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THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

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THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER
ANNUAL REPORT FOR 1972-1973

The Asian Vegetable Research and Development Center,
Shanhua, Tainan, Taiwan, Republic of China
1974

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* *Left during 1973*

DIRECTOR'S INTRODUCTION

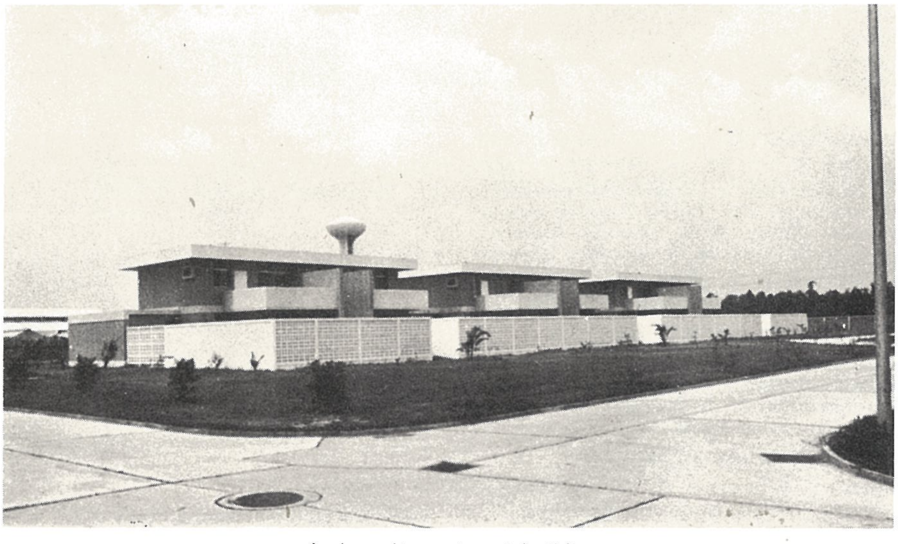
This is the first published annual report of the Asian Vegetable Research and Development Center (AVRDC). Although the Center was formally organized on May 22, 1971, it did not acquire a staff and a physical plant until some time later.

The first phase of building construction started in January, 1972. By October of the same year we were able to occupy the administration building, the laboratory building, the service building and eight residences for senior staff.

In 1973, the Center built six more senior residences, an apartment house for six research associates and six greenhouses. During the latter part of the year, work began on the cafeteria-dormitory building, which is scheduled to be finished in August, 1974. Except for such minor structures as a weather station, screenhouses and a water treatment plant, this will complete the building program as it is now envisioned.

By the end of 1973, the installation of facilities for the experimental fields was nearly completed. These included roads, border fencing and an irrigation and drainage system. Several further improvements in the experimental fields will be made as funds permit.

Financial support. Unlike the other international agricultural research centers (all of which are supported by bilateral grants within the framework of the Consultative Group on International Agricultural Research), AVRDC was organized by and is mainly supported by seven countries; namely, the Republic of China, Japan, the Republic of Korea, the Republic of the Philip-



A six unit apartment building.

pines, the Kingdom of Thailand, the United States of America and the Republic of Vietnam. In addition, the Asian Development Bank provided a grant of $300,000 to be used for general support during the first two years.

After its organization the Center received a grant from the Taiwan Canners' Association. Also it received one from the Kresge Foundation, for constructing the cafeteria-dormitory building, an essential facility for the training program.

Three unrestricted grants were received as well: $5,277.05 from the USI Far East Corporation, $4,160 from an anonymous donor and $2,500 from the International Minerals and Chemical Corporation.

The total funds received through December 31, 1973 are listed in the following table:

Grants to the Asian Vegetable Research and Development Center from 1971 through 1973

(in U.S. dollars)

Donor	Amount
The Republic of China	$1,704,190*
The United States of America	1,800,000
The Republic of the Philippines	298,571**
The Kingdom of Thailand	225,000
Japan	155,000***
Korea	75,000
Vietnam	6,000
The Asian Development Bank	300,000
The Taiwan Canners' Association	250,000
The Kresge Foundation	300,000
Miscellaneous small grants	11,937
Total funds received through 1973	$5,125,698****

* Does not include land which was provided by the Chinese Government at an estimated cost of $750,000.

** This represents the Philippine contribution for four years: thus $75,000 was kept in reserve for spending in 1974.

*** In addition, Japan furnishes the salary of a soil scientist.

**** Of this total, approximately $4.3 million was spent or committed for constructing and equipping the physical plant. The remainder was used for operating expenses.

As noted in the foregoing table, about 4.3 million U.S. dollars were spent for constructing and equipping the physical plant. The funds for buildings came from all sources except from the U.S. grant, which was restricted to the purchase of equipment and supplies of U.S. origin and to the salaries of senior staff. The Asian Development Bank grant was used in equal amounts for electrical installations in the new buildings and for the development of experimental fields.

Operating expenses in 1972 and 1973 came from portions of all grants except those from the Asian Development Bank and the Kresge Foundation.

Originally, the entire support for the Center was expected to come from member countries. However, as the research goals were developed and as inflationary pressures increased, it became clear that the anticipated country contributions would not provide for a program of sufficient scope to have a significant impact on the yield potential of the crops selected for major attention. Consequently, additional support is being sought from various foreign aid agencies not now contributing to AVRDC.

The Rockefeller Foundation provides the salary of the Director (who is also an employee of the Foundation) and in 1973 approved a grant in support of the mungbean research program. Since the funds were not received until early 1974, the grant will be recorded in the annual report for that year.

Negotiations are under way for outreach programs in 5 Asian countries. These activities will be presented in a later report when the supporting funds have been received.

General concept and objectives of the research program. The purpose of AVRDC's research program is to bring higher yield potentials to important food crops that contain more protein, vitamins and minerals than do the staple cereal grains. Furthermore, the crops being worked on, because of their adaptability to upland soils and their demand in the market, give promise of higher income, as well as improved nutrition, for the Asian small farmer who often depends almost entirely on rice for his income and food. As rice will still be the staple food for monsoon Asia, the crops that AVRDC is working on will be improved primarily as produce to be grown in conjunction with that grain. From among the more than 100 different crops that authorities class as vegetables, AVRDC carefully selected 6 for early major attention. They are the mungbean, *Vigna radiata* (Syn. with *Phaseolus aureus*); the soybean, *Glycine max*; the tomato, *Lycopersicon esculentum*; the sweet potato, *Ipomoea batatas*; the Irish potato, *Solanum tuberosum*; and the Chinese cabbage, *Brassica pekinensis*.

These six particular crops were selected for the following reasons.

The mungbean is an ancient and well-known leguminous crop of Asia. It is an excellent source of protein and is eaten in many forms, including bean sprouts, green beans, boiled dry beans, noodles and bean curd. The mungbean has never received the kind of research attention that has been directed to most other important food crops. Yet, through a concerted large-scale research program, its yield potential, now only about 1.5 metric tons per hectare, might well be doubled. This would be achieved by breeding varieties that not only make more efficient use of solar energy and soil nutrients but that are more resistant to insect and disease attack.

The soybean is a major world crop particularly in the U.S.A., Brazil and China. However, varieties suitable for the Asian tropics have never been developed. Those Asian countries (such as Japan and Taiwan) sufficiently affluent to support a large domestic animal population import huge quantities of soybeans. Given varieties better adapted to tropical conditions, the soybean could well become an important export crop for the less-developed countries of the tropics and subtropics, and a high-protein crop for local use as well.

Many of the present varieties of soybeans are unsuitable for the tropics because of sensitivity to short days and to high temperatures. It is AVRDC's objective to collect the world's soybean germ plasm and to develop improved varieties that have not only tolerance to tropical climates, but, also, greater resistance to insects and diseases.

The tomato is a popular crop almost everywhere. It is an excellent source of vitamins A and C and, in Asia is an important cash crop for small farmers. Unfortunately, in the tropics it is beset by many handicaps, principally those of disease susceptibility and of poor fruit set in hot weather. These problems are so severe that in the lowland tropics almost no tomatoes are grown during the rainy season. AVRDC has started the first truly massive approach to tomato breeding ever to be conducted in the true tropics. We expect a major breakthrough in developing high-yielding varieties for hot climates.

The sweet potato, in our opinion, is an underrated food crop for the tropics and subtropics. More people can be fed from a hectare of sweet potatoes than from a hectare of rice. In addition to vitamin A, the crop contains more minerals than does rice, and the tops can be eaten as a source of protein, vitamins and minerals. AVRDC has initiated a sweet potato improvement program with the objective of tripling the protein content and significantly increasing the carotene content of the roots of the varieties now being commonly grown. While working toward these primary goals, efforts naturally will be made to develop in the same varieties early maturity, higher yields and insect and disease resistance.

Although the white potato is a staple food crop in many parts of the world, it does not do well at low elevations in the tropics. AVRDC, in cooperation with the International Potato Center in Peru, will make a major research effort to develop a white potato that will form tubers under tropical conditions, particularly during the hot, rainy months.

The heading type of Chinese cabbage is another extremely popular crop that has seasonal difficulties in Asia. Although well adapted to higher altitudes and cooler seasons in the tropics, in hot weather it does not form heads and is readily attacked by several serious diseases. AVRDC plant breeders hope to create — as already has been done for the common cabbage — new heat-tolerant, disease-resistant varieties of the Chinese cabbage.

The staffing pattern. As is true in all the international agricultural research centers and institutes, the senior scientific staff is composed of people from many different countries. AVRDC now has scientists from 6 nations, and an even greater diversity of origin is expected in the future.

The principal staff members of the Center are listed at the beginning of this report.

One feature of our Center that is different from other such international institutions is the creation of the Research Associate position. Those holding these positions are scientists with recent Ph. D. degrees or with M.S. degrees and experience. Although the majority are Chinese, scientists from other countries are also included in this category. These positions provide for a larger and more diverse staff of well-trained scientists capable of attacking the multitude of problems in vegetable research.

Although it is still too early to evaluate this policy, it does allow an organization to maximize the efficiency of a finite budget and still compete successfully with national institutions for competent people. From the standpoint of the young scientist himself, it provides an opportunity to do independent research work, to establish a reputation and to progress to a more senior position in another organization or within the Center itself.

The departments that were staffed in late 1972 and during 1973 include plant breeding, plant pathology, plant physiology, entomology, soil science and chemistry. In addition, such essential service departments as administration, buildings and grounds, the experimental farm and the library were also formed during that period.

The Board of Directors. When the Center was formally organized on May 22, 1971, each participating country designated its member of the Board of Directors (as listed at the beginning of this report). The one change during 1973 was that Dr. Phit Panyalakshana of Thailand retired and was replaced by Dr. Bhakdi Lusanandana.

At their last annual meeting in 1973, the Board amended the Charter to provide for an expansion of its membership by four, so as to broaden the representation. These additional members will not represent countries but will be chosen for the special value of their background and experience to the development of AVRDC's program and policies. Each to serve for 4 years, they will be appointed in 1974, 1975, and perhaps 1976, in order to stagger the expiration of their terms.

Highlights of the research achievements. Although most of the remainder of this report deals with the accomplishments of our scientists since the beginning of AVRDC, we are presenting in the following paragraphs a few highlights of our research activities, for the benefit of those who do not have the time to read the full report.

The world germ plasm collection of the six vegetable crops which AVRDC stresses reached the following number of accessions by the end of 1973:

Tomatoes	3,916
Soybeans	3,064
Mungbeans and closely related species	2,176
Sweet potatoes (clones and seedlings)	1,691
White potatoes	1,501
Chinese cabbage	303

The collection of mungbeans was screened for disease and insect resistance, and varieties have been found that are resistant to one or more of the following disease or insects: *Cercospora* leaf spot, powdery mildew, yellow mosaic virus, *Pythium* root rot, root knot nematodes and bean fly.

The protein content of mungbean accessions varied from 22.5 to 27.5 percent. Preliminary studies of the physiology of the mungbean indicate that its net photosynthesis is less than that of the soybean. In addition, perhaps closely connected with this phenomenon, is the fact that the mungbean does not respond in yield to increasing plant densities.

Many mungbean varieties in the collection proved to be insensitive to photoperiod.

The soybean collection was found to contain varieties that are resistant to one or more of the following diseases: downy mildew, rust, purple seed stain, root knot and cyst nematodes and a virus disease.

When population densities were increased to 400,000 plants per hectare, a yield of 4 metric tons was obtained with soybeans.

Accessions in the collection varied in protein content from 28 to 41 percent, and in oil content from 11 to 21.5 percent.

Among the accessions of the tomato collection, 27 proved to set fruit at high night temperatures, and varieties with resistance to the following diseases have been identified: bacterial wilt (Taiwan strains), leaf mold, gray leaf spot, early and late blight, root knot nematode, tobacco mosaic virus, and *Fusarium* and *Verticillium* wilts. As inoculation studies in connection with several of these diseases have not been made, further tests are necessary.

The addition of boron to tomato pollen culture media increased both percentage germination and pollen tube growth, especially at temperatures above the optimum for fruit setting.

Net photosynthesis of a heat tolerant line was higher at high temperatures than that of a heat sensitive line.

Over 40 isolates of the bacterial wilt organism have been collected on Taiwan, their virulence tested on the tomato, and a bacterial wilt screening nursery established.

A number of accessions of Chinese cabbage have been found that will form heads in the hot season. Accessions have been identified that are resistant to bacterial soft rot, downy mildew and the turnip mosaic virus.

The sweet potato collection varied in protein content in the roots from 2.25 to 9.25 percent. This four-fold variation appears to be genetic because varieties that had high protein contents in other environments were still high when grown on our experimental farm.

The beta-carotene content of sweet potato roots varied from 0 to 22 mg per 100 grams of fresh weight.

About 10 percent of the white potato collection of tetraploid cultivars produced tubers at high temperatures, and 8 out of 18 wild diploid species tuberized at high temperatures. All tubers were small, and it remains to be seen whether varieties can be developed that will produce an economically profitable crop during the hot season.

AVRDC cooperates with the other international agricultural research centers. This is a cowpea yield trial being carried out in cooperation with IITA in Nigeria.

THE RESEARCH PROGRAM

THE MUNGBEAN*

The experimental work conducted after the arrival of the first scientists, in the last half of 1972 until the end of 1973, is presented in the following sections. For ease of reference the discussion is organized by crops rather than by departments. Thus, the work of such departments as plant pathology, plant physiology and chemistry is presented under the heading of the crop receiving attention.

As mentioned earlier the mungbean has never received the research attention accorded, for example, to the soybean. Its yield potential is low, its susceptibility to insect and disease attack is high, and many present varieties are adaptable over only narrow ranges of environmental conditions.

It seemed appropriate to concentrate first on collecting the largest possible number of known varieties from around the world, then to screen this collection for response to population density, day-length and other climatic variations and for resistance to insect and disease attack. In addition we are studying the basic physiology of the plant in an attempt to understand better the criteria for selection of the breeding materials most likely to lead to the principal objective of increased yield potential.

This section first presents the various basic studies conducted on the mungbean and then describes briefly the present status of the breeding program itself.

The world collection. The first activity of the mungbean improvement program was to acquire as many cultivars as possible from world sources. So far, we have obtained 1,816 accessions of the mungbean, 128 of the adzuki bean, 157 of the black gram, and 75 of the rice bean, making a total of 2,176 accessions of closely related species in the *Vigna* genus. To our knowledge this is the largest single collection of these particular species in existence.

By the end of 1973, much of this collection had been grown, in three fairly distinct seasons, on the experimental farm at Shanhua. The field data recorded for each entry included the number of days from planting to flowering, plant height, number and length of branches, number of pod clusters and of pods per plant, number of seeds per pod, weight of seeds and the degree of infection by powdery mildew and *Cercospora* leaf spot.

From the large collection, some 220 accessions were selected for more intensive study. It was found that yield components varied considerably. For example, the weight of 1,000 seeds ranged from 23 to 83 grams. The number of seeds per pod varied from 8 to 15, and the number of pods per plant from 13 to 100. Those accessions with favorable yield component characteristics are being intercrossed in an attempt to make genetic combinations that will result in a higher yield potential.

Population density studies. Although the literature shows that soybean yields can be raised by increasing plant density, this relationship had not been explored with the mungbean. Therefore in cooperation with the department of plant physiology, studies of the impact of plant population on yield components were made. Three different crops were used — the mungbean, the adzuki bean and the soybean. Because the results for the mungbean and the adzuki bean were very similar, only the results for the mungbean (Var. Thai Green Oil) and soybean (Var. Shih-Shih) are reported here.

The population densities ranged from 10,000 to 800,000 plants per hectare, in twelve increments.

The influence of planting density on the dry bean yield of the two crops is shown

* In this report the following common and scientific names will be used for the mungbean and those close relatives that are being studied: mungbean (called green gram in some countries), *Vigna radiata* (Syn. with *Phaseolus aureus*); Black gram, *Vigna mungo:* adzuki bean, *Vigna angularis:* rice bean, *Vigna umbellata*; and moth bean, *Vigna acontifolia.*

graphically in Figure 1. Note that mungbean yields did not increase after the planting density exceeded 120,000 plants per hectare, while the soybean yield curve did not flatten out until a density of 400,000 plants per hectare had been reached. The other significant fact is that the highest yield of the mungbean was only 1 metric ton per hectare, whereas under the same environmental conditions the soybean yields reached 4 tons/ha.

Similar relative results were obtained for the dry weight of green pods (Fig. 2) and the dry weight of pods at the green shell bean stage (Fig. 3). As would be expected for both species, there was a positive correlation between plant density and plant height (Fig. 4) and a negative correlation between density and branching (Fig. 5). Of the yield components, only the number of pods per plant was affected by population density (Fig. 6). There was no significant change, as the population density was increased, in number of seeds per pod or in the weight of 1,000 seeds.

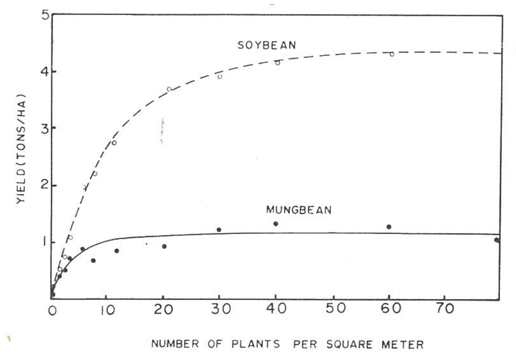


FIG. 1. EFFECT OF PLANT DENSITY ON THE YIELD OF DRY BEANS.

