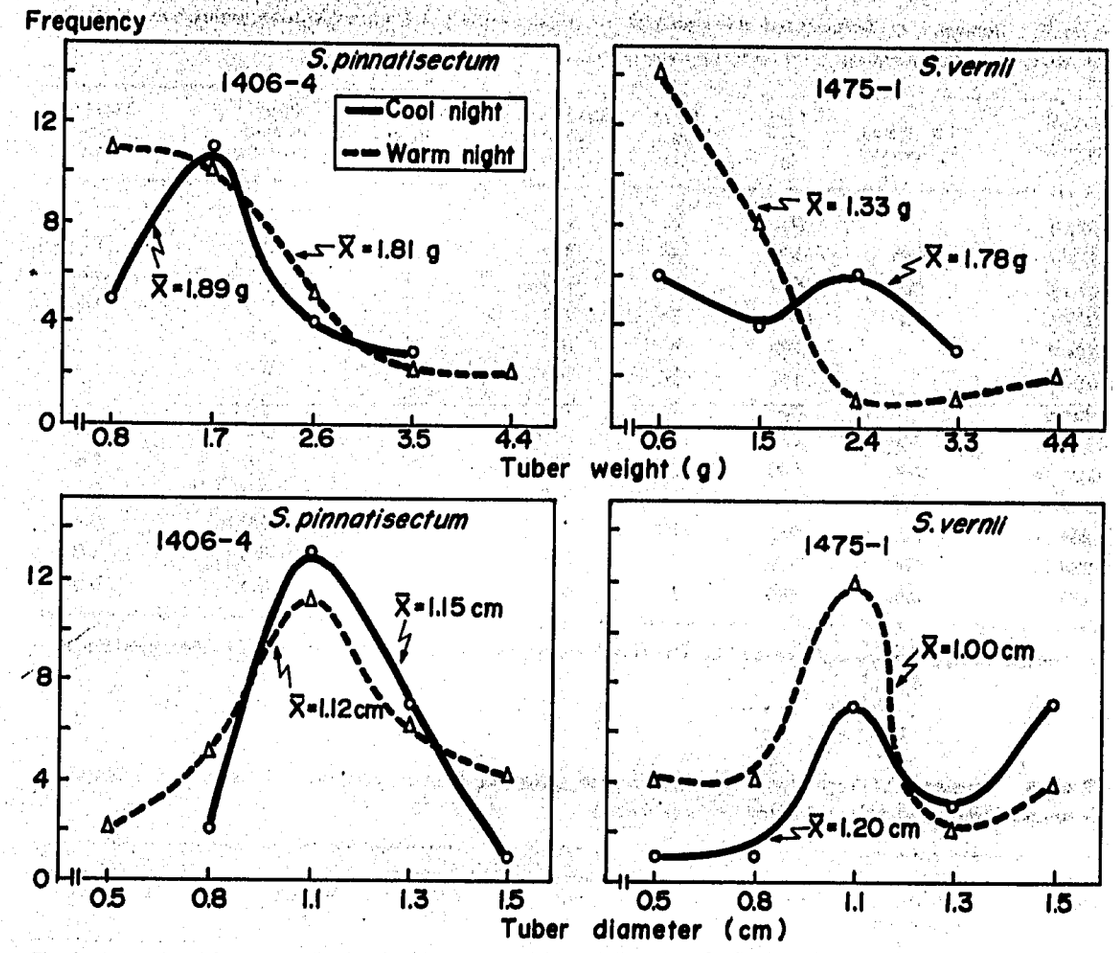


Fig. 1. Intra-clonal frequency distributions by tuber weight and diameter of a *S. pinnatisectum* clone when grown under cool and warm night conditions.

University of Guelph (Canada) collection is summarized in *Table 5.* In general, higher marketable yields were obtained from these selected clones than from those of the Mexican collection (see *Table 3*).

Selection 1282-4 produced the highest marketable yield (400 grams) as well as the highest total yield (650 grams). Although this selection had the highest number of marketable tubers (8), its tuber-bulking efficiency was the lowest (0.3) among the selections. However, this selection had the lowest top-to-tuber ratio (0.4) indicating that most of the photosynthate was utilized for tuber production at the expense of vegetative growth.

The screening results of populations from the *S. andigena / S. tuberosum* crosses are shown in *Table 6.* Only one population (1512) produced segregants with marketable tubers. This particular population resulted from the cross N 506 / NY-48. The best yield among these segregants was produced by 1512-1, which had a total yield of 400 grams and a marketable yield of 320 grams. The yields of the other two segregants were considerably lower, possibly because of insufficient vegetative growth.

Of the 25 intervarietal crosses (Katahdin background) screened, only four populations had segregants that produced marketable tubers *(Table 7).* These were populations 1487 (Krasava / Katahdin), 1491 (Mittelfruhe / Katahdin), 1492 (Moona / Katahdin), and 1500 (Zeeburger /

Table 5. Summary of horticultural characteristics of potato selections from segregating populations from the University of Guelph (Canada); 1974 heat-tolerance nursery.

AVRDC selection no.	Top growth (g fresh wt)	Total yield (g)	Total tuber no.	Marketable yield (g)	Marketable tuber no.	Tuber-bulking efficiency a/	Top-to-tuber ratio
1282-1		580	15	335	6	0.4	
1282-3	690	460	12	355	6	0.5	1.5
1282-4	250	650	31	400	8	0.3	0.4
1282-5	760	400	13	300	6	0.5	1.9
1284-1		490	17	300	5	0.3	
1284-4		480	12	340	6	0.5	
1284-5		500	13	360	6	0.5	
1284-7	150	360	6	320	4	0.7	0.4
1284-14	700	460	16	300	6	0.4	1.5
1284-15	360	500	15	320	5	0.3	0.7
1284-16	150	385	10	310	5	0.5	0.4
1284-18	680	430	11	335	5	0.5	1.6
1289-1	320	390	10	300	5	0.5	0.8

a/ Tuber-bulking efficiency is the ratio of the number of marketable tubers to the total number of tubers produced.

Table 6. Summary of horticultural characteristics of segregants from *S. andigena* / *S. tuberosum* crosses that produced marketable tubers; 1974 heat-tolerance nursery.

AVRDC selection no.	Top growth (g fresh wt)	Total yield (g)	Total tuber no.	Marketable yield (g)	Marketable tuber no.	Tuber-bulking efficiency a/	Top-to-tuber ratio
1512-1	380	400	9	320	5	0.6	0.9
1512-2	110	240	6	180	2	0.3	0.5
151203	140	330	10	200	4	0.4	0.4