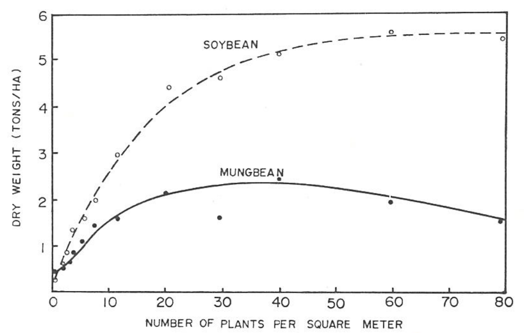


FIG. 2. EFFECT OF PLANT DENSITY ON THE YIELD OF GREEN PODS.

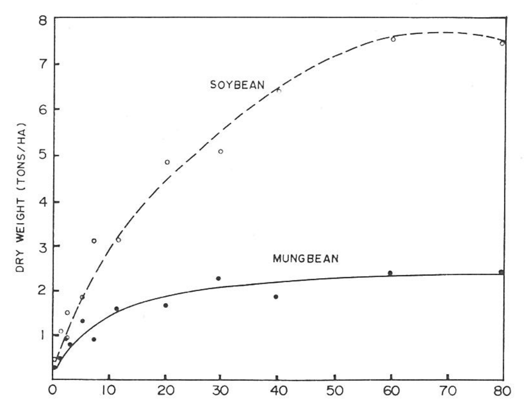


FIG. 3. EFFECT OF PLANT DENSITY ON THE YIELD OF GREEN-SHELL BEANS.

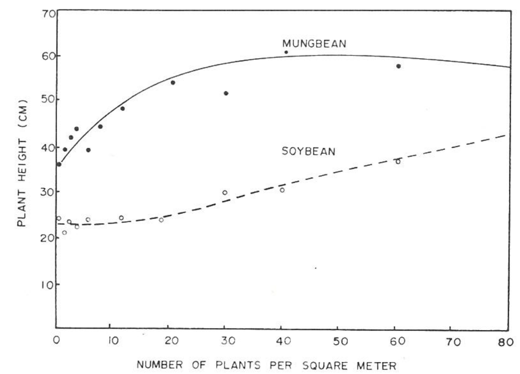


FIG. 4. EFFECT OF PLANT DENSITY ON PLANT HEIGHT.

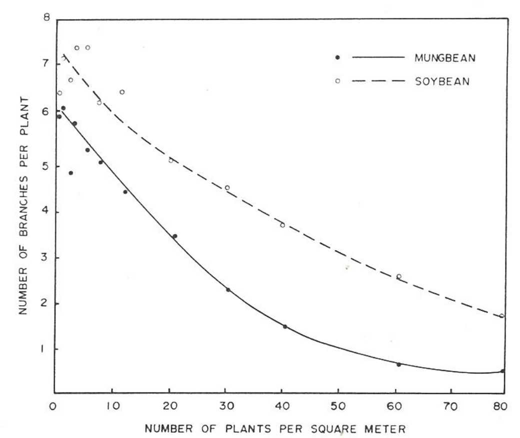


FIG. 5. EFFECT OF PLANT DENSITY ON PLANT BRANCH NUMBER.

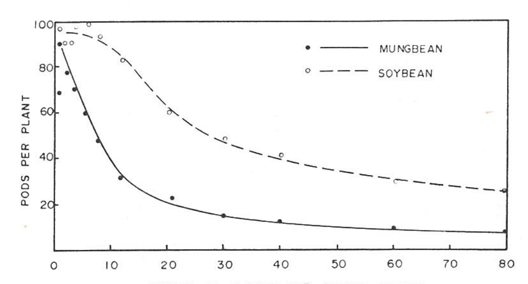


FIG. 6. EFFECT OF PLANT DENSITY ON THE NUMBER OF PODS PER PLANT.

As plant density increased, the number of flowers per plant decreased for both species (Fig. 7). However, the relative decrease was much greater for the mungbean than for the soybean. The number of flowers per plant at low populations was much higher for the mungbean than for the soybean.

Both the duration of the flowering period and the rate or intensity of flowering during this period were recorded for both species (Fig. 8 and 9). The mungbean produces flowers over a longer period of time than does the soybean. Both species exhibit a distinct peak in intensity of flowering. However, the number of flowers produced per plant is not suppressed by increased plant density nearly as much in the soybean as in the mungbean.

The percent of flowers that form mature pods was markedly different for the two species but was little affected by population density. Almost 100 percent of the soybean flowers set pods at all densities, whereas pod setting with the mungbean was only 40 percent. We believe this to be a meaningful factor affecting yield potential, since the soybean produced so much more than the mungbean. However, the physiological basis for this finding is not understood and needs further study.

With respect to breeding for higher yield potential in the mungbean, our plant density studies indicate that we must screen the world collection for those varieties that form the most pods at high densities and use them as parents in the crossing program.

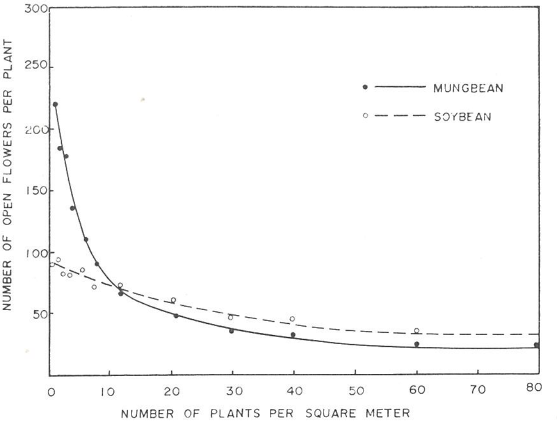


FIG. 7. EFFECT OF PLANT DENSITY ON THE NUMBER OF FLOWERS PER PLANT.

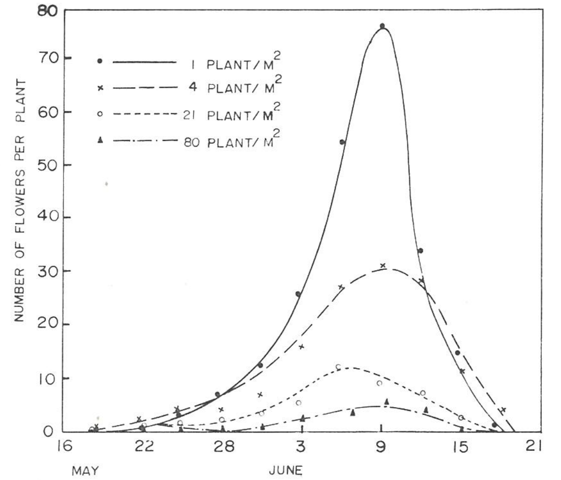


FIG. 8. EFFECT OF PLANT DENSITY ON THE INTENSITY OF MUNGBEAN FLOWERING.

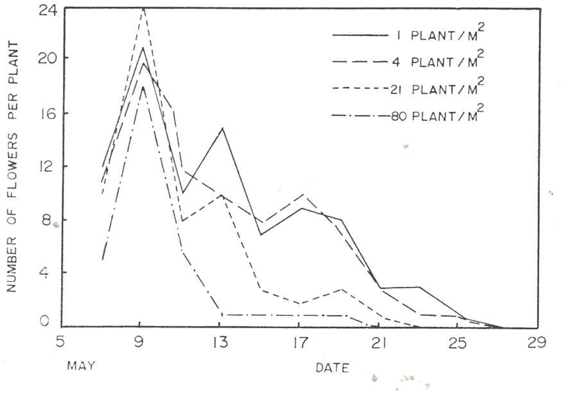


FIG. 9. EFFECT OF PLANT DENSITY ON THE INTENSITY OF SOYBEAN FLOWERING.

The effect of population density on mungbean and soybean yields is being studied by the physiologists.

Sensitivity to photoperiod. In developing mungbean varieties with wide adaptability, it seems obvious that day neutral varieties would be superior.

In 1973, in cooperation with the plant physiology department, studies were made of the flowering response of 1,602 accessions of mungbean, black gram, adzuki bean, rice bean and moth bean at 12 and at 16 hours of light (Table 1).

The mungbean is classified as a short-day plant. However, as can be seen in Table 1, many of the accessions are day neutral; so there should be no difficulty in breeding new varieties that are insensitive to length of day.

Among the relatively small number of accessions of the black gram and the rice bean tested, it is interesting to note that only 10 percent of the black gram varieties, and none of the rice bean accessions, were day neutral.

In the experiment reported in Table 1, the photoperiod was regulated by artificial illumination, which was used to extend the length of day beyond the normal light. Obviously, the studies were conducted in the months between the autumnal and vernal equinoxes in order to have maximum natural daylight of less than 12 hours.

As a further aid in selecting mungbean varieties with wide adaptability to be used as parents in the breeding program, three crops a year are grown, with the consequent exposure to variations in length of day and temperature. Furthermore, by growing three crops a year rapid advances can be made, of course, in developing improved varieties.

Table 1. Flowering response of five *Vigna* species to differential day lengths expressed as a percentage of the number of accessions flowering at 12 and at 16 hours of light.

Species	Number of accessions tested	Day length insensitive (%)	Flowering delayed at 16 hours (%)	Did not flower at 16 hours (%)	Did not flower at 12 or 16 hrs (%)
Vigna radiata var. *radiata* (mungbean)	1273	47	18	31	4
V. mungo (black gram)	131	10	10	78	2
V. angularis var. *angularis* (adzuki bean)	103	35	4	61	0
V. umbellata (rice bean)	70	0	1	43	56
V. acontifolia (moth bean)	25	32	44	24	0

By the use of artificial lights, the selection of photoperiod insensitive varieties of the mungbean are idenified.

Other physiological studies. As mentioned earlier, the population density studies were conducted in close cooperation with the plant physiologists. In addition, however, the department of plant physiology has conducted a number of separate studies which bear directly on the factors limiting the yield potential of the mungbean.

First, it seemed important to measure the yield potential of some of the more promising cultivars from the world collection. Among the various monthly trials, the planting made in March, 1973 provided the highest yields. The data for certain characteristics and for yield of 7 selected varieties are given in Table 2.

As indicated in this table, there were wide variations in dry bean yield, ranging from 867 to 2,404 kg/ha. The relative efficiency of the varieties can best be expressed in kilograms per hectare per day. The figures varied from a low of 11.9 to a high of 34.3 kg/ha/day. These top yields are much higher than those obtained by most farmers. Clearly, there is a need to create varieties that resist the environmental stresses that normally exist on farmers' fields.

A shading and nitrogen experiment was conducted to determine the degree to which bean yields are limited by the source (the availability of photosynthates and nitrogen) and by the sink (the bean's capacity either to use assimilates or to compete with other organs for assimilates).

From the preliminary data obtained in this experiment the physiologists concluded that 80 to 90 percent of the limitation in mungbean yields can be traced to source, rather than to sink (the beans themselves).

These estimates, the physiologists realize, are preliminary; and additional work will be conducted on this problem during 1974.

There are at least three facets of the source problem to be considered in connection with a leguminous crop; namely, light interception patterns of the crop canopy, photosynthetic rate per unit leaf area and the nitrogen metabolism of the plant.

Generally speaking, a good "plant type" is one in which the assortment of morphological characters ensures good light transmission into the canopy and thus allows a crop at high population densities to give a greater yield response to nitrogen applications. This suggests that to obtain maximum yields with the mungbean we should develop a plant with essentially no branching and with a relatively small leaf area per plant.

The yield of dry beans per unit land area is the product of the following major components:

$$\text{Yield (kg/ha)} = \frac{\text{Number of plants}}{\text{ha}} \times \frac{\text{Number of pods}}{\text{plant}} \times \frac{\text{Number of beans}}{\text{pod}} \times \frac{\text{Average weight}}{\text{bean}}$$

Depending on the gross plant type, the number of plants per unit area can be rather easily manipulated by growers. of However, the other yield components are relatively less susceptible to manipulation, and a proper understanding of their interrelationships seems to be important in defining the more subtle aspects of the desired mungbean plant type.

Table 2. Dry bean yield of seven mungbean varieties (March, 1973 planting)

Items / Varieties	Days to first flower	Days to last harvest	Ave. No. of pods/ plant	Ave. No. of seeds/ "filled" pods	100 seed weight (g)	Observed bean yield (air-dry weight, kg/ha)	Relative efficiency (bean production kg/ha/day)
Th - 1	39	70	21	13	6.0	2404	34.3
Th - 2	43	73	12	13	5.7	867	11.9
Th - 3	38	71	16	13	6.3	1911	26.9
Th - 4	41	72	18	13	5.3	1796	24.9
Th - 5	40	71	19	13	5.7	2047	28 8
M	34	61	19	11	3.4	947	15.5
T - 1	40	98	18	13	4.4	2046	20.9

All figures in the table are averages of three replications.

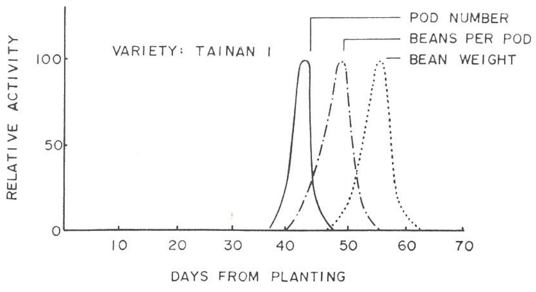


FIG. 10. THE SEQUENTIAL PATTERN OF YIELD COMPONENT IN THE MUNGBEAN.

Figure 10 reveals the sequential nature of yield component development in the mungbean. The degree of overlapping between the curves is probably controlled by both environmental and genetic factors. This pattern of development of yield components suggests the following possibilities:

(A) Since the intensity and capacity of metabolic inputs for the production of reproductive organs are likely to be limited from time to time, there may be strong competition among the various yield components. How

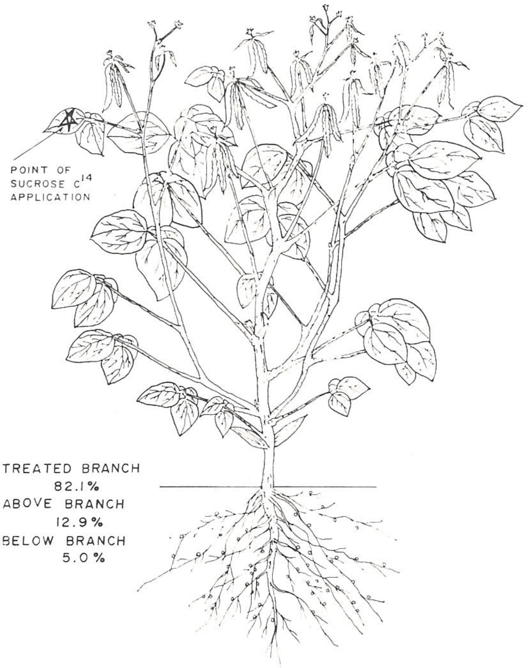


FIG. 11. THE RELATIONSHIP BETWEEN BRANCH AND MAIN STEM.

strongly they will be inversely related to each other depends on the degree of overlapping between their activity curves as well as the timing of the source limitation. Such negative correlation between yield components may not necessarily lead to a low yield but certainly prevents a truly high one.

(B) Competition is also likely to occur within any one of the three yield components, as well as among them. This implies that a growing pod may not only compete for nutrients with opening flowers and growing seeds, but also with the other growing pods on the plant. Minimizing the competition between organs in a similar stage of development seems to be an important consideration in maintaining a high number of pods per plant.

With these ideas in mind, two series of experiments were conducted with the aim of obtaining information concerning the proper patterns of leaf and pod arrangement on the stem of the mungbean plant.

The first series consisted of translocation studies with sucrose-UL-C^{14}. The second series was composed mainly of defoliation studies with the mungbean. Some high points of these experiments follow.

A branch of a plant similar to that depicted in Figure 11 was treated with C^{14}. Later analysis showed that 82.1 percent of radioactive carbon was still in the treated branch, 12.9 percent was above the branch and 5 percent was below. Thus:

(A) It seems that the branches and the main stem of the mungbean plant can be treated as independent entities. That is, the main axis of the plant does not receive a significant nutritional input from the branches. Furthermore, they compete with each other for a common input (the root system). Thus, the elimination of branches would not appear to be detrimental to the development of the main axis of the plant.

(B) About 50 to 60 percent of the recovered radioactivity was found in the trifoliate leaf on the main stem and the pod-bearing raceme in its axil. This suggests the existence of "production units" in mungbean plants. It is possible to visualize the main stem of the mungbean plant as a structure composed of several such production units. The implication of this model is of course that more units per plant will give higher yield per plant. This is depicted in Figure 12.

The result shown in Figure 13 indicates that the C^{14} in lower leaves was not appreciably translocated upward. This point deserves further checking, for the lower leaves will be shaded when the plant density is high. We need to evaluate, in normal field stands, the contribution of lower leaves to the growth organs positioned above them.

(C) The effects of partial defoliation on the elongation growth of the pod are shown in Figure 14. The lower leaves in this experiment included all of those leaves that were positioned lower than the first pod-bearing node on the main stem of a mungbean plant. The lower leaves accounted for 35 percent of the total leaf area per plant for the variety B-1. The results shown in Figure 14 clearly demonstrate that the elongation growth of the upper pods is not appreciably affected by the removal of lower leaves. However, we did observe a tendency of lodging by those plants whose lower leaves had been removed. This problem of lodging deserves serious attention by plant breeders. It means that we have to breed plants with either shorter internodes or thicker stems. The arrangement of pods on the stem (either top-heavy or evenly distributed) is also an important consideration with respect to lodging problems.

Another study was made in which all foliage was removed from a flowering and fruiting mungbean plant. Within 24 hours, all open flowers had dried. The still elongating pods became desiccated in 2 to 3 days. Flower buds and pods that had begun to swell remained viable and continued to grow at the expense of the other organs. This suggests a strong pod-to-pod and pod-to-flower competition for assimilates when the metabolic input is limited. Distributing the pods into different production units and allowing some degree of spread in time for pod development seems to be a promising way of obtaining higher yield as, obviously, this would prolong the growth duration of the crop.

It was observed in greenhouse and field experiments that flower and pod abscission are most serious when the plants are subjected either to low light intensity (through shading) or to high temperatures. The rate of flower dropping as a function of the position on the plant is shown in Figure 15. It seems that those flowers that are associated with a production unit have less tendency to absciss. On the other hand, flowers on the lower branches and those near the top of the main stem are highly susceptible to abscission when the population density is high; the rate of flower abscission seems to remain relatively constant while fewer flowers are produced (Figure 16). The temperature response curves of the mungbean's net photosynthesis and dark respiration (Figure 17) further suggest that the lack of assimilate is one of the major reasons for flower and fruit abscission and probably accounts for the production of a lesser number of flowers. These observations may have some bearing on the frequently observed unstable yield response of different mungbean varieties in different seasons. They are also relevant to any consideration of the arrangement and distribution of pods on the model mungbean plant.

Most biological scientists know that as far as CO_2 photosynthetic uptake is concerned plants are divided into C_3 and C_4-types and into those that exhibit crassulacean acid metabolism (CAM). C_4-plants are considered to be the most efficient users of low concentrations of CO_2 in photosynthesis.

Studies by the plant physiologists show definitely that the mungbean (as well as the soybean) belongs to the C_3-type with respect to photosynthetic activity.

In addition to possible change of mungbean plant type (to provide a better light distribution within the crop canopy), it seems that the intrinsic photosynthetic rates per unit leaf area also need improvement. Although the mungbean is basically a C_3-type, it is possible that quantitative differences exist among varieties of the mungbean and related species. A mass screening program for low CO_2 compensation concentration involving all of AVRDC's mungbean collections and other genotypes is in process.

As mentioned earlier under the population density section, the most important variable is the number of pods per plant. It seems clear that mungbean populations should be screened for high pod number per plant in dense populations, to select possible cultivars or genetic lines that excel in this respect.

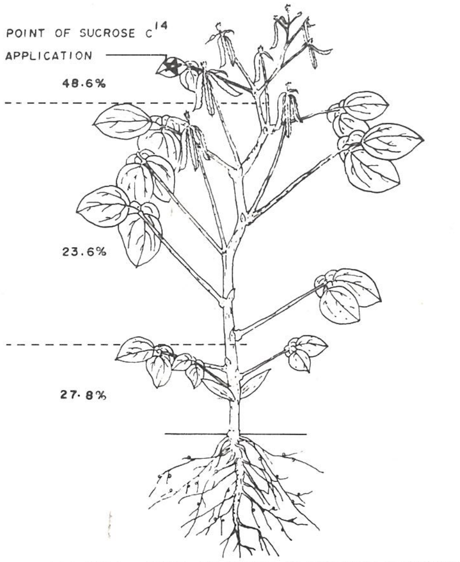


FIG. 12. TRANSLOCATION PATTERN OF LEAVES AT DIFFERENT POSITIONS ON THE MAIN STEM.

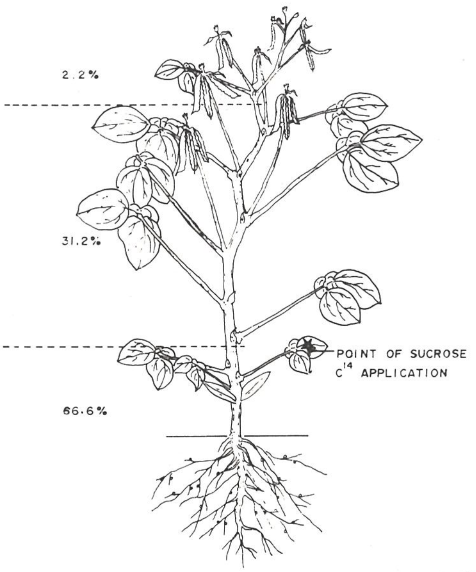


FIG. 13. TRANSLOCATION PATTERN OF LEAVES AT DIFFERENT POSITIONS ON THE MAIN STEM.

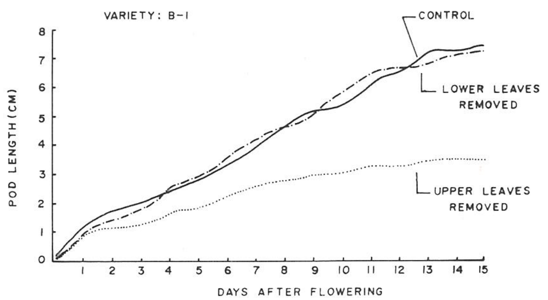


FIG. 14. EFFECTS OF PARTIAL DEFOLIATION ON THE ELONGATION GROWTH OF MUNGBEAN PODS.

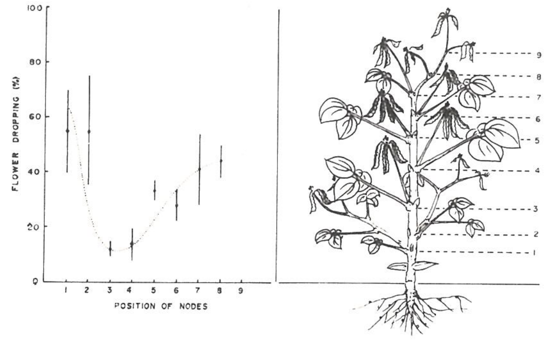


FIG. 15. RELATIONSHIP BETWEEN POSITION OF FLOWERS AND PERCENT FLOWER DROPPING IN THE MUNGBEAN.

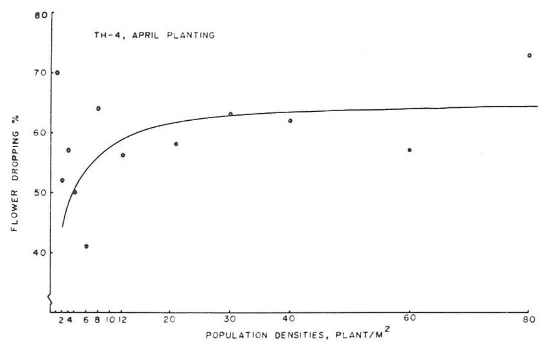


FIG. 16. EFFECTS OF POPULATION DENSITY ON THE PERCENTAGE OF FLOWER DROPPING IN THE MUNGBEAN.

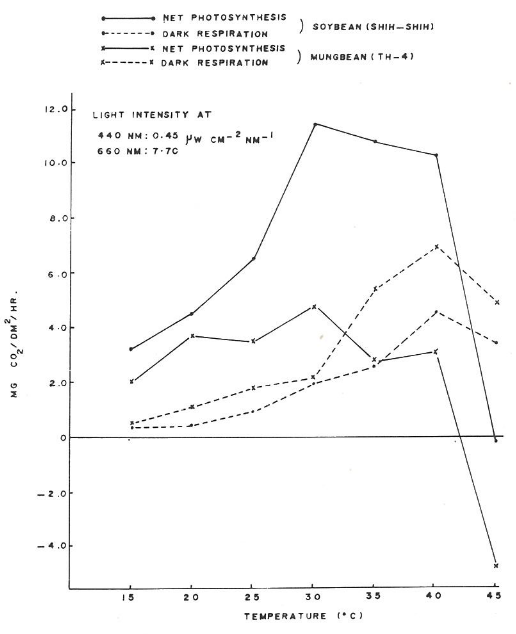


FIG. 17. EFFECTS OF TEMPERATURE ON THE RATES OF NET PHOTOSYNTHESIS AND DARK RESPIRATION IN SOYBEANS AND MUNGBEANS (WARBURG MANOMETRY).

Chemical studies. The chemistry department was not established at AVRDC until nearly mid-1973. During the early stages suitable analytical methods were tried for rapidity and accuracy.

With respect to the mungbean, the work was largely concentrated on determining the range in protein content of the seed. The frequency distribution curve for the protein (N x 6.25) content of mungbean seeds from the crossing blocks of the mungbean breeding program is presented in Figure 18. Note that the range is from 22.5 to 27.5 expressed as percent of air dry weight. As will be seen later, neither the range nor the amount is so high as for the soybean. Nevertheless, it may be possible to raise the protein level of the mungbean plant through breeding.

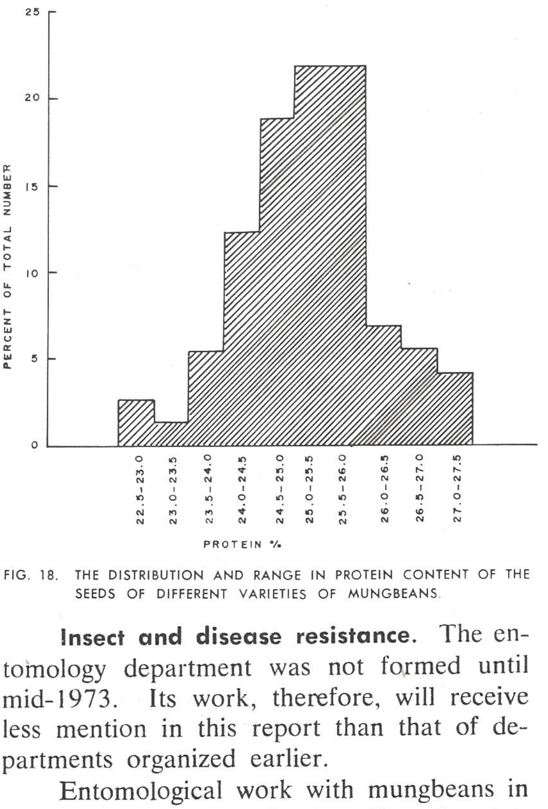


FIG. 18. THE DISTRIBUTION AND RANGE IN PROTEIN CONTENT OF THE SEEDS OF DIFFERENT VARIETIES OF MUNGBEANS.

Insect and disease resistance. The entomology department was not formed until mid-1973. Its work, therefore, will receive less mention in this report than that of departments organized earlier.

Entomological work with mungbeans in 1973 was concentrated on studies of resistance to *Melanagromyza* sp. bean flies. These flies lay their eggs in the tissues of the leaves and the larvae mine through the petiole and into the stem, often resulting in the death of the plant while it is still only a seedling. Entire crops are frequently lost to these insects unless insecticides are used. In an October planting of 900 varieties of mungbeans, 7 varieties showed 20 percent or less infestation and 19 varieties exhibited 21 to 25 percent damage. In all, 48 of the 900 varieties were infested at the rate of 35 percent or less. That the insects were present in large numbers is evidenced by the fact that 794 of the 900 varieties were infested at rates of over 50 percent. Further field experiments are being conducted in 1974 to index the entire mungbean collection with regard to susceptibility and resistance to bean fly attack. Those varieties proven resistant in Taiwan will be propagated and seed will be disseminated for further field testing at other locations in Asia. The physiological basis of resistance will also be investigated and, in cooperation with the plant breeding department, efforts will be made to combine resistance with other desirable plant characteristics.

An insecticide testing program has also been initiated, and for mungbeans one major objective is the identification of the best insecticide and application methods for bean fly control.

Another very important pest of mungbeans in Asia is a weevil, *Callosobruchus chinensis,* which initially attacks the beans in the field before harvest, but principally occurs as a pest of the beans in storage. Parasites of this insect have been isolated, propagated and will be evaluated as part of a biological control program of insect pests of mungbean.

Probably the most serious disease of the mungbean is *Cercospora* leaf spot. It is particularly damaging during the rainy season and on susceptible varieties can cause complete defoliation and great reduction in yield.

The plant pathology department has studied the species of *Cercospora* attacking mungbean on our experimental fields and has concluded that among the four species that are known to attack beans, *Cercospora canescens* is by far the major one. Occasionally conidia have been observed that resemble *C. caracallae.*

It was first necessary to find a suitable medium for growing the fungus. As can be seen in Table 3, mungbean leaf extract in an oatmeal agar stimulated conidia production at 28C in the dark. Later work showed that an extract from carrot leaves added to

Table 3. Effect of temperature and light on growth and sporulation of *Cercospora canescens* on 4 media*

Temperature and light	Sporulation								Colony diameter							
	PDA		APDA		MOA		AMOA		PDA		APDA		MOA		AMOA	
	G*	R	G	R	G	R	G	R	G	R	G	R	G	R	G	R
	no. conidia/(0.2 cm)^2 colony								cm.							
15C, Dark	0	0	0	0	1	5	0	0	0.8	1 0	0.7	1.0	0.6	0.8	0.6	0.7
20C, Dark	0	8	0	0	0	20	0	0	2.7	2.5	2.4	1.9	2.2	2.7	1.8	1.9
24C, Dark	2	32	1	0	40	200	—	200	3 5	3 0	2.7	2.2	2.6	2.8	—	2.6
28C, Dark	9	8	2	0	300	100	35	14	4 0	2.8	3.3	2.2	3.3	3.0	2.5	2.4
28C, D + L	0	100	0	26	7	300	16	30	3.0	2 2	2.5	2.0	3.0	2.4	2.5	2.4

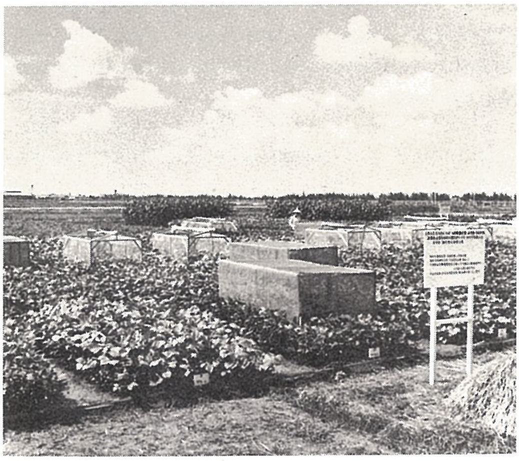
* PDA: potato-dextrose Agar, APDA: acidified PDA, pH = 4.2, MOA; mungbean leaf extract-oat meal agar, AMOA: acidified MOA, pH = 4.5, G and R refer to green and red fungal isolates, respectively.

a water agar produced more abundant sporulation. Cooked carrot slices also proved to be a good medium.

At least four types of lesions can be found on mungbean leaves: lesions with a brown halo and a white center, lesions with a clear white center but no halo, lesions with a prominent halo but no white center, and zonated brown lesions without a white center. However, when isolates were plated on agar from the different types of lesions there was little variation. Thus one assumes that these are reactions among varieties as to symptoms but are not reflections of variations in the pathogen.

In a preliminary study of the host range of *C. canescens*, the disease was found to infect the adzuki bean but not cowpeas or soybeans. A closely related species, *C. kikuchi*, attacks soybeans and seems to infect mungbeans occasionally. This needs further research.

The dissemination of the spores of *C. canescens* was studied by placing vaseline-coated microscope slides at different heights above the ground, during the various seasons. It is evident that as the rains begin in late May, the number of spores in the air increases greatly. This study will be conducted more thoroughly in 1974. As would be expected, more spores were collected at one meter above the ground than at 1.5 meters. However, there is ample evidence that the spores are disseminated from field to field by wind.



Center physiologists are studying source-sink relationships in the mungbean through shading and CO_2-enrichment studies.

Hundreds of progeny of the F_2 generation of mungbeans are being screened in this field for resistance to Cercospora leaf spot

The screening of mungbean varieties for resistance to *Cercospora* got under way in September, 1973. A preliminary screening of 230 selected varieties in the greenhouse and in the field revealed the presence of varietal resistance (Table 4). Some inconsistences between greenhouse and field studies are evident. However, several varieties were resistant in both environments. The work will be continued more intensively during the rainy season of 1974 when infection rates will be high. It is clear from the 1973 data, and from even earlier preliminary observations, that high resistance to *C. canescens* exists and that there is every reason to believe that this characteristic can be transferred to otherwise superior varieties.

Benomyl, when applied to the soil, gave rather good control of *C. canescens* but seemed to increase root infections from *Pythium* and *Rhizoctonia*. Undoubtedly, varietal resistance will prove to be the best weapon against *Cercospora* leaf spot attack.

Other diseases that attack the mungbean, and which are receiving the attention of AVRDC plant pathologists, are *Rhizoctonia* root rot, which can cause severe damping off of seedlings when cool temperatures prevail; *Pythium* blight, which may damage both young and old plants in the rainy season; the root knot nematode; powdery mildew (*Erysiphe polygoni*), which on Taiwan seems to cause damage only in the winter season; and an apparent virus disease, the symptoms of which are bright yellow patches interspersed with green areas on the leaves.

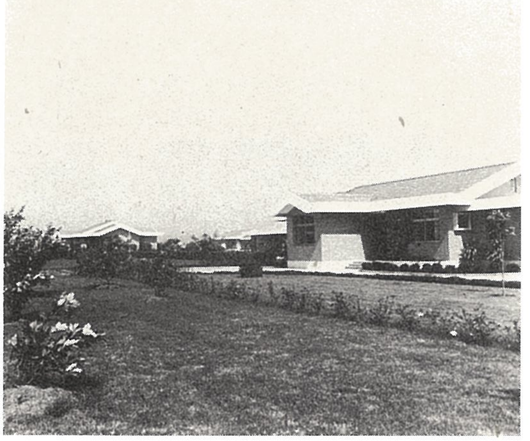
Each of the diseases listed above will be studied much more intensively in 1974 and 1975, and our pathologists will travel widely to observe the symptoms and occurrence of mungbean diseases in other Asian countries. Throughout their work, of course, our pathologists, in cooperation with the breeders, will seek varietal resistance to all major diseases of the mungbean.

The breeding program. As can be seen from the preceding sections of this report on mungbean research, the world collection has been screened for such characteristics as yield components, maturity, photoperiod sensitivity, adaptability to seasonal variations in both temperature and day length, and resistance to insects and diseases.

Crossing blocks composed of about 100 varieties selected from the world collection are established each month (except during the cold months of December, January and February). The composition of these blocks is changed monthly as superior varieties are identified from the screening work.

By December, 1973, 902 successful crosses had been made. Of these, 671 were in the F_1 generation, 332 in the F_2, and 129 in the F_3. We know of no other mungbean program anywhere that has been carried out with such intensity. We are confident that it is a start in bringing the mungbean out of its semi-wild state into that of a truly domesticated crop. As the F_3 generation is observed, there is evidence that increased disease resistance and superior yielding ability are developing.