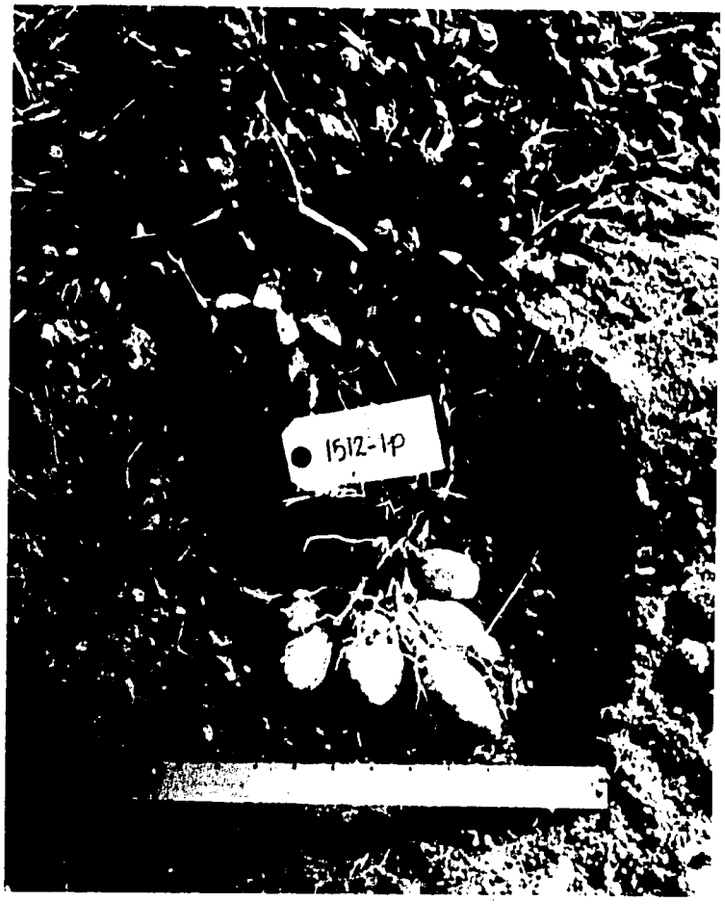
a/ Tuber-bulking efficiency is the ratio of the number of marketable tubers to the total number of tubers produced.

Katahdin). Selected segregants from populations 1487 and 1500 had the highest total and marketable yields. However, only those from population 1487 produced a reasonable number of marketable tubers.

PLANT PHYSIOLOGY

Studies on the physiology of the white potato were initiated to better understand the reasons for low tuber production in hot, humid climates. Several factors have been designated for consideration *(Fig. 2)*.

The effect of high air temperatures on the white potato was examined by growing the cultivar Nohrin 1 under two night temperature treatments in the greenhouse. The day temperature was constant at 25°C and the night temperatures ranged from 15° to 20°C and from 20° to 25°C, respectively, for the cool and warm night treat-



This is one of the three segregants from the only population of the *S. andigena/S. tuberosum* crosses to produce a marketable yield in the 1974 heat-tolerance nursery. It produced 5 marketable tubers.

Table 7. Summary of horticultural characteristics of segregants from intervarietal crosses (Katahdin background) that produced marketable tubers; 1974 heat tolerance nursery.

AVRDC selection no.	Top growth (g fresh wt)	Total yield (g)	Total tuber no.	Marketable yield (g)	Marketable tuber no.	Tuber-bulking efficiency a/	Top-to-tuber ratio
1487-3		500	16	300	6	0.4	
1487-5		540	14	400	7	0.5	
1491-1	350	380	14	150	2	0.1	0.9
1492-2		350	11	210	3	0.3	
1500-1	210	600	17	300	4	0.2	0.4

a/ Tuber-bulking efficiency is the ratio of the number of marketable tubers to the total number of tubers produced.

ments.

Leaf samples were taken from plants in each treatment to measure both the rate of net photosynthesis and the rate of dark respiration.

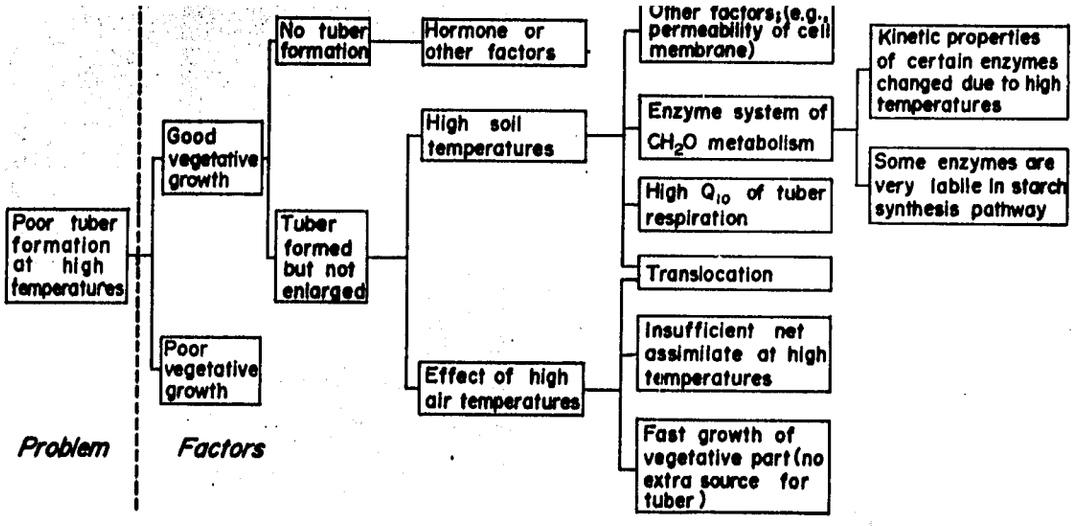


Fig. 2 Possible factors involved in poor tuber formation.

The leaf samples from the cool night treatment maintained a higher net photosynthetic rate when subjected to high temperatures than those taken from plants grown in the warm night treatment *(Fig. 3)*. This difference in response will be investigated further.

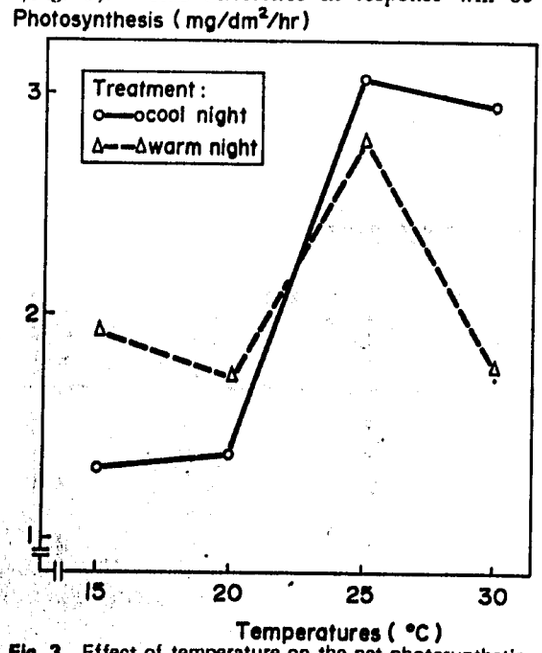


Fig. 3. Effect of temperature on the net photosynthetic rate of white potato plants grown under different night temperature conditions.

SOIL SCIENCE

It has been reported that for each ton of potatoes harvested per hectare, approximately 3 kg/ha N, 0.5 kg/ha P, 4 kg/ha K, and 1.5 kg/ha Mg must be supplied during the growing period. Therefore, to produce a yield of 40 tons per hectare, 120 kg/ha N, 20 kg/ha P, and 160 kg/ha K would be required.

A field experiment was conducted to determine the response of white potato to fertilizer application. Nohrin 1, which matures in 120 days, was planted in the field September 19 and harvested after 91 days.

The best yield was obtained when 80 kg/ha N, 31 kg/ha P, and 100 kg/ha K were applied *(Table 8)*. Plots treated with more than 80 kg/ha N showed a decrease in yield (see *Table 8*).