Already some of the advanced segregating lines are being sent out to cooperating scientists in other countries. For example, in the fall mungbean harvest of the 380 F_2 populations, 38 selections were identified that had good to excellent qualities with respect to disease resistance and yield components. These populations were bulk harvested and offered to 34 scientists in 20 countries. There has been a good response to this offer. As AVRDC gets its outreach programs under way, many more tests of the adaptability of our advanced lines in other environments will be undertaken.



The Center has residential accomodations for 20 senior staff families.

Table 4. Reaction of mungbean accessions to *Cercospora canescens* in greenhourse and field screening*

Acc. No.	Disease score**			Acc. No.	Disease score**		
	Greenhouse	Field			Greenhouse	Field	
		Rep. 1	Rep. 2			Rep. 1	Rep. 2
1323	VS	S	MR	1892	S	S	S
1324	VS	S	S	1476	R	R	R
3120	MR	R	RR	1301	S	VS	S
3121	R	R	R	1340	S	S	S
3127	MR	MR	*	1342	MR	S	S
3122	MR	S	R	1417	R	R	R
F3#5	S	R	R	1948	R	R	R
1047	MR	MR	—	2340	S	MR	MR
1308	R	MR	R	2344	MR	MR	MR
1960	R	R	R	2345	S	S	S
1545	MR	S	S	2010	S	S	S
Cy-13-8	VS	VS	VS	1152	VS	S	S
1888	R	R	S	2174	S	S	—
1054	R	R	R	2179	R	R	R
1056	R	R	R	2182	MR	S	S
1059	MR	MR	MR	2184	R	MR	S
2367-1	MR	R	R	2193	S	S	S
2367-2	S	MR	—	2224	MR	R	R
2779	R	R	—	2273	MR	MR	MR
1330	R	R	R	1066	MR	R	MR
5039	MR	S	S	2281	S	R	R
5048	VS	S	VS	2282	S	S	MR
1542	VS	S	S	2284	MR	MR	S
1854	S	MR	S	1381	MR	S	R
1963	MR	S	S	1944	MR	MR	MR
1412	MR	S	S	1398	S	S	R
1948	R	R	MR	1392	MR	S	MR
1944	R	R	R	1350	MR	R	R
1398	R	MR	R	2357	VS	VS	S
1392	R	S	S	SN759	VS	VS	MR
1390	R	S	S	SN760	VS	S	MR
1321	R	R	R	SN763	VS	S	R
1322	R	S	S	SN766	MR	MR	MR
1326	VS	S	S	SN767	VS	MR	R
1946	VS	VS	VS	SN769	MR	MR	MR
1952	VS	S	VS	SN770	S	MR	MR
1954	VS	S	S	SN771	S	R	R
1944	VS	S	S	SN772	S	MR	R
SN78	VS	S	S	SN773	S	S	MR
1548	S	MR	MR	SN774	VS	S	MR
	—	—	—	SN775	VS	S	MR
1693	S	S	VS	SN776	S	MR	MR
1810	VS	S	VS	SN777	VS	S	MR
1851	VS	VS	VS	SN780	VS	S	MR
1852	VS	VS	VS	SN790	S	MR	MR
1852(SN262)	VS	VS	VS	2384	VS	S	—
1889	S	S	S	F3#20	MR	R	R

* Accessions through 2179 were screened in greenhouse in September and October 1973 and accessions 2182 F3#20 were screened in greenhouse in November, 1973. Field screening was conducted in November 1973 for all the accessions.

** Disease score, R: resistant, MR: moderately resistant, S: susceptible and VS: very susceptible.

In studying certain closely related species of the mungbean, it was discovered that the rice bean (*V. umbellata*) seems to be highly resistant to bean fly attack. Since, as yet, no true mungbean variety has shown this degree of resistance, we have been anxious to make an interspecific cross between the mungbean and the rice bean. Of the 59 attempts at this cross, only one plant survived to flower in the F_1 generation. This plant was completely sterile and all efforts to backcross it to the parents have failed.

Other interspecific crosses, also, interest us. The black gram (*V. mungo*) appears to have better resistance to the bean fly than does *V. radiata,* and some varieties are highly resistant to powdery mildew. The adzuki bean (*V. angularis*) has some striking plant characters which may add yield potential to the mungbean, one being a lanceolated leaf that would reduce mutual shading, the other, a dwarf stature that resists lodging.

So far the only "successful" cross we have made is between the mungbean and the black gram. However, because we have been unable to get viable seed from backcrosses to the parents, the success was truly a limited one. When natural selfing was allowed to occur in the F_1 generation, only 85 F_2 seeds were harvested, all of poor quality. Of this number, 43 were induced to germinate and will be observed further in 1974.

The breeders plan to explore embryo culture techniques for interspecific crosses, and chemical treatment to induce compatibility.

Over 900 mungbean crosses had been made by the plant breeders by the end of 1973.

THE SOYBEAN

The soybean is a major world crop, yet no international agricultural research center is giving it major emphasis. Therefore in March 1973, AVRDC decided to take it on as one of its six principal crops.

The goal of AVDRC's soybean improvement program is to develop and select varieties that are particularly well adapted to the tropics and subtropics, where too few soybeans are grown today and where yields on farmers' fields are low.

Our early opinion is that the tropical soybean should have low photoperiod sensitivity, should not flower too early in hot weather (some varieties when grown in the tropics start flowering before they have developed enough plant size to produce a satisfactory crop) and should have high resistance to insect and disease attack.

As with the mungbean, the plant breeders' first effort was to accumulate a sizable germ plasm collection from around the world to serve as the basis of our breeding and selection program.

The research achievements in 1973 with soybeans are less noteworthy than those with mungbeans because the program got off to a late start. By the time sufficient soybean varieties had been acquired, the year was half over. However, a substantial foundation for the 1974 program has been laid.

The world collection. By the end of 1973, the plant breeders had obtained 3,064 soybean accessions for AVRDC's germ plasm collection, and many more varieties are expected in 1974. These accessions came from 10 countries directly to us, but basically the collection had a much wider origin. For example, the varieties from Taiwan, which totalled 1,939, came from an earlier search for germ plasm from around the world.

During the summer of 1973, an observational trial of 1,994 varieties was carried out. Based on such characteristics as crop duration, number of pods per plant and apparent resistance to insects and diseases, 230 accessions were selected. Seven of these cultivars exhibited low leaf-feeding insect damage, and 12 produced exceptionally high numbers of pods. Such selections will form the basis of the crossing program.

Physiological studies. As was shown in the section on mungbeans (Figures 1 to 9), the soybean can stand close planting much better than can the mungbean. Therefore, the highest yields undoubtedly will be obtained in dense populations (400,000 to 600,000 plants/ha) under intense management.

In late 1973, a large number of soybean varieties from the world collection were tested for photoperiod sensitivity. However, since the experiment was not completed until 1974, the results will be included in the next annual report.

As with mungbean varieties, wide adaptability requires photoperiod insensitivity. The University of Minnesota reported that they had identified six accessions of plant introductions that were insensitive to day length in Minnesota. Because such a phenomenon needs testing in other environments, we obtained these lines and determined their response to photoperiods ranging from 8 to 18 hours.

This is an international soybean trial that AVRDC is conducting in cooperation INTSOY of the University of Illinois.

Table 5. Mean number of days from emergence to flowering of soybeans under six photoperiods

Photoperiod Treatment		Accessions					
		153,212	189,876	297,550	196,529	154,194	227,323
T1	8 hr.	20.7	18.3	19.3	16.3	19.3	22.7
T2	10 hr.	19.0	17.3	17.0	15.3	17.3	18.3
T3	12 hr.	21.7	17.3	19.7	16.3	17.7	18.0
T4	14 hr.	22.0	19.7	20.7	18.0	20.0	18.7
T5	16 hr.	22.7	18.7	19.0	16.0	19.3	18.7
T6	18 hr.	23.7	19.7	19.3	18.0	20.3	23.0
Total		129.8	111.0	115.0	99.9	113.9	119.4
Mean		21.63	18.50	19.20	16.65	19.00	19.90

The plants were grown in clay pots. Those that were to receive a light period less than the normal day length at that season were placed in a dark room, after having received their allotted exposure. Artificial light from incandescent lamps was used to extend the photoperiod beyond normal day lengths. The results of this experiment are shown in Table 5.

It will be noted that all six accessions are insensitive to day length under the temperature conditions of Shanhua, Taiwan. Although it is evident that day-neutral soybean germ plasm exists, these particular accessions, when grown in a warm climate, tended to flower too early. The result is that the plant has too little leaf and stem surface to produce a sizable crop. Soybean breeders consider that 35 to 40 days of vegetative growth before flowering is ideal. Time will tell whether photo-insensitive varieties that have this characteristic can be found or can be developed.

Chemical studies. The protein content of several hundred soybean varieties from the crossing blocks was determined by analyzing for nitrogen by the Kjeldahl method. The distribution of the protein (N x 6.25) content of the seeds of the varieties is shown in Figure 19. Note that the range is from 29 to 40.5 percent.

Soybean breeders need a quick method for separating individual seeds for oil and protein contents. Since these characteristics are negatively correlated and since oil is lighter than protein, it was reasoned that a simple measurement of the specific gravity would suffice. Studies by the chemistry department revealed the following coefficients of correlation among oil content, protein content and specific gravity of individual seeds:

Protein and fat, r = -0.777
Protein and specific gravity, r = 0.767
Fat and specific gravity, r = -0.862

It can be concluded that specific gravity is as good an indicator of fat content as is a measurement of protein content.

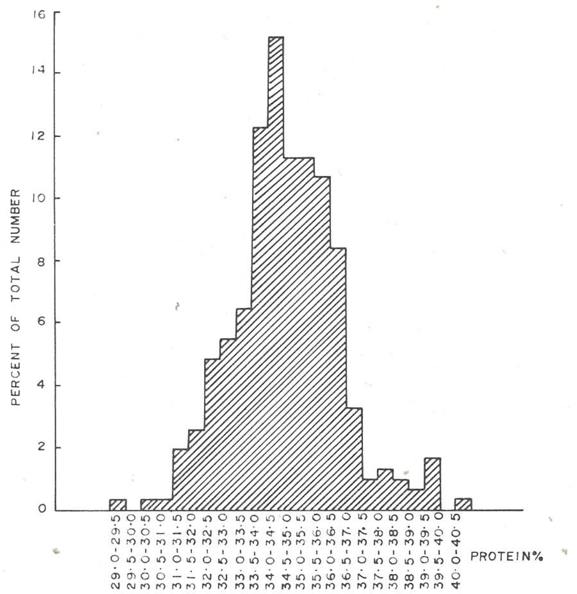


FIG. 19. THE DISTRIBUTION AND RANGE OF PROTEIN CONTENT OF THE SEEDS OF DIFFERENT VARIETIES OF SOYBEANS.

Entomological studies. Several hundred different species of insects occur on soybeans throughout the world with most major pest problems occurring in the lower latitudes. Among the more important pests of soybeans observed at AVRDC in 1973 were the southern green stinkbug (*Nezara viridula*), spider mites (*Tetanychus* sp.), beanflies (*Melanagromyza* sp.), leafhoppers (*Empoasca* sp.) and various leaf-feeding beetles including *Adoretus sinicus* and *Anomala cupripes*. Podboring moth larvae may also be a serious problem in Asian countries. It was found that when soybeans were grown continuously, stink bug populations increased to serious economic levels. They feed on the developing bean in the pod, reduce crop yield and lower seed germination rates. Where soybeans are grown near grassy areas, the adults of several species of white grubs frequently feed on the foliage leaving the leaves riddled with holes or fragmented. However, soybeans can tolerate considerable defoliation before yield is affected. Those insects that feed on the plant when it is young or on the developing beans in the pod are usually the most damaging.

In addition to evaluating numerous insecticides for soybean insect control, the entomology department is in the process of conducting a search for useful biological control agents including virulent strains of insect pathogenic fungi (*Beauveria bassiana* and *Metarrhizium anisopliae*) and parasites that may be reared in an insectary for field release.

Large-scale testing of soybean varieties for resistance to bean flies was begun in late 1973 and will be reported in 1974. As with mungbeans, the entomology department is working to classify the entire AVRDC soybean collection in regard to resistance and susceptibility to these highly important pests. Varieties proven resistant in Taiwan will be propagated for testing elsewhere in Asia and used in the development of new and better soybean varieties.

Pathological studies. Observations made on Taiwan and elsewhere in Southeast Asia indicate that the most serious disease of soybean is soybean rust (*Phakopsora pachyrhizi*). This fungus disease develops on the leaves, on the leaf stalks and sometimes on the stems. The first symptoms are small grayish brown spots which gradually change to brown or dark brown. The infected spots are more abundant on the under side than on the upper side of the leaves. If the infection is severe, the leaves and even the stems turn yellow. Eventually the leaves drop off. Usually the disease attacks the lower leaves first, gradually working up the plant.

The plant pathology department, in cooperation with the soybean breeders, screened 1,996 entries in the world collection during the summer of 1973. No varieties proved to be free of disease.

In a later study of over 1,000 varieties in the Pingtung area of Taiwan, where soybeans are grown commercially following the second rice crop, all varieties again showed symptoms of the disease. However, in that study the symptoms were separated by degrees of severity. The results are shown in Table 6.

Note that 23.7 percent of the varieties had only 1 to 10 lesions per leaf. These preliminary investigations indicate that varieties can be developed that will be sufficiently resistant to rust so that no serious economic loss will occur even though no fungicides are applied.

In 1974, detailed studies of soybean rust will be conducted, including relationships between weather conditions and the severity of the disease, the establishment of a rust screening nursery, the host range and possible physiological races of the rust. Eventually, estimates of economic loss from disease infection will be made.

Table 6. Screening of rust, *Phakopsora pachyrhizi*, infection among AVRDC's soybean accessions planted at Pingtung, DAIS.

Uninfected	0	
Mildly infected*	245	23.7%
Moderately infected	483	46.8
Heavily infected	304	29.5
Total screened	1,032	100.0

* mildly infected — about 1 to 10 lesions per leaf.
moderately infected — between 11 and 50 lesions per leaf.
heavily infected — over 50 lesions per leaf.

Date planted — 10/17/1973.
Date screened —1/3 and 1/4/1974.

Downy mildew (*Peronospora manshurica*) can be serious on soybeans in the tropics during the hot, rainy season. About 150 varieties in the soybean crossing blocks were observed for their susceptibility or resistance to downy mildew. In the season of heaviest infection 67 percent of the varieties showed resistance. Thus it appears that there is adequate parental material to impart resistance to improved varieties.

A pod-rot and a purple seed stain disease have been observed on our soybean plots, and their nature and seriousness will be studied in 1974.

Soybean mosaic virus is present to a limited extent in most soybean-growing areas. However, generally it does not cause severe losses. It is carried by seed and by aphids and can also be mechanically transmitted. AVRDC will screen its varieties for resistance in the greenhouse, using mechanical inoculation techniques.

Root knot nematodes attack the soybean, and resistant varieties will be sought.

The breeding program. Based on the screening activities for disease and insect resistance, for favorable yield components and plant type, 863 crosses had been made by December 31, 1973. Of this total, 613 were in the F_1 generation, 250 were in F_2, and 3 were in the F_3.

The soybean exhibits a greater variation in leaf type, seed size, protein content and pod number per plant than we have yet observed in the mungbean. This is partly due to the fact that man has investigated the soybean rather thoroughly and has developed varieties with widely differing characteristics. We are confident that we can develop improved varieties for the tropics and subtropics that will be superior to those now being grown.

The 863 crosses that have been made include, as parents, varieties that appear to be superior in one or more characteristics. These consist of resistance or tolerance to the following: soybean rust, root knot nematodes, *Phytopthora*-caused root diseases, cyst mematodes, mosaic virus, leaf-eating insects, poorly drained soils and shattering. In addition, of course, a number of crosses were made to incorporate insensitivity to day length, high protein content, and high yield potential. From these crosses, and from many others to come, exciting new varieties should develop.

Center scientists made over 500 soybean crosses in 1973.

THE TOMATO

The principal objectives of the tomato improvement program are to develop new varieties that will set fruit during the hot rainy season in the tropics and will have high resistance to such serious diseases as bacterial wilt, tobacco mosaic virus, and to a number of fungus diseases that attack the leaves.

As with the mungbean and the soybean, our first effort was to acquire as much as possible of the world's tomato germ plasm, which could then be screened for heat tolerance and disease resistance.

The world collection. By December 31, 1973, the Center had received 3,916 accessions of *Lycopersicon* from 78 different countries. The numbers by country of origin are shown in Table 7.

From a collection of such size and diversity, we should be able to create new cultivars for the tropics that are superior to anything that now exists.

Most of the accessions belong to the common garden tomato species, *Lycopersicon esculentum*. However, we were able to ac-

Table 7. Distribution of *Lycopersicon* accessions from 78 countries

Country	No. of Accessions	Country	No. of Accessions
Afghanistan	12	Iran	63
Argentina	53	Iraq	2
Australia	25	Israel	20
Balearic Islands	1	Italy	63
Baluchistan	3	Japan	21
Bangladesh	1	Korea	4
Bolivia	65	Lebanon	2
Brazil	88	Malaysia	10
Guyana	1	Manchuria	14
Bulgaria	25	Mexico	95
Canada	126	Morocco	15
Canary Islands	1	Nepal	1
Ceylon (Sri Lanka)	1	Netherlands	30
Chile	64	New Caledonia	1
China (Mainland)	51	New Guinea	2
China (Taiwan)	63	New Zealand	1
Cook Island	2	Nicaragua	2
Columbia	98	Nigeria	19
Costa Rica	9	Norway	1
Cuba	7	Palestine	2
Czechoslovakia	64	Panama	16
East Africa	1	Peru	315
Ecuador	120	Puerto Rico	22
Egypt	2	Philippines	113
El Salvador	371	Poland	44
England	25	Romania	5
France	12	Scotland	10
Galapagos Islands	3	South Africa	17
Germany	19	South America	1
Ghana	3	Sweden	3
Greece	5	Switzerland	2
Guam	3	Syria	6
Guatemala	264	Thailand	9
Honduras	18	Turkey	192
Hong Kong	10	U.S.A.	787
Hungary	136	U.S.S.R.	77
India	75	Venezuela	28
Indochina	1	West Pakistan	3
Indonesia	2	Yugoslavia	68
	Total		3,916

quire some of the other species of the same genus as well as some crosses. The distribution by species is recorded in Table 8.