The heavy soil of the AVRDC experimental farm is a major obstacle to tuber production. Studies were initiated on possible soil amendment techniques to improve soil conditions for growing root and tuber crops.

An experiment was conducted using Nohrin 1 as the test variety. This experiment used large clay pots with four different treatments:

Table 8. The response of white potato to fertilizer application.

Treatment (kg/ha)				Tuber weight		Mean yield per plant (g)	Mean no. of tubers per plant
N		P	K	Range	Mean		
Basal	Top[a]	Basal	Basal	(g/tuber)			
0	0	31	100	5-170	42	343	8
10	10	16	50	11-185	38	357	9
40	40	31	100	13-190	52	497	10
60	60	63	150	11-130	47	407	9
80	80	63	150	5-165	40	273	7

a/ Top dressing made Oct. 30.

(i) farm soil alone; (ii) farm soil and sand; (iii) farm soil and compost; and (iv) farm soil, sand, and compost.

The sprouting seed potatoes were planted November 2. The experiment was arranged in a randomized, complete block design with the treatments replicated four times and with two plants per treatment in each replication.

During the growth period, various horticultural traits were recorded *(Table 9)*. Unfortunately, late blight *(Phytopthora infestans)* infection became serious despite regular spraying with fungicide (Dithane M-45), and the experiment was lifted prematurely (Jan. 7, 1975).

No detectable differences in vegetative growth between the treatments were found. However, highly significant differences were apparent in tuber production (see *Table 9*). The highest yields (total and marketable) were obtained when compost and fine sand were incorporated with farm soil. Although the plants grown on farm soil gave the highest mean number of tubers (8.6), their total yield (177 g), and marketable yield (66 g) were the lowest of the different treatments.

Table 9. Summary and tests of significance for various characters of Nohrin 1 grown on different soil mixtures in clay pots.

Treatment	Total yield (g)	Total no. of tubers	Marketable yield (g)	No. of marketable tubers
Soil only	177	8.6	66	1.0
Soil + Sand	189	5.9	136	2.3
Soil + Compost	269	7.8	177	2.6
Soil + Sand + Compost	293	7.5	226	3.3
LSD .05	32.9	0.8	37.7	0.6
LSD .01	50.7	1.2	58.0	0.9

A related experiment was conducted in the field (Dec. 5) to determine the effect of sand application on the growth and yield of white potato. The marketable yield was higher for the no sand treatment *(Fig. 4)*. The lower yield for the sand treatment indicated that the addition of sand reduced the intensity of plant nutrients in the root zone, thus lowering the yield.

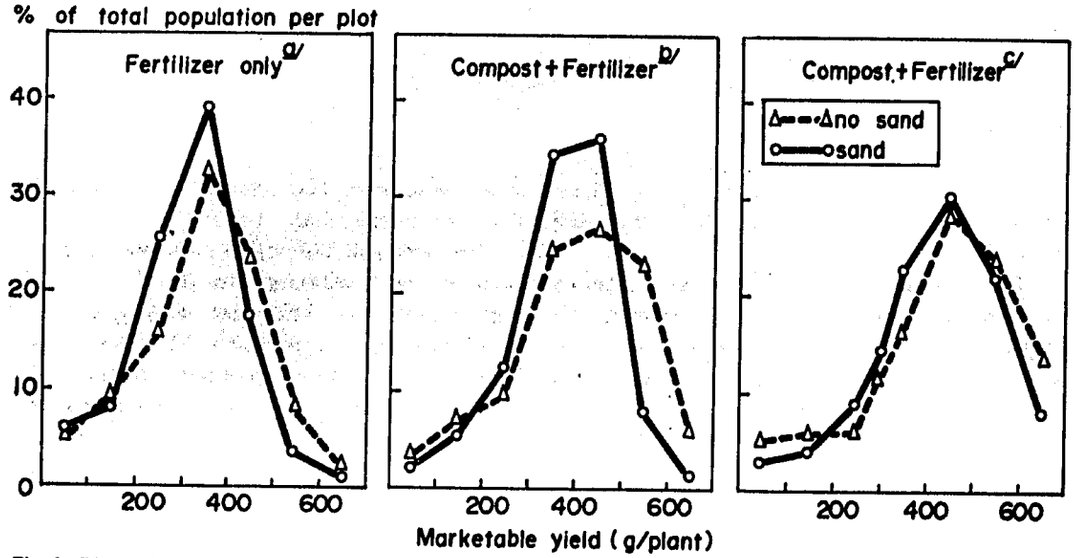


Fig. 4. Effect of sand application on the frequency distribution of marketable yield.
a/ Basal dressing: 30 kg/ha N; 45 kg/ha P; 140 kg/ha K.
b/ Basal dressing (same as 'a') plus 20 tons/ha of compost, which was mixed with the surface soil.
c/ Both basal dressing and compost (same amounts as 'b') were banded at a depth of 20 cm.

AGRICULTURAL ECONOMICS

Percentages of major production cost factors from studies conducted in the highland areas of India, the Philippines, and Taiwan *(Table 10)* show considerable differences in cost factors. In Mysore State, India, the major expense was certified seed. In the Atok Mountain area of the Philippines, both seed materials and fertilizer were major cost items. However, in the Taichung area of Taiwan, labor costs were considerably more than the expenditures for fertilizer or seed materials.

With further data collection, the production differences will be better defined so that research directions (in agricultural economics, crop management, etc.) can be developed.

From 1972 production data and estimates for various Asian countries *(Table 11)*, it can be noted that the tropical countries of Indonesia, Thailand, and the Philippines have comparatively low yields from limited areas of production.

INTERNATIONAL ACTIVITIES

In September, our cooperation with the International Potato Center (CIP) in Peru was strenghened with the visit to AVRDC of Dr. Richard Sawyer, CIP Director–General, and Dr. John Niederhauser, a consultant for outreach and training programs. We received additional segregating populations to include in our screening program from CIP and its various contract projects in December.

The distribution of white potato germplasm in vegetative form to other countries is limited because of rigid quarantine regulations. These precautionary measures are, of course, necessary because of the immensity and the severity of many pests and diseases that could be easily spread from one coutnry to another.

However, we were able to send 43 clones to the AVRDC Sub-Center in Korea in 1974.

In 1975, new populations will be produced

Table 10. Relative production costs in three Asian white potato production areas.

Area	Production cost factors				
	Seed	Fertilizer	Pesticides	Labor	Other
	(% of total costs)				
Atok, Benguet Prov., the Philippines a/	36	35	11	9	9
Mysore State, India b/	41	25	3	16	15
Taichung Hsien, Taiwan, R. O. C. c/	8	21	77	44	20

a/ Adapted from "Farm Management Study of Vegetable Farms in Atok, Benguet Province" by V. L. Cabezon, University of the Philippines, Los Baños, Philippines, 1971. Undergraduate thesis.

b/ Adapted from the "Farmer Planning Manual" by J. Nanja Reddy, K. C. Hiremath, and Estel H. Hudson, University of Agricultural Sciences, Hebbal, Mysore State, India. Preliminary draft for extension purposes. (No date - cir. late 1960s). p. 75.

c/ Adapted from "A report on the Survey of Production Costs of Taiwan's Agricultural Products," 1974 Edition, Provincial Department of Agriculture and Forestry, Taiwan. p. 144.