Table 8. Species distribution of *Lycopersicon* accessions

Species	Number
L. esculentum	3533
L. pimpinellifolium	132
L. peruvianum	70
L. cheesmanii	1
L. hirsutum	15
suspected crosses:	
L. esculentum x *L. pimpinellifolium*	163
L. esculentum x *L. hirsutum*	2
Total	3916

The wild species of *Lycopersicon* have served as sources of important economic traits. For example, *Fusarium* wilt resistance was derived from *L. pimpinellifolium*, and resistance to root knot nematodes was found in *L. peruvianum*.

Much of the world collection was screened for heat tolerance during the summer of 1973. The results are shown in Table 9.

Table 9. The distribution of fruit setting among 3,259 tomato accessions during the summer of 1973.

Fruit Setting Score	Number of Varieties	Percentage of Total
1.0 — 1.9	2,570	78.9
2.0 — 2.9	509	15.6
3.0 — 3.9	153	4.7
4.0 — 5.0	27	0.8
Total	3,259	100.0

Legend: 1.0 — No fruit to light setting
2.0 — Light to medium setting
3.0 — Medium setting
4.0 — Medium to heavy setting
5.0 — Heavy setting

During the screening period (mid-April through July), minimum night temperatures were never below 21C and most of the time were between 23 and 25C.

It is obvious that nearly 80 percent of the tomato varieties set almost no fruit during the warm months. Only 27 (0.8 percent) of them showed high levels of heat tolerance. These, of course, are being used as parents in the crossing program.

Physiological studies. The principal objective of the physiology program with tomatoes in 1973 was to find out why high night temperatures have such an adverse effect on fruit setting.

It is known that in other plants poor fruit set is caused mostly by low pollen grain germination, or by slow pollen tube growth, or by both. A series of experiments was set up to investigate these possibilities with the tomato.

The first experiment was to study the impact of the composition of the cultural medium on pollen germination and growth. Some years ago evidence was found that boron influences pollen growth; so several of the treatments involved this element. The results of the first study are presented in Table 10.

Table 10. Effects of composition of the medium on tomato pollen germination and pollen tube growth.

Composition of the Medium	Germination (%)	Pollen tube length (microns)
10% Sucrose only	0	—
10% Sucrose + 100ppm H_3BO_3	21.2	807.2
10% Sucrose + 300ppm $Ca(NO_3)_2$	0	—
10% Sucrose + 100ppm KNO_3	0	—
100ppm H_3BO_3 only	7.7	494.4
All of the ingredients listed above	28.7	735.6

Variety tested: Healani
Germination temperature: 25C.
Duration of study: 3 hours

Bacterial wilt screening nurseries are being established in tropical Asia to identify resistant lines in segregating populations.

Next we investigated the effect of the concentration of boric acid in the cultural medium. As shown in Figure 20, the optimum concentration for pollen tube growth was 100 ppm of boric acid while that for pollen grain germination was 200 ppm. However, there was so little advantage of 200 over 100 ppm that in all future experiments a concentration of 100 ppm of boric acid was used.

Next to be studied was the effect of temperature on pollen tube growth at a fixed concentration of boric acid. The results are shown in Figure 21. It is apparent from this *in vitro* experiment that pollen tube growth increases as temperature increases up to 28C, and then decreases. As indicated earlier, high night temperature is considered to be the critical factor in limiting fruit set. Other workers have reported a temperature range of from 15 to 20C to be optimum. Other preliminary results obtained by our physiologists show that pollen tube growth (*in vitro*) is significantly increased at temperatures well above the optimum range for fruit set when boron is added to the medium. Analyses of the boron content of various parts of a heat-tolerant and heat-sensitive variety showed that the stamens, petals and calyx of the heat-tolerant line had a higher boron content than did those organs of the heat-sensitive variety.

During the course of these boron studies it was noted that the heat-tolerant variety tended to grow faster in the summer, and more slowly in the winter, than did the heat-sensitive variety. The heat-tolerant variety also had a higher net photosynthetic rate at high temperatures (30-35C). However, the rates for the two varieties were similar at lower temperatures.

The studies on factors responsible for heat tolerance in the tomato will continue, with the expectation of further clarifying the relationships involved. The physiologists are seeking a test that will allow the screening of tomato varieties for heat sensitivity at an early growth stage.

Pathological studies. The most serious disease of the tomato in the tropics and subtropics is considered to be bacterial wilt. The pathogen is *Pseudomonas solanacearum*. Like many other diseases, the organism mutates readily, and many strains, races, or pathotypes therefore occur.

The pathologists have established a bacterial wilt screening nursery on the AVRDC experimental farm. They have collected more than 40 isolates of the organism on Taiwan and have inoculated susceptible varieties with them in the nursery.

At the end of 1973, the disease organisms were well established in the nursery, in preparation for a mass screening of tomato varieties to be initiated in early 1974. Similar nurseries eventually will be established throughout the Asian tropics.

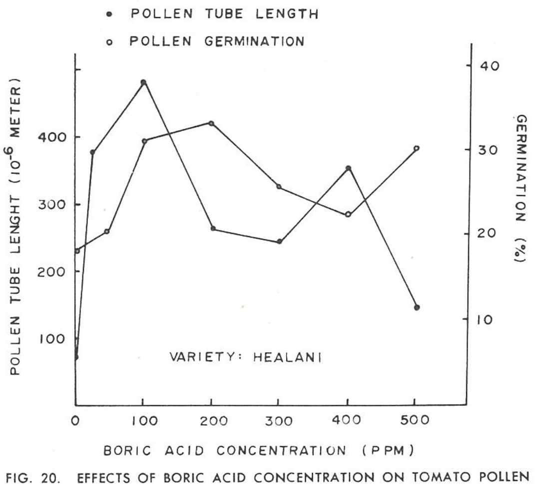


FIG. 20. EFFECTS OF BORIC ACID CONCENTRATION ON TOMATO POLLEN GERMINATION AND POLLEN TUBE GROWTH.

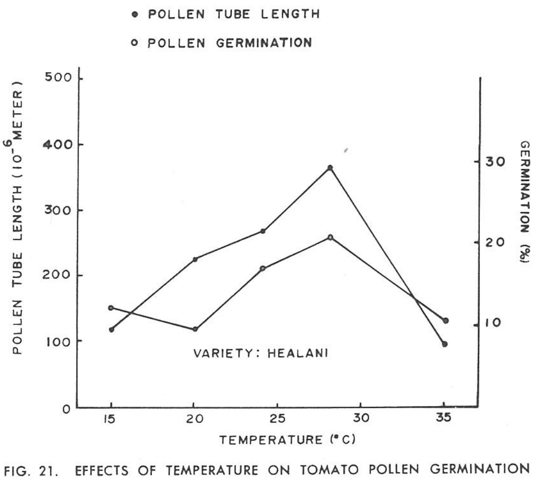


FIG. 21. EFFECTS OF TEMPERATURE ON TOMATO POLLEN GERMINATION AND POLLEN TUBE GROWTH. (BORATE CONCENTRATION: 100 PPM)

Most of the work with bacterial wilt in 1973 was centered on establishing the best techniques for inoculation and for screening large numbers of tomato varieties. An important consideration, of course, is the virulence of the different isolates of the pathogen.

Using a standard susceptible variety, Yellow Plum, plants were inoculated with 6 different isolates at varying ages. The results are shown in Table 11.

Table 11. Average number of days after inoculation with *Pseudomonas solanacearum* that plants of a susceptible tomato variety wilted.

Age of plants (days after planting)	Isolate					
	44	23	11	8	2	19
39	11	7	0	9	8	19
46	20	9	0	11	10	+*
53	16	10	0	10	10	+
60	14	9	0	10	10	+

* + indicates that the plants wilted mildly but did not die.

From the data it is clear that plants can be inoculated at any age between 39 and 60 days with satisfactory results. Furthermore, isolates vary from non-virulent (No. 11) to highly virulent (Nos. 23, 8 and 2).

Temperature is another important factor. Varieties that are resistant in cooler climates are often susceptible when grown in a warmer climate.

To demonstrate the influence of temperature, plants were grown in flats inside a greenhouse and the same varieties were grown simultaneously outside. The results are shown in Table 12.

From these data it is clear that susceptible varieties show increased resistance when grown at lower temperatures. The average maximum soil temperatures inside the greenhouse during the course of the experiment were 10 to 15C higher than outdoors, and the average minimum temperatures were 3 to 5C higher inside than outside.

There are several other serious diseases of the tomato in tropical regions, of which the tobacco mosaic virus probably is the most important.

A survey of our experimental fields showed that only the wild species of *Lycopersicon* are free of tobacco mosaic virus. However, if infection does not occur until the fruiting stage of the plants, little economic loss results.

Two surveys were conducted of the incidence of tomato diseases in our world collection of varieties. One was on three plantings made in April and harvested in August, 1973, when temperatures were high. The other was on crops planted in late October and early November, when weather, of course, was much cooler.

The April plantings showed high inci-

Table 12. Reactions of bacterial wilt-resistant lines of tomatoes to isolates of *Pseudomonas solanacearum* in the greenhouse and outdoors during the winter months.

Acc. No.	CK		Isolate 2		8		23		35		40		42	
	G	O	G	O	G	O	G	O	G	O	G	O	G	O
3180	O	O	S	MS	S	MR	S	R	S	MR	S	MR	S	MR
95	O	O	MS	R	MS	MR	MR	R	MR	R	MR	R	MR	R
97	O	O	S	MR	S	MR	S	R	S	MR	S	MR	S	MR
37	O	O	S	MR	S	MR	MS	R	S	R	S	R	S	MR
29	O	O	R	R	R	R	MR	R	R	R	R	R	MR	R
21B	O	O	MR	R	R	R	R	R	R	R	R	R	R	R
96	O	O	MR	R	MR	R	MS	R	MS	R	MS	R	MS	R

G = Greenhouse O = Outdoor S = Susceptible MS = Moderately Susceptible
R = Resistant MR = Moderately Resistant

dence of leaf spot (*Stemphylium solani*), of leaf roll (cause unknown) and of tobacco mosaic virus. The October-November plantings showed a high frequency of powdery mildew (*Erysiphe polygoni*) and late blight (*Phytopthora infestans*), and a medium infection with tobacco mosaic virus.

Other tomato diseases which occur during the hot, rainy season are leaf mold (*Cladosporium fulvum*), Septoria leaf spot (*Septoria lycopersici*) and root-knot nematodes (*Meloidogyne* sp.).

Entomological studies. The principal insect pests of tomato in tropical and subtropical Asia are fruitworms. Several species of noctuid moth larvae attack tomato, but *Heliothis amigera* and *H. zea* are usually the most frequently damaging species and they often necessitate the use of insecticides for their control. *Heliothis* species also seriously attack a number of other crops including corn, eggplant, peppers, beans, cotton and tobacco and on these crops they are also known as the tobacco budworm, cotton bollworm and corn earworm. Because of their very broad host range and the lack of promise of tomato varietal resistance, the entomology department has currently focused its control efforts for fruitworms on the evaluation of insecticides and the application of an insect virus disease as a biological control agent.

The breeding program. From the previous discussion it is obvious that the tomato, when grown in the tropics, is beset by many problems. A comprehensive breeding program is under way at AVRDC to overcome these barriers to successful tomato production in monsoon Asia and in other tropical regions of the world.

As pointed out earlier, the world collection was screened for heat tolerance, and 27 varieties were found that would set fruit well in the hot season. However, none of these varieties had enough of the other positive characteristics to make them suitable varieties in themselves and thus are being used as parents.

More than 500 crosses were made in 1973 to combine resistance to the more important tomato diseases with such desirable characteristics as heat tolerance, fruit quality, determinate growth habit and earliness.

A majority of the first crosses were made among varieties that from experience elsewhere the plant breeders knew to possess desirable characteristics. Later, many parents were selected based on our own screening for disease resistance and for other characteristics.

In Table 13 we have listed the more important varieties or lines that were used as parents in many of the earlier crosses.

By using improved varieties from other breeding programs we believe we can make much faster progress than would be possible if we started in where others began by making interspecific crosses.

The most serious disease, of course, is bacterial wilt. We have used three principal sources of resistance to this disease: the tomato breeding programs of the colleges of agriculture of the Universities of the Philippines, Hawaii and North Carolina.

In the Philippines, the disease resistance came from Professor Deanon's breeding line #1169. In Hawaii, Dr. J. C. Gilbert and his colleagues selected PI 127805 A (*L. pimpinellifolium*) for the resistance sought. The resistance in the North Carolina genetic materials was originally derived from Beltsville No. 3841 (*L. esculentum* var. *pyriforme*) from Puerto Rico, and P.I. 129080 (*L. esculentum* var. *cerasiforme*) from Colombia.

Because the original sources of resistance appear to be unrelated, we assume that they involve different inheritance genes. Furthermore, if the resistance to bacterial wilt is governed by multiple recessives acting additively, then a three-way cross among these sources should impart more resistance to the progeny than would otherwise be possible. To our knowledge, our plant breeders are the first to have made these particular crosses in seeking bacterial wilt-resistant varieties that will withstand infection under the most severe environmental conditions. Within the next few years, the success of this effort will be known.

Many thousands of F_2 and F_3 plants that came from crosses made in 1973 will be evaluated in 1974. The segregating populations will be tested both on Taiwan and in other Asian countries.

Table 13. Listing of the more important varieties or genetic lines used in the tomato hybridization program in 1973

AVRDC accession number	Variety	Origin	Known Disease Resistance or Tolerance	Other desirable characteristics
1	VC 48-1	Philippines	B	Heat tolerance, earliness
8	VC 9-1	"	B	Heat tolerance, earliness
21	VC 11-1	"	B	Heat tolerance, earliness
33	VC 8-1-2-1	"	B	Heat tolerance, earliness
39	(TR x VC 11-2)-9-1	"	B, S, C.	Heat tolerance, earliness
44	(TR x VC 8-1)-5-4	"	B, S, C.	Heat tolerance, earliness
94	Florida MH-1	Florida	F (races 1 & 2) S, C, TMV	Cracking resistance
95	Venus	North Carolina	B, F (race 1)	Cracking resistance
96	Saturn	"	B, F (race 1)	Cracking resistance
97	Healani	Hawaii	F, S, N, SWV	—
118	Manalucie	Florida	F, S, C.	Can be picked at the pink stage
126	Nova	New York	F, V, P	Good for processing
203	Floradel	Florida	F, S, C.	—
208	Manapal	"	F, S, C.	Can be picked at the pink stage
224	NRG 6805	Canada	—	Heat tolerance earliness
243	Plum	Thailand	—	Heat tolerance
245	KL_1	Malaysia	—	Heat tolerance, earliness
246	KL_2	"		Heat tolerance, earliness
274	Kewalo	Hawaii	B, F, S, N, SWV	Spider mite resistance
365	Ohio MR12	Ohio	F, TMV	Cracking resistance

Legend for disease resistance or tolerance:

B — bacterial wilt
S — gray leaf spot
C — leaf mold
V — *Verticillium* wilt
F — *Fusarium* wilt
N — root knot nematode
P — late blight
TMW — tobacco mosaic virus
SMV — spotted wilt virus

THE SWEET POTATO

The objectives of the sweet potato improvement program are to develop varieties that are early and high yielding and that have more protein and carotene than the varieties now popular in Asia. In addition, since the tops of the sweet potato, also, are used for food, we shall attempt to produce varieties with more palatable and nutritious greens.

The world collection. The collection of sweet potato varieties is not nearly so large as those for the other crops. This is mostly because the sweet potato is asexually propagated and it is difficult to introduce either tops or roots because of plant quarantine regulations. However, we have been able to acquire 191 cultivars and breeding lines and about 1,500 open-pollinated seeds. We do expect to receive, in 1974, a large seed collection from the International Institute of Tropical Agriculture in Nigeria.

We have listed the distribution of 185 sweet potato accessions by flesh color, intensity of flowering and time of flowering (Table 14).

Table 14. The distribution of 185 sweet potato accessions by flesh color, degree of flowering and time of flowering.

Flesh color of roots		Flowering intensity		Time of flowering	
Purple	1	None	33	Early	7
White	56	Light	53	Medium	54
Light yellow to yellow	43	Moderate	65	Late	91
Orange to deep orange	85	Heavy	34	No flowers	33
Total	185		185		185

The fact that some sweet potato varieties do not flower at all and that many of them flower in different months increases the difficulty of making crosses. The breeders used the technique of grafting to induce flowering. It was discovered some years ago that a scion grafted on to a rootstock of a free flowering variety will often produce flowers, even though the variety from which the scion was taken does not flower.

About 1,500 open-pollinated seedlings were obtained from Dr. D. T. Pope of North Carolina State University. These were planted at 24 x 24 cm spacing and grown for five weeks. They were then evaluated on the basis of flesh color, freedom from disease, and seedling vigor. Those selected as having special promise constituted only 5 percent of the original seedlings. Three to five cuttings of each selection were planted in the field a day later. When mature, they will be evaluated as possible parents in the crossing program.

Chemical studies. In analyzing the roots of 125 sweet potato varieties, we found that the protein (N x 6.25) content varied by over 300 percent (Figure 22).

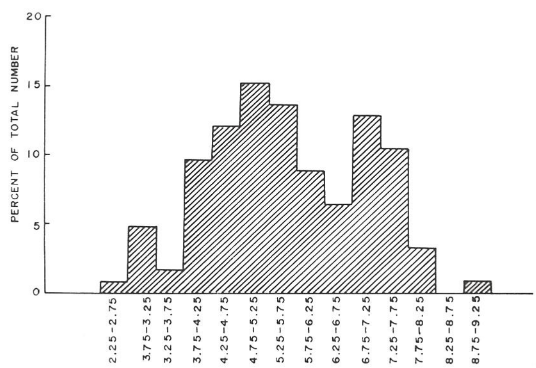
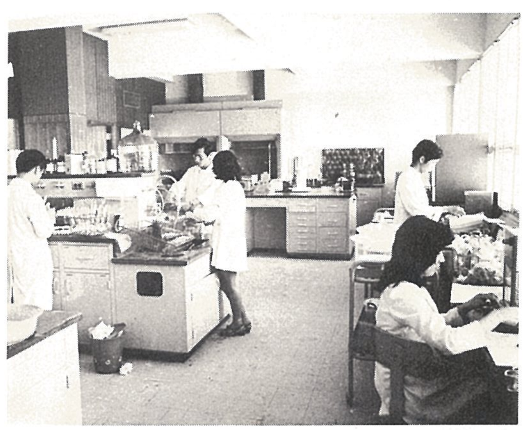


FIG. 22. THE DISTRIBUTION OF THE PROTEIN CONTENT OF THE ROOTS OF 125 VARIETIES OF SWEET POTATOES.