Table 11. White potato production, area, and yields in various Asian countries, 1972. a/

Country	Production (1,000 tons)	Area (1,000 ha)	Yield (tons/ha)
Japan	3,537	145	24.3
World average	*279,894*	*22,097*	*12.7*
Taiwan, ROC b/	27	2	11.7
India	4,834	496	9.7
Korea	459	52	8.8
Philippines	25	3	8.3
Thailand	9	1	7.5
Indonesia	42	10	4.2

a/ Adapted from *The FAO Production Yearbook, 1972* (Vol. 26, Rome). All estimates are from FAO unless otherwise noted.

b/ *Taiwan Agricultural Yearbook.* 1973 Edition. Provincial Department of Agriculture and Forestry, Taiwan. July 1973.

by intercrossing the more promising summer selections. The number of seeds produced should be sufficient to distribute among our cooperators.

Farm & market surveys

In 1974, the Agricultural Economics Department was formed, and a number of studies were undertaken to obtain data on the production and marketing of vegetables in Asia. Although the initial studies discussed in this report were conducted in Taiwan, we expect to extend our research into other Asian countries. Reports have been written on the various studies and may be obtained on request.

SURVEY OF 300 VEGETABLE PRODUCERS

To determine characteristics of vegetable producers and vegetable cultivation in two distinctly different production areas of Taiwan *(Fig. 1)*, a survey of 300 vegetable producers was conducted in 1974. A vegetable producer is defined as a farmer who grew at least one vegetable crop during the 73-74 crop year and sold 50 percent or more of his produce.

The average farm size of the surveyed farmers was 0.85 hectares with 68 percent of the farms smaller then one hectare. These 300 farmers cultivated 682 parcels, 47 percent (322) of which were less than 0.25 hectares in area. In several instances, different parcels of the same farm were planted in various patterns, resulting in complex cropping systems.

For example, some of the ways that vegetables were cropped on a per parcel basis were: (i) only vegetables grown year-round with occasional short fallow periods; (ii) vegetables grown year-round except for one rice or field crop; (iii) relay intercropping of summer vegetables or sequential winter vegetables between two full rice crops; (iv) winter vegetables between either a rice and field crop or between two field crops; and (v) randomly planted vegetable crop(s) to follow or be intercropped with long-term crops such as sugarcane or orchard trees. The ways vegetables were (or were not) combined with other crops varied according to location; likewise particular types of vegetables were more prevalent in certain areas than in others.

According to the sampling design and the cropping pattern data, there were fairly concentrated areas of vegetable production rather than an even distribution of vegetable production around the population centers. Although a larger number of vegetable producers were nearer the market; the further the vegetable producers were from the market, the more intensively they grew vegetables relative to other crops.

Using the relative vegetable intensity index (RVII), it was determined that as vegetable crops increased relative to other crops; farm size decreased, the length of the family work schedules increased (more hours), and the available irrigation water (from the public irrigation system) decreased. Parcels outside the public irrigation areas that were planted in vegetables were often irrigated by using a pumpset to draw water from wells, streams, etc. Rice was the main crop with which vegetables were cropped.

The most frequent reasons from not growing vegetables (as stated by 492 non-vegetable producers) were labor shortages, unsuitable growing conditions, land limitations, 'other work', and shortage of fertilizer, in that order. Labor shortages affected all sizes of farms to a notable degree.

The primary motive for producing vegetables was cash income (212 or 70% of total response), followed by utilization of land (10%) and soil improvement (5%). The three primary constraints for vegetable production were fertilizer shortage, lack of family labor, and pests and diseases in that order. Price fluctuations and limited returns were mentioned as secondary constraints. Due primarily to the lack of family labor, fertilizer shortage, and land size limitations (in that order); 97 percent of the vegetable producers did not plan to expand their vegetable production area. The three variables that were significantly related to cropping intensity were farm size (small), available public irrigation water, and available farm family labor.

SPECIALIZED VEGETABLE PRODUCTION AREAS

An integrated production and marketing system to compete with the existing 'middleman-controlled' vegetable-marketing organizations as well as to provide a larger supply of summer vegetables, the Specialized Vegetable Production Area (SVPA) Program, was initiated by the government (Taiwan). This intergrated approach included the following components: (i) groups of interested vegetable producers in favorable vegetable producing areas (suitable climate and sufficient water supply) were identified and organized; (ii) production incentives such as capital, materials, and technical assistance were provided; and (iii) a collective marketing system with a network of strategically located assembly stations linked through the Farmers Association organizations to large wholesale markets in major consumption areas was

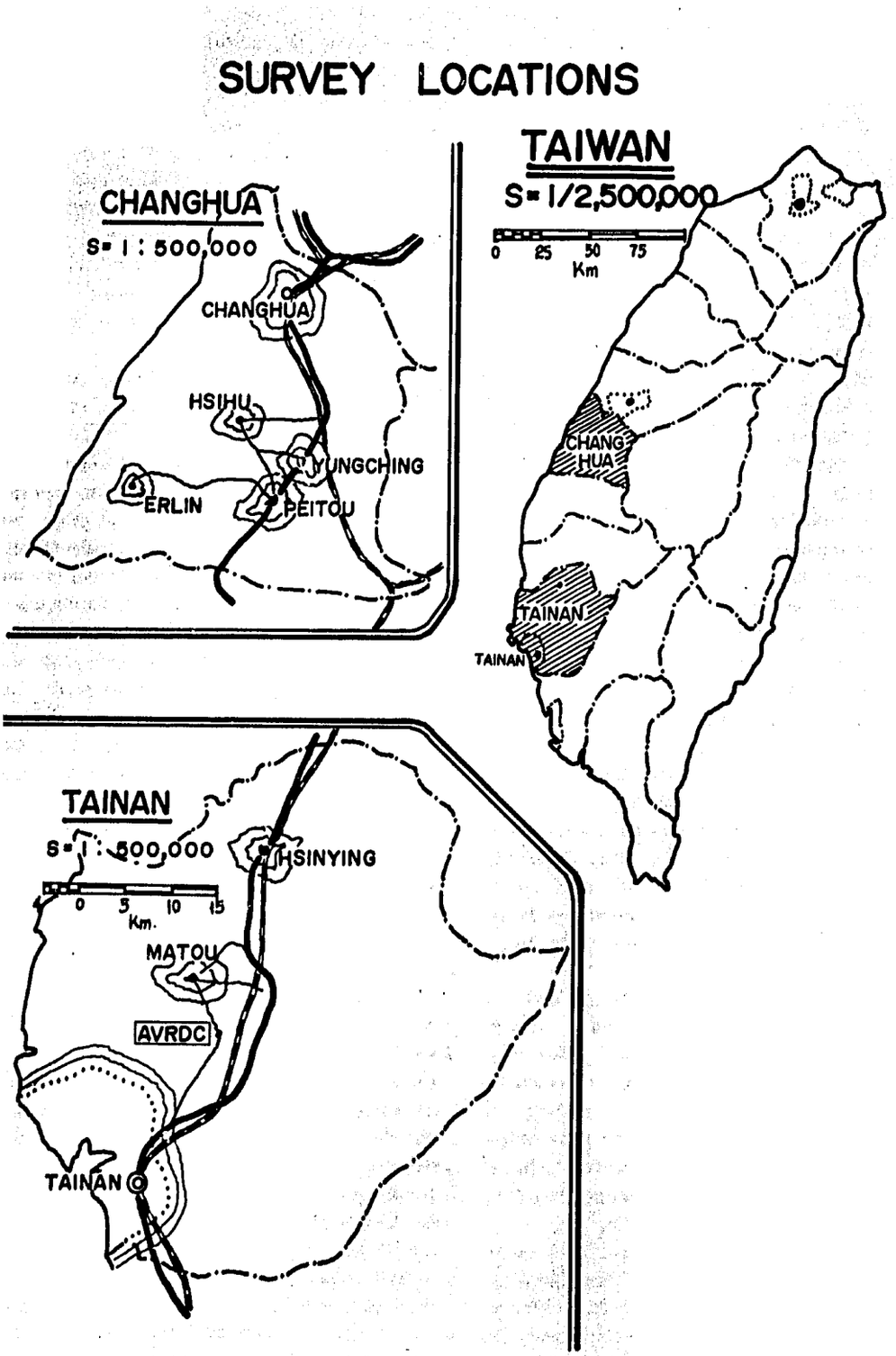


Fig. 1. The counties (hsiens) of Changhua and Tainan are two major vegetable production areas in Taiwan.

formed.

The most promising aspect of this approach has been that it involved no drastic changes in the local patterns of cultivation. Instead, it improved and ensured the availability of production inputs and the accessibility of the marketing infrasfructure. As a method to efficiently test and introduce agriculture research findings, e.g., new techniques of cultivation and improved varieties, this program functions well. A report describing the SVPA program and some of its participating farmers is available on request.

CROP INTENSITY INDEX

Vegetable crops constitute a special challenge to the researcher searching for a common base of reference concerning both the extent of land use and the types of crops involved. The numbers of and variations among parcels (i.e., separate plots of land) on the same farm adds to the diversity as well as the complexity of cropping patterns. A time-weighted land use index, Crop Intensity Index (CII), was developed to provide a total farm perspective of cropping systems *(Chart 1)*.

Chart 1.

$$\text{Crop Intensity Index} = \frac{\sum_{i=1}^{n} A_i t_i}{A_f T + \sum_{j=1}^{m} A_j t_j}$$

i = 1,2,3,. . . . . ., n

n = total number of crops during time period "T"

A_i = area occupied by the ith crop (the jth crop(s) included if applicable)

t_i = the duration of the ith crop, i.e., months during which crop "i" occupied area A_i.

A_f = the farmer's total cultivated land area during time period "T"

T = time period under study, usually 12 months

m = total number of crops grown on land area A_j available for use during time period t_j.

A_j = land area available for short-term use (e.g., seasonally rented land, river bed cropped during the dry season, and the like)

t_j = time period A_j is available.

The crop intensity index is defined as [the summation of the product of each crop's area (A_i) times its duration in the field (t_i)] divided by [the product of the farm's total cultivated land area (A_f) times the period (T) being studied plus the sum of the product of any possible short-term land (A_j) times its available time period (t_j)]. The framework of this index formulated at AVRDC was found to be somewhat similar to the land utilization index reported in a paper by Mr. Fu-Tien Chuang+.

We have selected two farms from the survey of 300 vegetable producers to illustrate how the CII can be used *(Chart 2)*. The period covered by the survey was from June 1973 through May 1974.

The formula for the rice intensity (RI) is similar to that of the CII, excpt that the '$\sum_{j=1}^{n} A_i t_i$' term only includes rice crops. The vegetable intensity (VI) and the field crop intensity (FI) are calculated by using only vegetable crops and only field crops, respectively *(Chart 3)*.

In other words, the role of each type of crop (i.e., rice, vegetables, and field crops) in the intensity of land use was determined by dividing the corresponding ha-months by the $A_f T + \sum_{j=1}^{m} A_j t_j$ term. Thus, the rice intensity (RI) is .45, or 45 percent of the farm area was in rice during the period studied (T). The other intensities are calculated similarly. The sum of RI + VI + FI + any miscellaneous crop intensity equals the CII value which, in this case, was .72 (see *Chart 3*).

The relative rice intensity (RRI) is the ratio of rice crops to all crops; the relative vegetable

+ Chuang, F.T. 1973. An analysis on the change of Taiwan's cultivated-land utilization in recent years. JCRR, Taiwan (in Chinese).

Chart 2.

Mr. Chen's .41 ha farm in Hsihu with 2 parcels.

Double rice crop land a/	(0.17 ha)	2nd Rice Crop / Pea / 1st Rice Crop / Fallow	
"	(0.24 ha)	Leek	

Crop (Duration)		Area (A_i) in ha	x	Time (t_i) in months	=	Area-time in ha-months
2nd Rice	(3.5 months)	.17	x	3.5	=	.595
Pea	(3.5 months)	.17	x	3.5	=	.595
1st Rice	(4.0 months)	.17	x	4.0	=	.680
Leek	(all year)	.24	x	12.0	=	2.880
						4.750

$$CII = \frac{4.75}{.41 \times 12} = \frac{4.75}{4.92} = .97$$

Mr. Huang's 1.5 ha farm in Hsinying with 3 parcels.

Rotation crop land	(0.20 ha)	2nd Rice Crop / Sweet Potato / Fallow
Double rice crop land	(1.00 ha)	2nd Rice Crop / Fallow / 1st Rice Crop / Fallow
	(0.30 ha)	Vegetables

Vegetables
- Summer: Cabbage, Water Convolvulus, Asparagus Bean, Pai Tsai, Edible Rape.
- Winter: Garlic, Celery, Water Convolvulus

Crop (duration)	Area (A_i) in ha	x	Time (t_i) in months	=	Area-time in ha-months
2nd Rice Crop (3.5 months)	.20	x	3.5	=	0.7
Sweet Potato (6 months)	.20	x	6.0	=	1.2
2nd Rice Crop (3.5 months)	1.00	x	3.5	=	3.5
1st Rice Crop (4.0 months)	1.00	x	4.0	=	4.0
Vegetables (all year)	.30	x	12.0	=	3.6
					13.0

$$CII = \frac{13.0}{1.5 \times 1.2} = \frac{13}{18} = .72$$

.....

a/ Sufficient public irrigation water for 2 rice crops per year.
b/ Sufficient public irrigation water for 2 rice crops every 3 years.

Chart 3. From Mr. Huang's farm.

Rice Intensity (RI)	=	$\frac{0.7 + 3.5 + 4.0}{1.5 \times 12}$	=	$\frac{8.2}{18}$	=	.45
Vegetable Intensity (VI)	=	$\frac{3.6}{1.5 \times 12}$	=	$\frac{3.6}{18}$	=	.20
Field Crop Intensity (VI)	=	$\frac{1.2}{1.5 \times 12}$	=	$\frac{1.2}{18}$	=	.07
Crop Intensity (CII)	=	$\frac{13}{1.5 \times 12}$	=	$\frac{13}{18}$	=	.72
Fallow					=	.28
Land use as						1.00 or 100%

Chart 4. From Mr. Huang's farm.