The chemistry laboratory is engaged in analyzing crops for proteins, vitamins and minerals.

The range is from 2.25 to 9.25 percent. We are rather confident that the protein content of sweet potato roots is a heritable character, because several of the varieties which we found to be high in protein were also reported as being high when grown in a completely different environment.

The 10 varieties highest in protein are shown in Table 15.

Table 15. The ten varieties of sweet potatoes that had the highest protein content in their roots.

Acc. No.	Variety or Line	Protein (percent dry matter)
40	Julian	9.15
30	Centennial	8.20
36	Copper Skin Goldrush	8.12
81	286619	7.92
47	Puerto Rico #198	7.81
69	Georgia Red	7.78
149	OK-9-10	7.47
35	Old Goldrush	7.32
28	Calred	7.25
31	Rose Centennial	7.12

As food crops go, this spread of between 300 and 400 percent in protein content among varieties is unusual. Varieties of cereal grains usually show no more than 20 to 30 percent variability in heritable protein content.

We shall attempt to introduce high protein into the roots of heavy yielding varieties. This should increase the nutritional value of the sweet potato for both man and farm animals (in Taiwan over 65 percent of the sweet potatoes are fed to animals, mostly swine).

Another nutritionally important constituent of the sweet potato is vitamin A (carotene). The color of the flesh is a fairly accurate means of separating the high-carotene from the low-carotene varieties.

The chemistry department analyzed the roots of 112 varieties and breeding lines of sweet potatoes for beta-carotene. The distribution is shown in Figure 23.

The 10 varieties that had the highest beta-carotene content are listed in Table 16.

Table 16. The ten varieties of sweet potatoes that had the highest beta-carotene content in their roots.

Acc. No.	Variety or Line	Beta-carotene (mg/100g)
40	Julian	30.0
67	Redmar	20.1
171	Taichung 63	18.2
31	Rose Centennial	17.5
149	OK-9-10	17.5
30	Centennial	17.1
39	Red Jewel	16.9
34	Gem	15.3
147	OK-8-100	15.0
29	Carogold	14.6

The breeding program. Based on origin, flesh color and nutritional value, a series of sweet potato varieties and genetic lines were selected as the parents in the initial crossing program (Table 17).

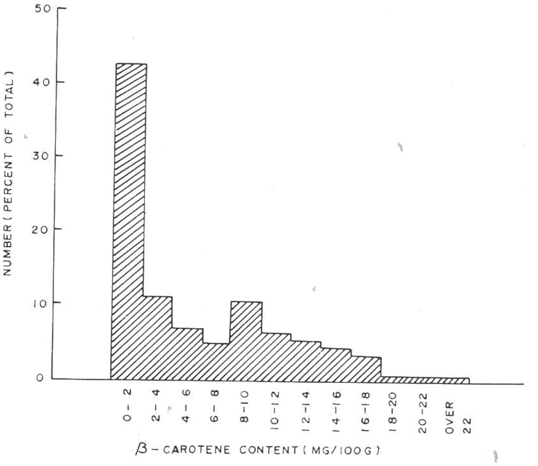


FIG. 23. THE DISTRIBUTION OF THE β – CAROTENE CONTENT OF THE ROOTS OF 112 VARIETIES OF SWEET POTATOES

Many thousands of F_2 and F_3 progeny in the tomato breeding program were screened for heat tolerance and disease resistance in 1973.

Table 17. The core lines in AVRDC initial sweet potato hybridization program, 1973

AVRDC Acc. No.	Variety	Origin	Protein* Root	Protein* Top	Beta* Carotene	Flowering Habit	Flowering Earliness
			(% Dry Basis)		(mg/100g)		
1	BNAS-White	Philippines	5.61	29.2	1.1	light	late
2	BNAS-Red	Philippines	6.27	21.8	2.8	light	late
7	Karja #381J	Indonesia	6.98	29.1	1.4	light	late
8	Daja #380	Indonesia	4.96	28.0	0.6	light	medium
10	HDK-8	Laos	5.22	27.2	1.2	moderate	early
15	HDK-6	Laos	3.83	21.7	0.8	heavy	late
16	HDK-12	Laos	2.96	27.1	1.0	moderate	medium
21	Hom Kao	Thailand	5.19	27.0	—	heavy	medium
30	Centennial	U. S. A.	8.23	31.3	17.1	heavy	medium
40	Julian	U. S. A.	9.02	27.9	30.0	heavy	medium
44	Nemagold	U. S. A.	5.61	29.6	—	no flower	
171	Taichung No. 63	Taiwan	5.37	27.6	18.2	moderate	late

* Data from the Chemistry Department

Tropical varieties from the Philippines, Indonesia, Laos and Thailand were crossed with high-carotene and high-protein varieties such as Julian and Centennial.

As mentioned earlier, hybridization of sweet potatoes is difficult since varieties vary so much in time of flowering and since some do not flower at all. However, with the exception of Nemagold, all varieties were induced to produce flowers by grafting them onto free-flowering varieties.

Because of difficulties with synchronization of flowering, the crossing program did not get well under way until late 1973.

Insect and disease studies. The sweet-potato weevil is the principal insect pest of sweet potatoes. Infestations start in the field and continue in storage. The weevil is particularly severe where sweet potatoes are cropped continuously. The screening of available varieties for weevil resistance is planned for 1974 and 1975. Numerous soil insecticides are being evaluated for control of this insect and natural control agents including diseases and parasites are also being sought.

Witches broom is a mycoplasma-like disease of sweet potatoes transmitted by leaf-hoppers (*Orosius ryukyuensis*) and by the inadvertent transplanting of infected cuttings. Resistance screening for this disease has been initiated and will continue through 1974.

THE WHITE POTATO

In the early stages, at least, our white potato research program will involve only testing and selection, as far as the varietal improvement program is concerned.

During the next few years we expect to study the physiology of the white potato under tropical conditions, in an attempt to understand more completely the reasons for low tuber formation in hot climates.

The principal objective of our potato research program is to screen large collections from around the world to determine whether or not varieties or genetic lines exist that will form marketable tubers in the hot months at low elevations in the tropics.

The work here will be carried on in close cooperation with the International Potato Center (CIP) in Peru. In 1973, our potato breeder visited the Center in Peru. In 1974, their principal potato breeder as well as the CIP director will visit AVRDC. It is expected that AVRDC will assume the role of the Asian outpost of the International Potato Center.

The world collection. The accessions of the genus *Solanum* numbered 1,501 at the end of 1973. These came mainly from what was formerly the International Potato Program of the Rockefeller Foundation in Mexico but has now been incorporated into the program of the International Potato Center in Peru, and from the United States Department of Agriculture.

The nature of the collection is shown in Table 18.

In addition to the listed accessions, 15 segregating populations of *S. andigena* x *S. tuberosum* crosses have been obtained from Cornell University through the courtesy of Dr. R. L. Plaisted. In addition, 9 populations derived from multiple crosses between *S. tuberosum* cultivars and several wild species have been obtained from the University of Guelph in Ontario, Canada.

The majority of AVRDC's collection consists of cultivated tetraploids. Our first search for heat-tolerant types is being made among the cultivated varieties because any superior selection that might be identified would be immediately useful, thus avoiding the complexities that are encountered when wide interspecific crosses are made.

Realizing, however, that high yielding varieties that can be grown in the hot season in the lowland tropics have not yet been found, we shall explore all possible sources in our attempt to locate valuable germ plasm that will contribute toward heat tolerance.

Aware that many useful genes in potato breeding programs throughout the world have come from wild diploid species, we are screening carefully our collection of this group.

The maintenance of a large collection of potato germ plasm in the tropics presents a formidable problem. This is not only because many varieties produce no tubers when grown in the hottest season but also because virus diseases are rampant and may eliminate many entries in the collection.

Of AVRDC's *Solanum* collection thus far assembled, only the cultivated tetraploids and a part of the wild species were received as clones; the rest were botanical seeds.

Table 18. Composition of AVRDC's tuber-bearing *Solanum* accessions.

Nature of collection	Major source	Number of accessions
Cultivated tetraploid	Mexico	1,282
Wild diploid species (29 different species)	USDA	146 (18 species tubers, the rest true seeds)
S. andigena materials	USDA	39*
Derived *S. tuberosum* haploids	USDA	9*
Intervarietal crosses (Katahdin background)	USDA	25*
Total		1,501

* True seeds

Table 19. Comparative tuber initiation in the field and in duplicate pot cultures of the Mexican collection.

Test site	No tubers	Tuber initiation	Total	Percent tuberizing
Field planting	947	118	1065	11.1
Pot culture	377	688	1065	64.6

The Mexican collection. Since the collection arrived at the start of the hot, summer months and the heat tolerance of the accessions was not known, we arranged to multiply a sample of each lot in the highlands near Taichung. We planted 1,260 varieties from Mexico in this way, all but 186 of which were successfully multiplied. The failure of some of them was due to the advanced state of sprouting of the tubers by the time they could be planted.

Although the tubers from Mexico were planted in the highlands to ensure against the loss of germ plasm, sub-samples of 1,251 accessions were planted at the AVRDC experimental farm on April 16, 1973, to be screened for heat tolerance. They were evaluated between July 11 and 25, 1973.

Because of the small size of the individual entries, we were able to plant only one hill of each accession. Of the 1,251 varieties planted, 1,065 (85 percent) survived until the evaluation period.

None of the accessions showed the capacity to produce good-sized, marketable tubers. A number of them, however, produced quite a few tubers. The distribution is shown in Figure 24. The shaded portion represents those accessions which initiated more tubers than the mean (8.9) of the same collection grown in the highlands. Note that over 1,000 of them formed essentially no tubers.

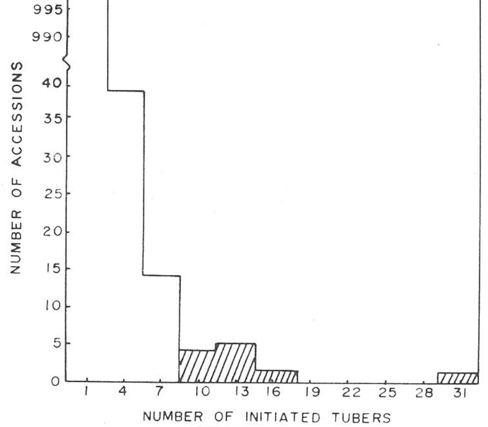


FIG. 24. DISTRIBUTION OF THE NUMBER OF TUBERS INITIATED PER PLANT AMONG 1065 TETRAPLOID CULTIVARS OF SOLANUM TUBEROSUM, SUMMER 1973.

Of particular interest is the one accession which produced 32 tubers. This is ASW 69-1 (Acc. No. 860), which is a breeding line rather than a named variety.

Another set of samples of the Mexican collection was planted in clay pots in early April, 1973. Originally we planned to use this lot for germ plasm increase, ensuring against loss by putting the pots into our cooling chambers for short periods. This procedure, however, proved to be impractical. Therefore, the potted plants served more usefully as a duplicate heat tolerance nursery. It is interesting to note (Table 19) that although these potato samples were grown in essentially the same season, the tuberization was considerably higher when the plants were grown in pots than in the field.

The reason for the difference is not fully understood. However, it may be because of the cooling effect of evaporation from the clay pots. Also, the soil in the pots was artificially prepared with a 3 to 1 soil-sand mixture, providing better aeration. Actually, the results worked in favor of maintaining our collection, because those cultivars that did not survive in the later highland plantings were propagated successfully in the clay pots.

Evaluation of the wild diploid species. Although we realize that it takes years of hard work and many backcrosses before the progeny of the diploid-tetraploid crosses can be developed into suitable commercial varieties, the lack of success in our tests of the cultivars from Mexico prompted us to get whatever information we could from our wild diploid species.

Clones of 18 different species were planted in clay pots on June 22, 1973. When

Table 20. The wild diploid species that tuberized in the summer trial under pot culture conditions.

AVRDC Acc. No.	Species	No. plants sampled	No. tuberizing plant	Tuber yield No.	Tuber yield Weight (gm)	Largest tuber Diameter (cm)	Largest tuber Weight (gm)
1293	*S. acaule*	7	2	2.5	b	0.76	0.35
1297	*S. acaule*	2	2	4.0	b	1.04	0.80
1312	*S. bulbocastanum*	6	1	2.0	b	1.27	1.90
1326	*S. cardiophyllum*	5	2	1.5	4.60	1.82	3.90
1327	*S. cardiophyllum*	12	11	2.7	4.40	1.37	2.60
1342	*S. hjertingii*	1	1	2.0	5.20	1.74	4.90
1382	*S. pampasense*	3	2	2.5	0.92	0.68	0.45
1406	*S. pinnatisectum*	12	7	2.7	3.31	1.06	1.67
1419	*S. sancta-rosae*	1	1	1.0	1.00	0.97	1.00
1475	*S. vernii*	3	3	9.0	12.80	1.83	3.70

a — Mean of tuberizing samples of each accession.

b — Total tuber weight not taken due to some tuber rotting.

the plants were harvested in August, eight species out of the total of 18 showed some tuberization (Table 20). As tuberization among the other 10 species was essentially nil, the results are not listed in the table.

Among the tuberizing species *S. vernii*, which initiated 9 tubers weighing 12.80 grams, is the most promising. It also produced the largest single tuber (1.83 cm in diameter), weighing 3.7 grams. Actually so little is known about the tuber-forming capacity of the wild diploid species that we have no reference points. Further studies during the cool season as well as the warm should indicate the importance of the wild species as sources of tuber-forming capacity in hot climates.

True seed collection. As mentioned earlier, most of the wild potato species and crosses were obtained as true seed. These were planted on AVRDC's experimental farm during the cool winter months and should provide some interesting material for evaluation in 1974.

Furthermore, AVRDC expects to receive from crosses already made at the International Potato Center in Peru, a large amount of true seed, which should contribute greatly to the scope of our potato improvement program.

THE CHINESE CABBAGE

The Chinese cabbage (heading type) is considered to be a cool season crop. Production in the tropics during the summer is limited primarily to the highlands. The volume produced in the cooler areas, however, is inadequate to supply the summer market. This situation is reflected in the price fluctuations between summer and winter in Taiwan (Fig. 25).

Another example of the seasonal problem is the size of head produced in the summer as compared with heading in the winter crop (Fig. 26). This study was conducted at AVRDC with the most heat-tolerant varieties that we were able to select from our varietal collection.

It is obvious from these data that the largest head in the summer was lighter than the smallest head of the winter crop.

In addition to exhibiting poor heading during the hot season, the Chinese cabbage is beset by a number of serious disease and insect problems.

The objective of our cabbage improvement program is to develop varieties that are heat tolerant and disease resistant, thereby increasing yield and reducing price fluctuations during the year.

The world collection. Because the Chinese cabbage is somewhat limited in its worldwide use, we have not been able to obtain as large a collection of this crop as we have of most of the others.

The 303 varieties or genetic lines that we have collected (Table 21) came principally (90 percent) from the 3 major producing countries of Asia; namely, Taiwan, Korea and Japan. The rest of the accessions were obtained from Hong Kong, the United States, Malaysia, Indonesia, Thailand, Guam and the Netherlands.

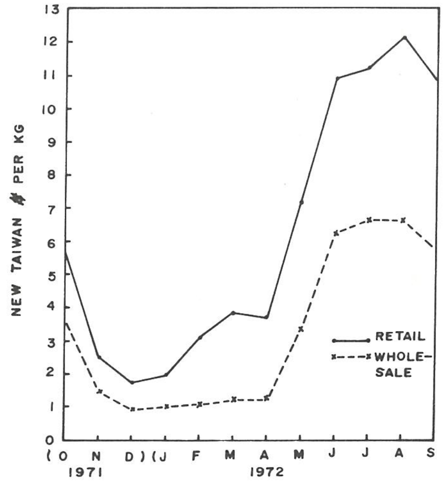


FIG. 25. PRICE FLUCTUATION OF CHINESE CABBAGE (BRASSICA PEKINENSIS) IN TAIWAN FROM OCTOBER 1971 TO SEPTEMBER 1972.

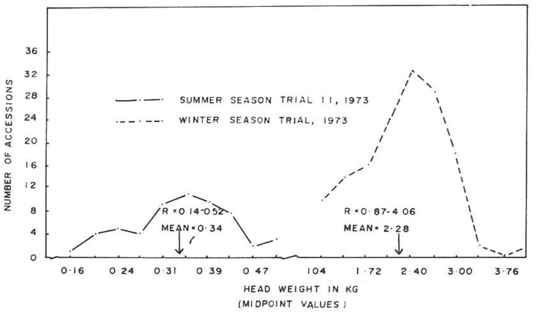


FIG. 26. COMPARATIVE HEAD WEIGHT (KG) DISTRIBUTION OF HEAT-TOLERANT CULTIVARS IN SUMMER-TRIAL II AND COLD SEASON CULTIVARS IN THE WINTER TRIAL.

Table 21. Composition of the Chinese cabbage germ plasm collection.

Species Name	F1 hybrids	Nature of Accession		Total
		Open-pollinated	Unknown	
B. pekinensis Rupr.	123	55	79	257
B. chinensis L.	—	40	—	40
B. juncea Coss.	—	3	—	3
B. napus L.	—	3	—	3
Total	123	101	79	303
%	41	33	26	

As can be seen, the largest group are F_1 hybrids. The so-called "unknown" group are mostly local collections from Taiwan and are probably open-pollinated varieties also.

The maintenance of open-pollinated populations is difficult because of the space required to maintain genetic materials that are not contaminated by cross pollination. As is described later in the breeding section, seed vernalization treatments were used to help overcome this problem.