Relative Rice Intensity (RRI)	=	$\frac{8.2}{13.0}$	=	.63
Relative Vegetable Intensity (RVI)	=	$\frac{3.6}{13.0}$	=	.28
Relative Field Crop Intensity (RFI)	=	$\frac{1.2}{13.0}$	=	.09
All Crops as				1.00 or 100%

intensity (RVI) is the ratio of vegetable crops to all crops; and the relative field crop intensity (RFI) is the ratio of field crops to all crops. For instance, the relative rice intensity is derived by dividing the ha-months of the rice crops by the total ha-months of all crops *(Chart 4)*.

Therefore, of all the crops grown on Mr. Huang's farm during the crop year (June 1973 to May 1974); 63 percent were rice crops, 28 percent were vegetables, and 9 percent were field crops. In this example, no miscellaneous crops were grown; and the summation of the RRI, RVI, and RFI equaled 100 percent of the crops during the time period T.

AVRDC FARMERS

To provide contact with local farmers in order to observe how they cultivate five of our crops and how their production practices vary from our experimental planting, two experienced farmers are each cultivating one hectare at AVRDC. On each parcel, they grow mungbean, soybean, tomato, sweet potato, and Chinese cabbage as

Mr. Hong, one of the two AVRDC farmers, is growing tomato for the fresh market. The economists are studying how he grows the crops, which AVRDC is concerned with, to gain a better understanding of local vegetable production problems and methods.

a part of their cropping pattern. Production cost data, field operation descriptions, decision-making factors, and related information are collected. By next year, sufficient data should be accumulated for analysis.

TRAINING PROGRAM

In September, AVRDC initiated a training program similar to those already in operation at other international agricultural research centers. These programs are designed to help meet the demand for properly trained and highly motivated agricultural specialists in tropical regions.

Two principal types of training are being offered. The *research training program* provides young scientists who are responsible for developing and conducting local research programs with the practical experience of selecting and organizing a significant research project, completing the field and laboratory work, interpreting the data, and, finally, summarizing their work in written form for possible publication. Participants generally spend 6 to 12 months at the Center and may select either non-degree, degree or post-degree training objectives. The degree candidates would, of course, complete their course work requirements at a college or university before coming to AVRDC to conduct their thesis research.

During 1974, Cora P. Villareal studied the influence of temperature on the enzymatic processes in white potato and sweet potato. She will submit the study as a thesis toward the requirements of a master of science degree at

Cora P. Villareal is conducting research on the enzymatic processes in white potato and sweet potato. She is a candidate for a M.Sc. degree at the University of the Philippines at Los Banos.

the University of the Philippines at Los Banos.

James A. Deutsch, a doctoral candidate at Cornell University, is conducting his thesis work at AVRDC. He had made an extensive collection of *Amaranthus* species and is studying the variability and inheritance of yield potential, nutritional quality, and consumer acceptance of this germplasm collection.

In 1976, the Center will offer a *production training program* for extension workers, production specialists, farm managers, educators, or others who wish to gain practical experience in the modern methods of vegetable production. Also included will be instruction in communication skills and in the importance of socioeconomic factors in agricultural production.

Through travels in Asian countries, AVRDC staff members have acquainted government officials and donor agencies with the training program. The response has been excellent. Many qualified candidates have been identified, and a number of donor agencies have shown an interest in sponsoring training participants. It is expected that the training program will be well established by mid-1975.

A training brochure has been published and widely distributed. Copies are available to interested persons on requests.

INFORMATION RESOURCES

More than 1,000 books and reprints were added to the library bringing the total collection to approximately 3,000 volumes. In addition,

James A. Deutsch, a doctoral candidate at Cornell University (New York, U.S.A.), collects field data in his study of the *Amaranthus* species at AVRDC.

another 572 volumes were reclassified, and more than 2,000 books are being processed.

We now suscribe to over 400 current scientific journals and periodicals. The table of contents of newly received journals are regularly photocopied and circulated among the staff. More than 955 bound volumes of periodicals were added to our collection, giving us a total of 2,746 volumes.

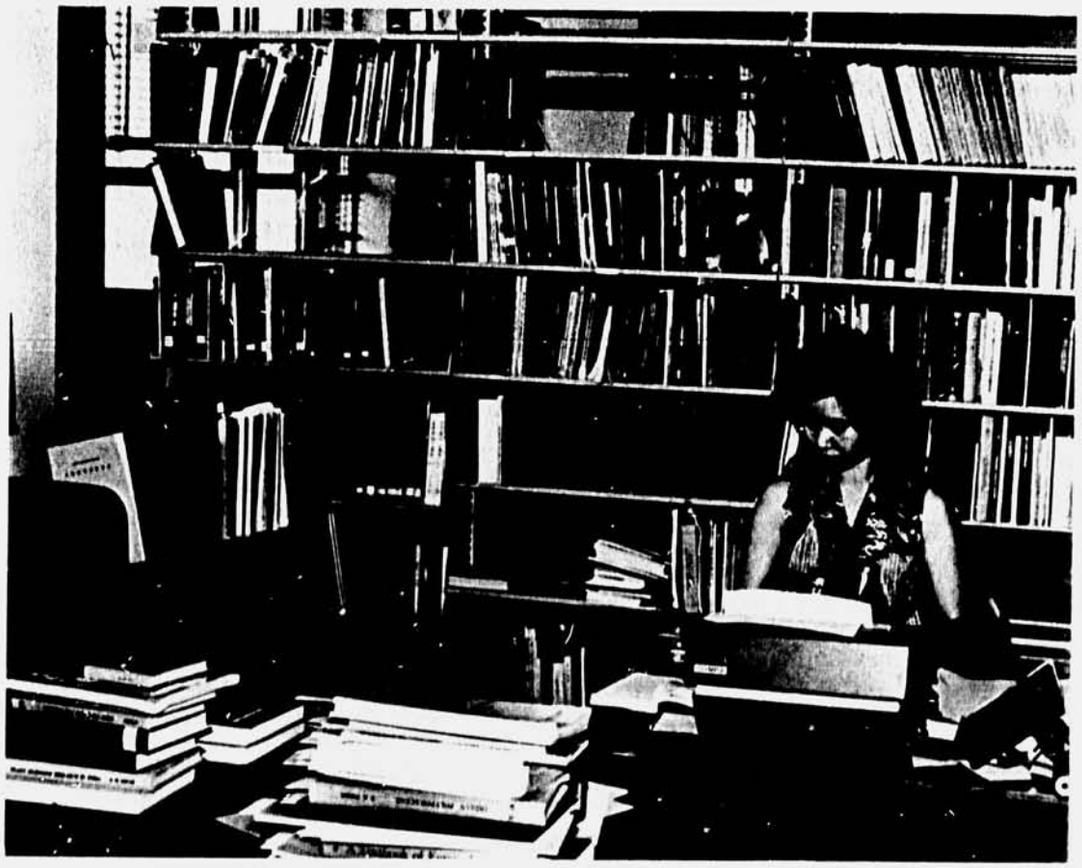
The library also received 1,500 books and reprints from the family of the late Dr. Henry B. F. Wu.

More than 2,500 copies of AVRDC's *72-73 Annual Report* were distributed among scientists, libraries, and administrators of development programs in 80 countries.

KOREAN SUB–CENTER

On May 5, the members of the Board of Directors met in Suweon, Korea and attended the dedication ceremonies of the Korean Sub-Center on the following day. The Sub-Center was established to promote vegetable research and development in temperate zones.

Activities during 1974 were devoted to collecting materials and initial screenings of Chinese cabbage, tomato, and soybean germplasm. In Chinese cabbage, two cultivars (Yung Ching 30 days and Tropicana) and five Hakuran lines were identified as heat tolerant. Seventeen tomato cultivars were selected to be parents in breeding for heat tolerance, and 18 cultivars were included in the cold-tolerance breeding program.



The AVRDC library is accumulating an extensive collection of the world literature on vegetable crops

More information on the activities of the Sub-Center can be obtain by writing its director, Dr Choi, who is also the director of the Horticultural Experiment Station. His address is:

Dr. Chung-il Choi
Director
Horticultural Experiment Station
Office of Rural Development
Suweon, Republic of Korea

SEMINARS

The following topics were the subjects of seminars held at AVRDC during 1974. Unless otherwise stated, the speakers were staff members.

Epidemiology of peanut mottle virus. *Dr. Mike K. C. Sun.*

Studies on a sudden wilt disorder in muskmelons. *Dr. Edwin B. Oyer.*

Downy mildew disease of sugarcane. *Mr. L. S. Leu, Taiwan Sugar Research Institute, Taiwan.*

Preliminary view of Taiwan's small farmer and his vegetable production problems. *Mr. Merle R. Menegay.*

The research program at the International Rice Research Institute and some lessons from it for AVRDC. *Dr. Robert F. Chandler, Jr.*

Philippine phytopathology in agriculture: Controlling plant diseases by host resistance. *Dr. Ruben L. Villareal.*

Environmental factors affecting the absorption and translocation of pesticides in plants. *Dr. N. S. Talekar.*

The role of a U.S. university in international agriculture development. *Dr. Edwin B. Oyer.*

Toxicological mechanism of organophosphate and carbamate poisoning; pesticide safety; some protective equipment for pesticide application; and safe use of pesticides. *Dr. Robert I. Rose.*

Effect of packeting materials on the longevity of vegetable seeds. *Dr. Ruben L. Villareal.*

Yield and protein content of green vegetable soybeans as affected by time of harvest and date of planting. *Mr. N. C. Chen.*

Effect of opaque-2 and floury-2 genes on yield in maize. *Mr. S. H. Wong.*

Yield trial of elite mungbean varieties. *Mr. Leonard I. L. Ho.*

Tomato trisomics in quantitative inheritance. *Dr. Romeo T. Opeña.*

Photoperiod insensitivity in soybean. *Mr. S. Shanmugasundaram.*

Crucifer seed production in Northern Thailand. *Prof. Min-Nan Chiang, National Taiwan University, Taipei.*

Races of plant pathogens. *Dr. Tom W. Mew.*

The effect of nitrogen source on the growth of plant–from the standpoint of plant nutrition. *Dr. Takashi Yoshida.*

Soybean rust. *Dr. Charles Y. Yang.*

Impressions of agriculture in mainland China. *Dr. Henry M. Munger, Cornell University, New York.*

Asparagus Growing in Taiwan. *Prof. L. Hong, National Taiwan University, Taipei.*

Research highlights at the International Potato Center. *Dr. Richard L. Sawyer, International Potato Center, Peru.*

Late blight work in Toluca Valley and some highlights of the International Potato Center Outreach Program. *Dr. John S. Niederhauser, International, Potato Center, Peru.*

Purple nutsedge: A scourge of vegetables. *Dr. Raymond D. William*

Some observations on AVRDC– from a newcomer. *Dr. James J. Riley.*

Some highlights of cropping system studies in Batangas, Philippines. *Mrs. Annie L. Frio, International Rice Research Institute, Philippines.*

Latest development on high lysine corn program in Taiwan. *Dr. H. Wan, Taiwan Agricultural Research Institute, Taipei.*

Apical dominance of higher plants. *Dr. W. C. Chang, Academia Sinica, Taipei.*

Impact of new technology on small farm agriculture. *Dr. Charles A. Francis, Centro Internacional de Agricultura Tropical, Columbia.*

A formal introduction to amaranth. *Mr. James A. Deutsch, Cornell University, New York.*

Taiwan's specialized vegetable production areas–an integrated approach. *Mr. Merle R. Menegay.*

Masagana 99. *Dr. Virgilio R. Carangal, International Rice Research Institute, Philippines*

Inheritance of locular cavitation in snapbeans (*Phaseolus vulgaris*). *Dr. Hyo G. Park.*

Entomology research highlights for 1974. *Dr. Robert I. Rose.*

PUBLICATIONS

Books and Monographs

Riley, James J. 1974. *Contributor to* Controlled-environment agriculture (Chapter 15) *and* Other promising water-conservation techniques (Chapter 16). *In* More water for arid lands: Promising technologies and research opportunities. National Academy of Sciences, Washington, D. C. 153 p.

Articles (Published and/or Submitted)

Chandler, Robert F., Jr. 1974. Can American universities provide appropriate graduate education for students from the less-affluent countries. HortScience 9(3) : 210-211.

Luh, C. L. 1974. Do not overlook the value of organic manures. Indian Farming 24 (5).

Mew, I. P., T. C. Wang, and T. W. Mew. 1975. Inoculum production and evaluation of mungbean varieties for resistance to *Cercospora canescens*. Plant Disease Reporter (Submitted 1974).

Mew, T. W. 1974. Leaf surface micro-organisms. pp. 75-85. *In* T. T. Kuo, *et al.* (ed.). Living organisms and environments. Proc. Col. Taipei, Taiwan. 1974.

Warren, G. F., R. D. William, H. H. Fisher, J. S. Sacco, R. V. Lamar, and C. A. Albert. 1973. Curso intensivo de controle de ervas daninhas. Coordinated and revised by J. J. V. Rodrigues and R. D. William. Imprensa da Universidade Federal de Vicosa, Vicosa, Minas Gerais, Brasil. 339 p.

William, R. D. 1974. Controle de *Cyperus rotundus* por medio del efecto sinergetico de la mexcla nitrofen en aceite. Resumes of 2: ALAM and 6: COMALFI Congress. 27 p.

William, R. D. 1974. Periodo critico de competencia entre algunas hortalizas y el *Cyperus rotundus*. Resumes of 2: ALAM and 6: COMALFI Congress. 28 p.

Papers Presented (Unpublished)

Chandler, Rober F., Jr. Problems and prospects of increased grain legume production in Southeast Asia. Paper given at First ASEAN Workshop on grain legumes, Bogor, Indonesia, Jan. 15, 1974.

Chandler, Robert F., Jr. New advances in rice research. Paper presented at a conference of science and agribusiness in the seventies, London, Feb. 19, 1974 (to be published in 1975).

Chandler, Robert F., Jr. Southeast Asia's renewable resources and their future – Rice. Paper presented at a conference sponsored by the Financial Times of London in Kuala Lumpur, on Southeast Asia's Natural Resources and the World Economy, September 20, 1974.

Chandler, Robert F., Jr. The potential impact of research on vegetable production. A paper presented at a conference on human nutrition at INCAP in Guatemala, December 1974. (The proceedings will be published in 1975).

Mew, I.P. Antagonism of soil microorganisms. Paper presented at the Annual Meeting of the Plant Protection Society of the Republic of China, Dec. 6, 1974.