To obtain promising parents, the accessions were screened for heat tolerance (ability to form heads during the summer months). Three plantings were made: one on April 28, 1973, another on June 14, and the third on August 2 (entirely the Korean collection, none of which headed).

The breakdown into heading or non-heading varieties in the first and second trials (Table 22) showed that 13 out of 69 produced heads in the first planting, and 61 out of 193 in the second. Unfortunately, however, in the first planting 11 out of the 13 that headed also bolted; thus they would have little value commercially for summer planting in late April on Taiwan.

Table 22. Number of heading and non-heading accessions of Chinese cabbage in two trials, summer 1973.

Reaction to summer condition	Trial I	Trial II
Heading	13 (11)*	61
Non-heading	56	132
Total	69	193

* Number of accessions indicating solid head formation but which prematurely bolted.

The 11 varieties that bolted as their heads formed in the April 28 planting headed *without* bolting in the second planting (June 14). Furthermore, the two cultivars that headed normally in the first planting failed to head at all in the second planting. Except for a few varieties from Japan, the promising heat-tolerant materials came from Taiwan. Of the heat-tolerant materials, none gave any indication of producing high yields under summer conditions. This was due not only to small heads (Fig. 26) but also to high susceptibility to downy mildew, soft rot and turnip mosaic virus. Consequently, the collections were screened for disease resistance. The Korean collection, although not able to produce heads in the summer, proved to contain the most disease-resistant varieties. The disease screening work is reported later under pathological studies.

When the Korean cultivars and a few Japanese ones were grown during the winter season, yields of 80 to over 100 tons per hectare were obtained with the better varieties.

In selecting for heat tolerance, it was observed that those cabbage varieties that showed a loss of turgor (incipient wilting) of the lower leaves in mid-afternoon on hot, sunny days did not produce heads. Those whose leaves remained turgid (before the heading stage, of course) later produced heads (Table 23).

Susceptibility to vernalization also seemed to be associated with heat tolerance. This is discussed in the next section.

Table 23. The relationship of plant turgidity and the ability to head under summer conditions (summer crop).

Heading Ability	Non-turgid	Turgidity Evaluation: Moderate	Turgidity Evaluation: Turgid	Total
Head	1(17.5)*	16(8.1)	13(4.4)	30
Non-heading	51(34.5)	8(15.9)	0(8.6)	59
Total	52	24	13	89
		$X^2(2df) = 60.5$,	$P < 0.005$	

* Figures in parentheses denote the expectations on the assumption of total independence between the two traits.

Physiological studies. The plant physiologists investigated the physiological basis for heat tolerance in the heading type of Chinese cabbage.

First, observations were made of the head-forming process in the cabbage. Head formation appears to start with the advent of the 8th to 10th leaves (Fig. 27). As later leaves develop they tend to form "hook-like" structures. The cabbage head is composed of these overlapping leaf hooks. Subsequent growth fills the head.

We investigated the influence of temperature and light on some head-forming activities (Table 24).

Table 24. Effects of temperature and light on the head-forming activities of two Chinese cabbage varieties.

Day & night tempera-tures °C	Variety Tropicana						Variety Saladeer					
	No. of leaves formed before first erect leaf			No. of leaves formed before first hooked leaf			No. of leaves formed before first erect leaf			No. of leaves formed before first hooked leaf		
	Con-trol*	50% shaded	Diff.	Con-trol*	50% shaded	Diff.	Con-trol*	50% shaded	Diff.	Con-trol*	50% shaded	Diff.
30/25	10	11	-1	17	17	0	10	10	0	18	18	0
25/20	9	7	2	16	13	3	9	7	2	17	16	1
20/15	8	6	2	11	10	1	10	7	3	16	12	4

* The control plants were grown in an air-conditioned greenhouse under natural daylight.

Lower light intensities at lower temperatures hasten head formation. The variety Tropicana formed only 6 leaves before the first erect leaf was formed at 15-20C when shaded, but when it was grown in full sunlight (control) the formation of 8 leaves was required before the first erect leaf was formed. Similar differences occurred with respect to leaf hooking. These results were more pronounced with the Saladeer variety than with Tropicana.

There were consistent differences in the water content of the plants under the same treatments (Table 25).

Based on additional studies, the physiologists have postulated a number of hypotheses for head formation. The one thing that becomes clear from these studies is that leaf turgidity is a prerequisite for both leaf erection and hooking (hence, head formation) to take place. This, of course, agrees with the field data in Table 23.

It was observed in the winter of 1972 that the heat-tolerant varieties of Chinese cabbage bolted before heads could form. On the other hand, the heat-sensitive types were more resistant to cool-temperature bolting.

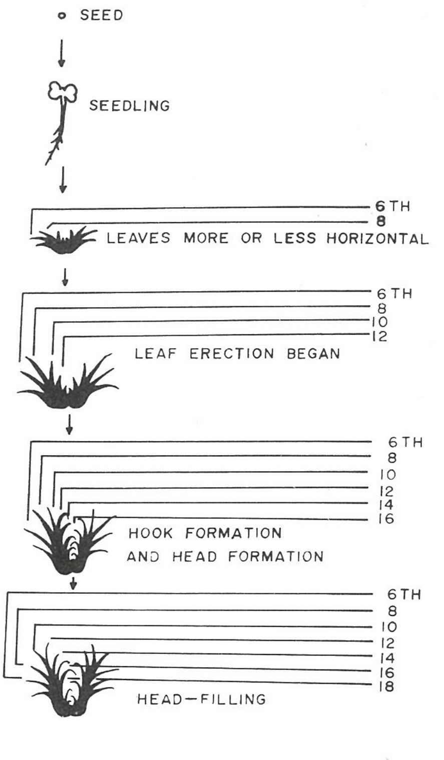


FIG. 27. CROSS-SECTIONAL VIEW OF THE DEVELOPMENTAL STAGES OF CHINESE CABBAGE. (VARIETY: TROPICANA)

Table 25. The water content (percent fresh weight) of two varieties of Chinese cabbage plants under different temperature and light regimes.

Day and night temperatures °C	Variety Tropicana			Variety Saladeer		
	Control*	50% Shaded	Diff.	Control	50% Shaded	Diff.
30/25	93.0	93 3	0.3	93.2	93.1	-0.1
25/20	92.9	94.6	1.7	92.9	94.3	1.4
20/15	92.3	93.8	1.5	91.1	93.4	2.3

* Control plants were grown in an air-conditioned greenhouse under natural daylight.

Table 26. Distribution of heat-tolerant and non-heat tolerant accessions according to number of days to bolting after cold (5°C) treatment of germinating seedlings. The figures denote number of accessions bolting at a particular period.

	Days to bolting after treatment									
Nature of Accession	27	29	31	33	35	38	40	42	45	48
Heat tolerant	29	26	2	0	0	0	0	0	0	0
Non-heat tolerant	0	14	26	27	18	37	14	12	3	2

If there is a reasonably consistent negative correlation between bolting response to vernalization and heat tolerance, it could form the basis for a mass-screening technique. This was tried on 210 *B. pekinensis* accessions. By and large, the heat-tolerant accessions bolted considerably earlier than the non-heat tolerant (Table 26). Although there is a striking difference at 27 days, there is considerable overlapping after 29 days; so this relationship must be examined in more detail before it can be recommended as a mass-screening method.

Chemical studies. The only chemical studies conducted on the Chinese cabbage were made to determine the variations in crude fiber content in the outside and inside leaves (Fig. 28).

Note that the crude fiber content is high in the outer leaves and decreases inward, with a more or less constant amount obtaining after the 25th leaf is reached.

A comparison of the fiber content of Chinese cabbage in the open field and when shaded by corn plants revealed a tendency for the shaded plants to have less crude fiber. It is assumed that the lack of light inside the cabbage head accounts for the low fiber content of the inner leaves.

Pathological studies. Many diseases attack the Chinese cabbage. The most serious ones on Taiwan are bacterial soft rot, *Erwinia aroidea*; downy mildew, *Peronospora parasitica*; and Turnip mosaic virus (perhaps Chinese cabbage mosaic virus is also present).

The pathologists examined the breeding plots, where all available accessions were being grown. They took readings on plantings made in April (spring), in June (summer) and in October (winter).

In the spring planting, among 64 accessions only 8 were scored as being resistant or moderately resistant to downy mildew. Thirteen accessions were resistant and 10 were tolerant to the mosaic virus. Seven accessions were resistant or tolerant to soft rot. However, in this trial no varieties were resistant to all 3 diseases.

In the summer trial (142 accessions), soft rot was the major disease problem and essentially all the entries were susceptible. However, many individual plants escaped. It was noted that varieties with erect leaves tended to be healthier than those with spreading lower leaves that touched the ground. No downy mildew was observed in this planting.

In the winter planting, very few varieties were infected with soft rot. There was, however, a high incidence of downy mildew. Only two entries were highly resistant, but 58 were moderately resistant. Most of the downy mildew-resistant plants showed virus infection, and it is possible that a genetic linkage exists between downy mildew resistance and mosaic virus susceptibility.

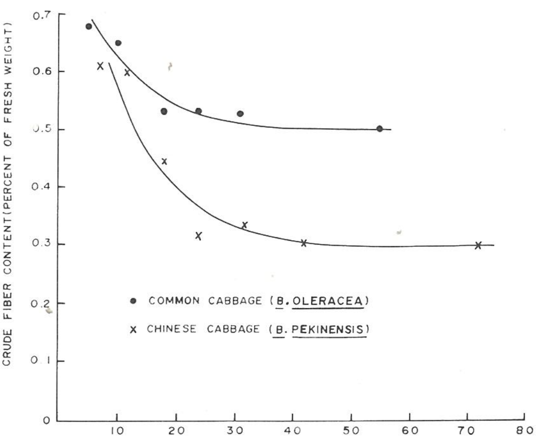


FIG. 28. THE CRUDE FIBER CONTENT OF INNER AND OUTER LEAVES OF CHINESE AND COMMON CABBAGE.

The pathology department set up a soft rot nursery in which 276 accessions of Chinese cabbage were inoculated with soft rot bacteria. Twenty seven of the 276 accessions proved to be resistant.

Readings of natural infection by downy mildew were taken on the same collection. Resistant ratings were recorded on 104 of them. However, because these plants were not inoculated, some of them could simply have escaped infection.

Inoculation studies of downy mildew resistance will be carried out in 1974.

The virologist studied the virus diseases of the Chinese cabbage. After some rather thorough tests, he concluded that the principal virus disease attacking cabbage on AVRDC's experimental farm is the turnip mosaic virus. However there is a possibility that the Chinese cabbage mosaic virus (synonymous with cauliflower mosaic virus) is also present. The external symptoms on the plant are the same, but the virus particles are of different shape. In 1974 we expect to define our virus diseases more accurately by the use of electron microscopes (available at other institutions on Taiwan).

Readings taken on 276 accessions showed 44 to be free of mosaic virus symptoms. Since the plants were not inoculated, however, the 44 entries will have to be tested again under more severe conditions.

Entomological studies. Chinese cabbage as well as most other important brassica food crops are very severely attacked by several important insect pests. Almost all current production of these crops requires the intensive use of insecticides to prevent complete insect devastation and to produce acceptable vegetables for the market.

Among the most damaging cabbage pests in tropical Asia are the diamond-back moth, *Plutella xylostella,* the imported cabbage worm, *Pieris rapae,* and the cabbage looper, *Trichoplusia ni.* All three of these lepidopterous species eat the foliage while in the larval stage and contaminate the plant with their feces. Aphids may also build up enormous populations on cabbage resulting in wilting, distortion and even early death of the plant. Their numerous bodies and the sooty mold that grows on their excreta also badly foul the plants. Common species include the cabbage aphid, *Brevicoryne brassicae,* turnip aphid, *Rhopalosphium pseudobrassicae* and *Lipaphis erysimi.* Another common insect pest which feeds on cabbage is the striped flea beetle, *Phyllotreta striolata.* In regard to these serious insect pests of cabbage, the entomology department is progressing with a program involving the selection of Chinese cabbage varieties that are minimally attacked and the evaluation of numerous insecticides and some biological control agents produced by many manufacturers throughout the world. Additionally, specific insect virus diseases were isolated in 1973 from the diamond-back moth, cabbage looper and imported cabbageworm. These diseases have been grown on their host insects in the laboratory and are undergoing field evaluation in comparison to conventional methods of chemical control. Other future insect control precepts include the integrated use of insecticides with biological control agents such as diseases, parasites and predators to achieve the most economical, safe and environmentally tolerable methods of cabbage pest management.

The breeding program. The first barrier to be overcome in the breeding program was to find an efficient way to maintain the genetic identity of our collection. The Chinese cabbage is insect pollinated, which requires that individual varieties be separated by 1,000 meters to avoid cross-pollination if maintained under field conditions.

A principal objective of the Chinese cabbage breeding program is to develop varieties that form good heads in the hot season.

In the early stages of our program, as mentioned before, it was found that the Chinese cabbage responds to water-imbibed seed vernalization (seed exposed to a temperature of 5C for one month). One of the responses was decreased plant size.

As noted elsewhere (Table 26), the plants coming from vernalized seed bolt sooner and because of the smaller size of the plants, they can be grown in the greenhouse in pots set close together. Thus they are protected from insects and wind, and many hand pollinations can be made successfully in a relatively small space. Because each silique produces many seeds, there is abundant progeny to work with from plants grown from vernalized seed even though there are fewer siliques per plant.

In selecting local cultivars for improvement, the plant breeders identified those that had the highest head weight and firmness.

Actually, in screening local varieties they found little variation in head firmness, only in head size. They finally chose 10 local, heat-tolerant cultivars (Table 27) with resistance to virus disease and, to the extent possible, to soft rot. Although the head weights of these cultivars were low as compared with those of the winter crop, they were the heaviest we could select from the varietal trials.

In order to increase the level of performance of these selected heat-tolerant cultivars, the following recurrent selection scheme is proposed:

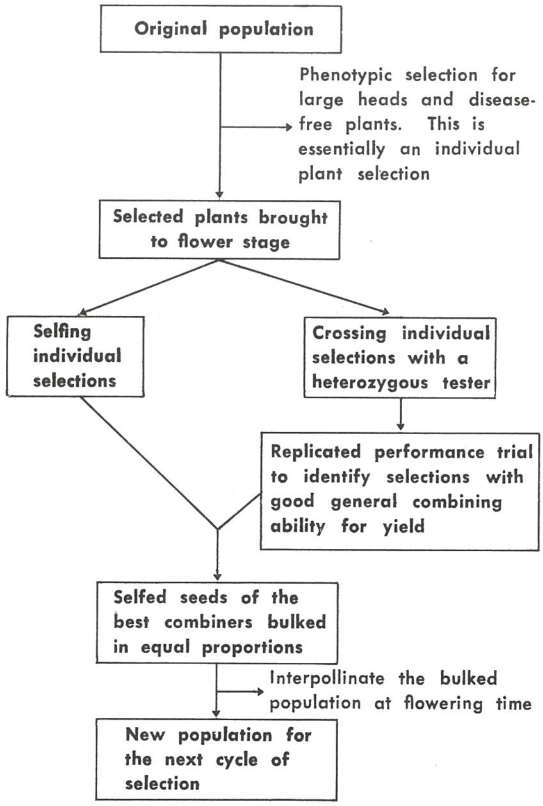


Table 27. Horticultural characteristics of ten local, heat-tolerant cultivars selected for population improvement, summer 1973.

Acc. No.	Variety	Head weight (kg)	Head shape index (L/D)	Solidity (gm/cc)	Premature bolting %	Disease reaction DM	MV	SR
28	Santung	0.41	1.71	0.45	0	S	R	S
126	Unknown	0.44	1.44	0.67	0	S	R	R
129	Hsia Sheng 35 days	0.41	1.68	0.53	0	S	R	S
140	Ta Feng Autumn Baby	0.49	1.44	0.62	3.6	S	R	S
152	Unknown	0.43	1.43	0.49	15.9	MR	R	S
155	Ching Ho Improved	0.45	1.46	0.59	0	S	R	S
162	Hsia Sheng	0.44	1.35	0.62	7.2	S	R	S
171	Homei	0.40	1.56	0.61	0	S	R	R
175	Unknown	0.39	1.44	0.62	4.3	S	R	R
189	Unknown	0.41	1.38	0.64	0	S	R	R

Legend: L/D = Length/width ratio of heads
DM = Downy mildew
MV = Mosaic Virus
SR = Soft rot

Basically, the initial selection from the original as well as in succeeding populations of each cycle is determined by individual plant performance. However, because yield *per se* is a highly complex character, it is necessary to identify the best selections from the original population by a general combining ability test. Ultimately, the parental components of any new population are selected in accordance with the yield performance in a carefully designed and adequately replicated test.

The population developed through this scheme may be utilized in a variety of ways. It may serve as a base population for isolating inbred lines and even components of a synthetic variety. Furthermore, the end product of a series of selection cycles may be maintained as an open-pollinated variety and released, if it proves to be outstanding, for commercial use.

In addition to the population improvement program with some selected heat-tolerant cultivars, a larger hybridization program is being carried out.

Table 28 indicates the number of crosses made and the nature of the combinations.

Major emphasis is given to incorporating soft rot resistance in the heat-tolerant parents. This arises partly because reports in the literature, as well as experience with the crop, show that this disease is the most troublesome of the 3 major ones that afflict the Chinese cabbage. Moreover, except for mosaic virus, soft rot is the only disease about which advance resistance information was obtained from the seed donors. It should be noted also that all of the heat-tolerant parents used in these crosses exhibited strong resistance to mosaic virus in all of our trials. A partial list of the most promising parental varieties used in the breeding program and their important horticultural attributes is shown in Table 29.

Although good head size has not yet been found in a heat-tolerant variety grown in the hot season, and even though no single selection has yet exhibited resistance to all three of the major diseases of the Chinese cabbage, we are confident that by crossing the varieties that are superior with respect to these qualities we shall soon develop cultivars that are better than any that now exist.

Table 28. Number of Chinese cabbage crosses made, and the objectives of the crosses.

To combine with heat tolerance to obtain	Number of crosses
Resistance to soft rot	169
Resistance to downy mildew	31
Multiple resistance	16
High yield and resistance to soft rot	25

Table 29. A partial list of some promising parental varieties used in the major crossing program and some of their important horticultural attributes.