Shanmugasundaram, S. AVRDC's Soybean Improvement Program. Paper presented at the First ASEAN Workshop on Grain Legumes in Bogor, Indonesia, Jan, 15-20, 1974.

Shanmugasundaram, S., T. S. Toung, T. D. Liou, and H. B. F. Wu. Photoperiod insensitivity in soybean. Paper presented at the 66th Annual Meeting of the Crop Science Society of America, Chicago, November 13, 1974.

Wu, H. B. F., T. D. Liou, S. S. Tsou, and S. Shanmugasundaram. The effects of changing source and sink relationship in field grown soybean and mungbean by CO_2 enrichment and shading. Paper presented at the 66th Annual Meeting of the Crop Science Society of America in Chicago on November 14, 1974.

Abstracts

Kommedahl, Thor, I. P. Mew, and Carol E. Windels. 1974. Microorganisms vs. captan as seed treatments for corn. Proc. Amer. Phytopathol. Soc. 1-107.

Mew, I. P., T. C. Wang, and T. W. Mew. 1974. Inoculum production and evaluation of mungbean varieties for resistance to *Cercospora canescens*. Proc. Amer. Phytopathol. Soc. 1-201.

Mew, T. W., and W. C. Ho. 1974. Evaluation of the isolation, pathogenicity and survival of the soft-rot bacteria of Chinese cabbage. Proc. Plant Protection Soc. Annual Meeting. 1974.

Mew, T. W., and W. C. Ho. 1974. Evaluation of varietal resistance to bacterial wilt in tomatoes. Proc. Plant Protection Soc. Annual Meeting. 1974.

Mew, T. W., and W. C. Ho. 1974. Isolation and pathogenicity evaluation of coliform soft rot bacteria in Chinese cabbage. Proc. Amer. Phytopathol. Soc. 1:320.

Shanmugasundaram, S., T. S. Toung, T. D. Liou, and H. B. F. Wu. Photoperiod insensitivity in soybean, Agronomy Abstracts, 1974 Annual Meetings. p. 78.

William. R. D. 1974. Competition of purple nutsedge in vegetable crops. WSSA meetings. (Abstract #174).

William, R. D. 1974. Nitrofen and hebicidal oil synergism for purple nutsedge control. WSSA meetings. (Abstract #191).

Wu, H. B. F., T. D. Liou, S. S. Tsou, and S. Shanmugasundaram. The effects of changing source and sink relationship in field grown soybean and mungbean by CO_2 enrichment and shading. Agronomy Abstracts, 1974 Annual Meeting. p. 79.

Participation in Professional Meetings

C. L. Luh, Tokyo, Kiryu, (Japan). IXth International Scientific Congress on the Cultivation of Edible

Fungi. Nov. 3-14.

C. L. Luh, Taipei (Taiwan). Annual Meeting, The Chinese Society for Horticultural Science. Dec. 7-9.

I. P. Mew, Vancouver, B. C. (Canada). American Phytopathological Society. 66th Annual Meeting. Aug. 11-15.

I. P. Mew, Riverside, Calif. (USA). Society of Nematologists, USA. 1974 Annual Meeting. Aug. 19-21.

I. P. Mew, Taipei (Taiwan). The Plant Protection Society of the Republic of China, 1974 Annual Meeting. Dec. 6-9.

T. W. Mew, Vancouver, B. C. (Canada). American Phytopathological Soc. 66th Annual Meeting. Aug. 11-15.

T. W. Mew, Taipei (Taiwan). 1974 Annual Meeting Plant Protection Society of the Republic of China. Dec. 6-9.

S. Shanmugasundaram, Bogor (Indonesia). Association of Southeast Asian Nations (ASEAN). Jan. 15-20.

S. Shanmugasundaram, Mayaguez (Puerto Rico). INTSOY. Feb. 4-6.

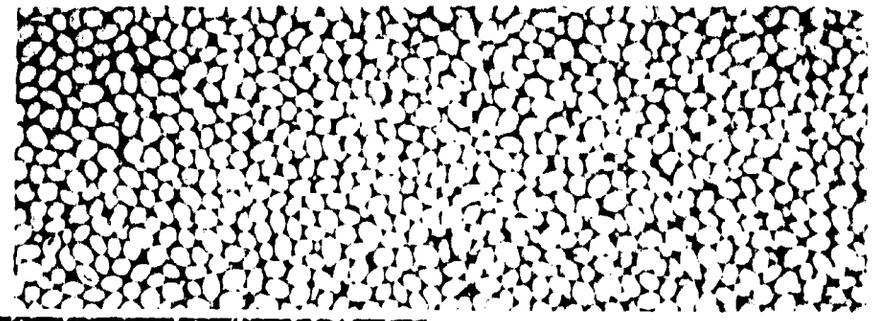
S. Shanmugasundaram, Chicago, Illinois, (USA). ASA, CSSA, and SSSA. Nov. 10-15.

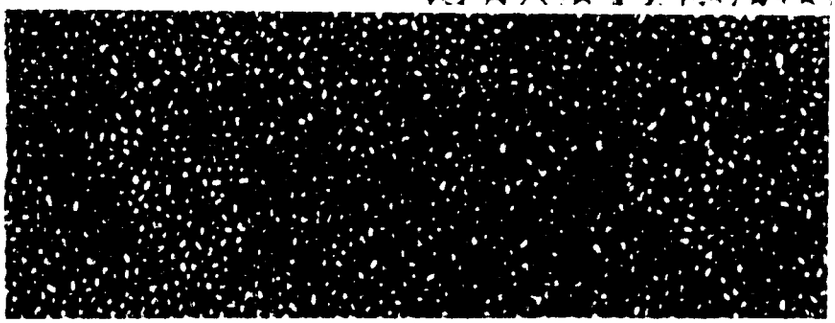
N. S. Talekar, Minneapolis, Minn. (USA). Entomological Society of America. Dec. 2-5.

T. Yoshida, Taipei (Taiwan). ASPAC Conference on Chemical Fertilizer in Asian and Pacific Region. May 29-31.

T. Yoshida, Tokyo (Japan. ASPAC Conference on Plant Problems in ASPAC Countries. July 9-11.

Glycine max



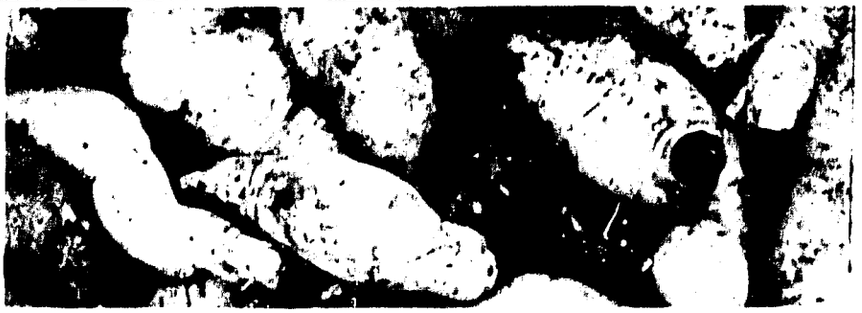


Vigna radiata

Lycopersicon esculentum

Brassica pekinensis

Ipomoea batatas



Solanum tuberosum

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