AVRDC Acc. No.	Variety	Important Horticultural Attributes*
16	Uji	Multiple disease resistance to soft rot, downy mildew, and mosaic
28	Santung	Heat-tolerant, resistant to mosaic virus; early
42	Fengshan Michihli	Multiple disease resistance to soft rot, downy mildew, and mosaic
77	Tropicana	Heat-tolerant, resistant to downy mildew and mosaic
126	Unknown collection	Heat-tolerant, resistant to mosaic, early
129	Hsia Sheng 35 days	" " " " "
140	Ta Feng Autumn Baby	" " " " "
155	Ching-Ho Improved	" " " " "
189	Unknown collection	" " " " "
233	Neabeng Bulam #3	" " " " "
234	Kang Jang	" " " " "
246	Se Mouchuk 80 days	" " " " "
262	Hung Nong #2	" " " " "
264	Sum Chunri	" " " " "

* Derived from field trials and/or provided by germ plasm donor.

WEED CONTROL

Although AVRDC expects to add a crop management specialist in 1974 who will handle weed control, the plant physiology department agreed to run some preliminary experiments in 1973 to give us a start in solving the weed control problems on our experimental fields.

Purple nutsedge is clearly the most serious weed on our farm (Table 30).

Table 30. Major weed species on AVRDC's farm in two seasons.

Spring-Summer Season

COMMON NAME	SCIENTIFIC NAME
1. Purple nutsedge	*Cyperus rotundus* Linn.
2. Goosegrass	*Eleusine indica* Gaertn.
3. Crowfoot grass	*Dactyloctenium aegyptium* (Linn.) Richter
4. Junglerice	*Echinochloa colonum* (Linn.) Link
5. Purslane	*Portulaca oleracea* Linn.
6. Spiny amaranth	*Amaranthus spinosus* Linn.
7. Slender amaranth	*Amaranthus viridis* Linn.
8. Black nightshade	*Solanum nigrum* Linn.

Fall-Winter Season

COMMON NAME	SCIENTIFIC NAME
1. Purple nutsedge	*Cyperus rotundus* Linn.
2. Goose grass	*Eleusine indica* Gaertn.
3. Junglerice	*Echinochloa colonum* (Linn.) Link
4. Mexican ageratum	*Ageratum houstonianum* Miller
5. Purslane	*Portulaca oleracea* Linn.

Several herbicides have been found to be somewhat effective in the control of nutsedge. However, crop tolerance differs considerably (Table 31).

Devrinol appears to be promising for the tomato, when applied at 1.5 kg/ha a.i. (active ingredient), and incorporated into the soil before transplanting the crop. However, we have found that Devrinol will not protect the crop for its duration; so it is recommended that Lasso be sprayed on the soil after transplanting, at the rate of 2.0 kg/ha a.i.

Devrinol works well as a pre-transplanting treatment for Chinese cabbage at a rate of 0.75 kg/ha a.i. incorporated into the soil. No herbicides which we tried worked on direct-seeded Chinese cabbage.

Our best recommendation for the suppression of nutsedge in soybeans is to apply Vernam at 3 kg/ha a.i. incorporated into the soil before planting. This should be followed by 2 kg/ha a.i. of Lasso sprayed on the soil surface after seeding but before seed emergence.

Our experience indicates that mungbeans are highly sensitive to herbicides. However, chemical weed control is needed if high population densities are to be used.

Weed control is an important ingredient in obtaining high yields. Center scientists are seeking chemicals that will provide cheaper control methods that the hand-weeding pictured above.

Table 31. Phytotoxicity and relative effectiveness of various herbicides in nutsedge control.

Trade name	Common name	Manufacturer	Rate tested (Kg/ha a.i.)*	Effectiveness in controlling nutsedge**	Phytotoxicity ***			
					Mungbean	Soybean	Tomato	Chinese cabbage (Direct seeds)
Amiben	Chloramben	Amchem	1.50	— —		0		
Basalin		FASF	0.50	— —	0			
			0.75	—	1			1
			1.00	+	2			
Dacthal	DCPA; DAC	Diamond Shamrock	7.50	— —	0			
			10.00	— —	0			0
			12.50	— —	1			
Devrinol	R-7465	Stauffer	0.50	+	1		0	1
			1.00	+	3	1	0	1
			1.50	+	4		0	2
			2.00	+			0	
Eptam	EPTC	Stauffer	1.00	—	1			
			2.00	+	3			
			2.50	+ +	4			
Herban	norea; noruron	Hercules	0.50	—	0			
			1.00	+	1			
			1.50	— —	3			
Lasso	alachlor	Monsanto	1.00	—	2			
			2.00	+	4	0	0	4
			3.00	+ +	5			
Lorox	linuron	du Pont	1.50	— —	5			
			2.00	—	5	0		
			2.50	—	5			
Machete	butachlor	Monsanto	0.75	— —	1			
			1.50	— —	2			
			2.25	—	2			
			3.00	—	2			
Preforan	fluorodifen	CIBA-Geigy	1.00	+	3			1
			3.00	—	4	0	1	
			5.00	+	4		1	
Premerge	dinoseb	Dow	5.00	+	1			
			7.50	+	2			
			10.00	+	4			
Ramrod	propachlor	Monsanto	2.00	+	2			
			3.00	+	2			
			4.00	+	3			
Tillam	pebulate; PEBC	Stauffer	4.00	—			0	
Treflan	trifluralin	Elanco	0.50	—	1			
			0.75	—	1			0
			1.00	—	2	0		
Vernam	vernolate	Stauffer	3.00	+	4	0		

Legend
* a.i. = active ingredient.
** + or — signs indicate % weed control (dry weight of weeds)
— —: 0—25%, —: 25—50%, +: 50—75%,, + +: 75—100%.
*** Scales of phytotoxicity: 0: no injury, 5: completely damaged.

We conducted a separate study on mungbeans to determine whether the delayed planting of the beans following the application of the herbicides to the soil would decrease the phytotoxicity. Selected for the study were the most promising herbicides, based on previous trials; but only Eptam, Lasso, Ramrod and Devrinol proved to be feasible. The data for these treatments are presented in Table 32.

It is apparent that if the herbicide is applied about 9 days before seeding, there will be no more than a 10 percent kill of the mungbean crop by the herbicide.

Obviously we need to continue our investigations of suitable herbicides for the mungbean, as well as for other crops.

Nutsedge control was greatly facilitated by growing a crop of lowland rice before planting an upland crop. Apparently the nutsedge cannot stand continuous submergence.

We are investigating the application of heavy doses of Eptam (which degenerates rather rapidly in the soil) several months ahead of planting the mungbean crop, in an attempt to control nutsedge.

A pesticide residue chemist will be added to our staff in February 1974. Thus we shall be able to measure the uptake of herbicides and insecticides by plants, as well as the persistence of the chemicals in the soil.

Table 32. The effect of delayed planting on the phytotoxicity of four herbicides on the mungbean.

Herbicide and rate of application in kg/ha of active ingredient	No. of days of delayed planting	Phytotoxicity* rating 21 days after planting	Survival of mungbean crop 44 days after planting (percent)
	0	4	23
Eptam	3	4	10
2.0 kg/ha	6	2	80
	9	1	90
	12	1	78
	0	2	70
Lasso	3	2	75
2.0 kg/ha	6	2	75
	9	1	88
	12	6	72
	0	1	88
Ramrod	3	1	92
3.0 kg/ha	6	1	83
	9	1	92
	12	1	93
	0	1	88
Devrinol	3	2	73
0.75 kg/ha	6	1	92
	9	1	90
	12	1	77
		0	100
Control		0	100
(No herbicide,		0	100
no weeding)		0	100
		0	100

* The scale for rating phytotoxicity was a sliding one from 0 to 5 0 is no toxicity and 5 indicates that all plants were severely damaged.

SOIL SCIENCE

Our soil scientists devoted their efforts in 1973 to making a survey of the soils on our 102-hectare experimental farm. In addition to identifying the soil types, they conducted many chemical and physical analyses to further characterize the soils.

The soil scientists ran a series of field and greenhouse experiments to study the response of several vegetable crops to fertilizers.

The survey of the experimental fields, including soil analyses. Because this portion of our work is of main interest only to our own scientists who grow experimental crops on the fields, we are presenting here only the highlights of the work.

AVRDC's experimental farm is composed of alluvial soils, derived from a mixture of sandstones and shales. They are light gray to yellowish brown in color, with textures in the surface soil ranging from sandy loam to loam.

The pH of the soil is high, ranging mostly between 7 and 8.4. There are calcium carbonate concretions in much of the subsoil. The concretions usually appear at depths between 20 and 60 cm.

The principal clay minerals were identified as being vermiculite, illite, chlorite and kaolinite, with the first two being predominant.

A mechanical analysis of many samples of the surface soil showed average values of 38 percent sand, 42 percent silt and 20 percent clay.

Because a relatively small percent of the clays were of the expanding type, and since 80 percent of the soil is made up of sand and silt, the cation exchange capacities are low, varying from 7 to 15 milli-equivalents per 100 grams of soil and averaging about 10.

Many samples were analyzed for total nitrogen (as an indicator of soil organic matter content) and high and significant positive correlations were obtained between total nitrogen and the following characteristics: cation exchange capacity, available potassium, available magnesium, available phosphorus and available copper. The organic matter content of the soil is low, from 0.7 to 2.0, with an average of 1.5 percent.

The soils are classed as moderately well drained. However, because of the high content of sand and silt, the low organic matter content and the low amount of expanding

The service building, headhouse and greenhouses.

clay minerals, the soils do not develop a good crumb structure. In addition, during the rainy season the water table is high and downward drainage is impeded.

The experimental fields are irrigated from deep wells. The soil scientists analyzed the well water for mineral nutrient content. It proved to be high in calcium, magnesium and sodium but low in potassium. Expressed in ppm, the average of 3 samples are as follows: CaO 118.7, MgO 37.8, Na_2O 10.6, and K_2O 3.13. The pH was constant at 7.2.

It is obvious that the potassium content is very low. If 400 t/ha of irrigation water is applied to one crop during its growth period, only 1.2 kg of K_2O would have been added. As will be seen later, crops respond to potassium on our farm soils.

Fertility studies on the farm soils. A pot culture experiment was conducted in our greenhouse. to determine the response of the tomato to nitrogen on soil from our experimental farm, at two levels of potassium (Fig. 29).

When adequate (90 kg/ha) of potassium was applied, there was no harmful effect of excess nitrogen. However, when no potassium was added, heavy applications of nitrogen reduced yields. It is obvious that both potassium and nitrogen are essential for tomato production on our farm.

Other experiments carried out with the tomato showed that NH_4-N in the culture solution was somewhat toxic at levels between 30 and 50 ppm, while nitrate nitrogen was not toxic even at 100 ppm.

In field planting, we noted that when NH_4-N was applied early growth was retarded by concentrations of only 50 kg/ha.

Chinese cabbage responded to applications of boron under field conditions.

The highest yields of all crops on our fields have been obtained with a combination of chemical fertilizer and compost.

In 1974 we plan to carry out more experiments to determine the optimum amounts and kinds of fertilizer to apply.

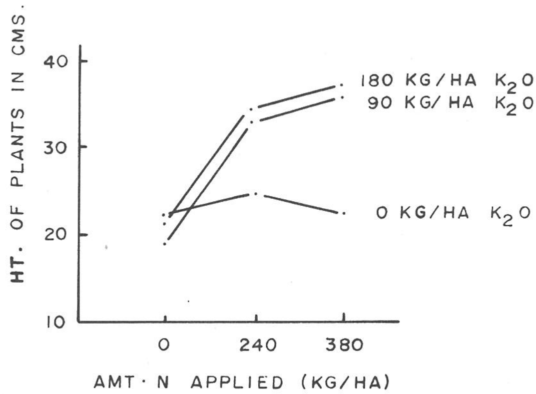


FIG. 29. RESPONSE (IN PLANT HEIGHT) OF THE TOMATO TO NITROGEN AT TWO LEVELS OF POTASSIUM. (ADEQUATE PHOSPHORUS SUPPLIED IN ALL TREATMENTS)

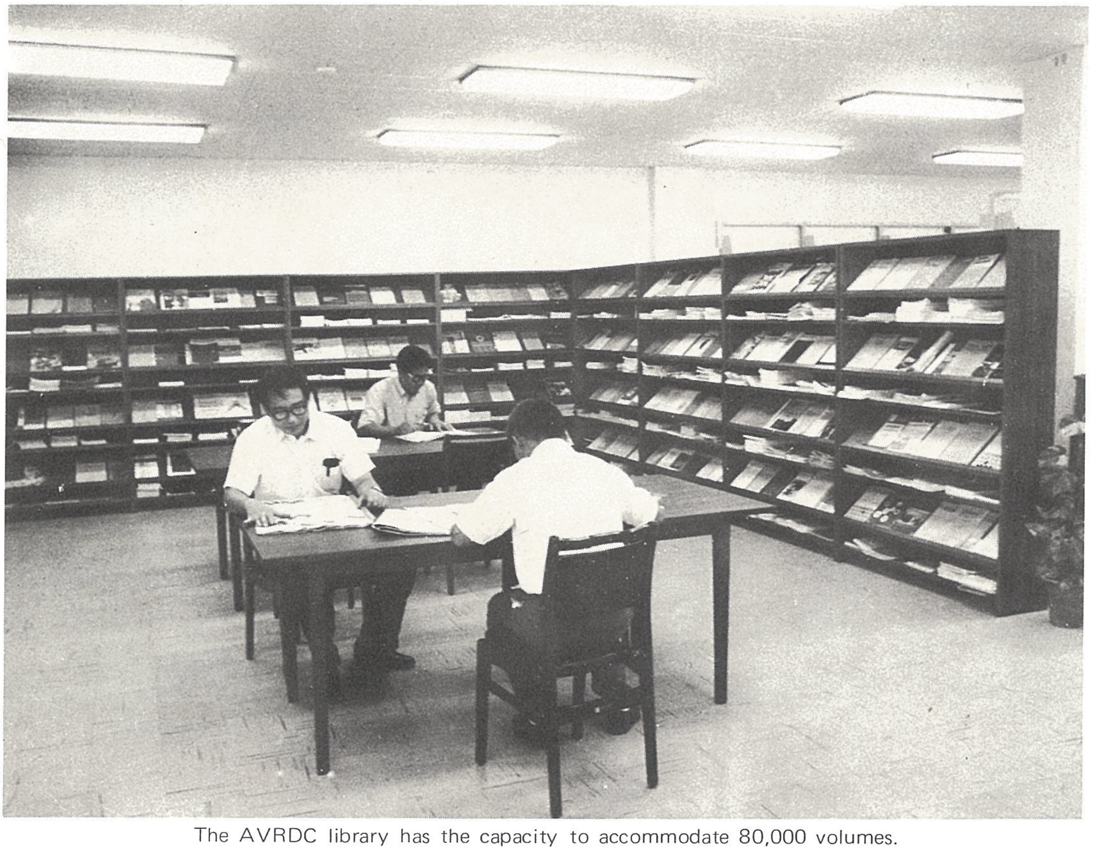
THE LIBRARY

The Center has a library that is staffed and operating. We subscribe to over 300 scientific journals and periodicals, in response to the requests from our scientific staff.

The stack space is sufficient to accommodate about 80,000 volumes. Naturally, it will be some time before this number is accumulated.

We were able to obtain the services of Dr. Whiton Powell, the librarian emeritus of the library of the College of Agriculture at Cornell University, to assist us not only in planning our library but in ordering the bulk of the basic books and periodicals. When possible, we have tried to obtain the back numbers of the more important periodicals for the past 10 years.

The Associate Librarian spent a short time at the library of the International Rice Research Institute in the Philippines, getting acquainted with their library acquisitions and methods of operation.



The AVRDC library has the capacity to accommodate 80,000 volumes.

INTERNATIONAL ACTIVITIES

The Center is working toward the establishment of outreach activities in a number of Asian countries, is cooperating with other international agricultural research centers, and has established many scientist-to-scientist relationships for the exchange of genetic materials and for testing segregating populations from our own plant breeding programs.

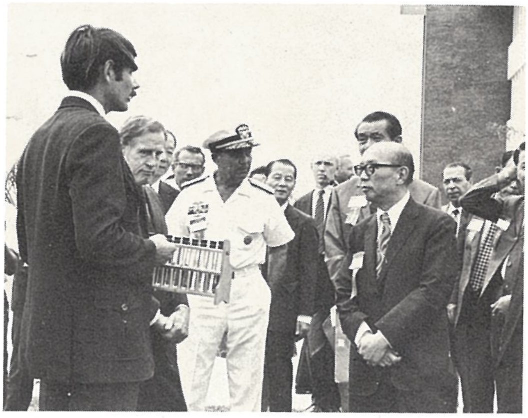
We are attempting to develop outreach programs of a substantial nature in 5 Asian countries: specifically, Korea, the Philippines, Thailand, Indonesia and Bangladesh. At the close of 1973, none of them had been formally established, but many of our scientists had travelled in the first 4 on the list and had sent seed collections to each of those countries for testing.

In July, 1973, the Board of Directors formally approved the establishment of a Korean Sub-Center affiliated with AVRDC. Although a formal agreement with the Korean Government is yet to be signed, it is expected that a cooperative program will soon be established which will allow AVRDC to test materials in a temperate zone climatic environment.

AVRDC is cooperating with IITA with respect to the improvement of sweet potatoes and soybeans, and with CIP in white potato research. The promising genetic lines originating from our breeding program will be supplied to IRRI for testing in its multiple cropping program.

The Director and Associate Directors of AVRDC are invited to attend International Centers Week in Washington, D.C. They also participate in the *ad hoc* group of Center Directors who meet twice a year to discuss common problems and to improve coordination among the programs of the worldwide network of international agricultural research institutes and centers.

The training center, which will house 40 trainees and eight guests plus a cafeteria and private dining room, will be completed in September 1974.



The mungbean breeder explains his program to the Vice President of the Republic of China, and to other visitors, on Dedication Day, October 17, 1974.

ERRATA

Page 10: In the footnote it should read "Vigna aconitifolia" instead of "Vigna acontifolia".

Page 13: The caption under the photo should read "identified" instead of "idenified".

Page 14: In the 3rd line of the last paragraph in the 2nd column, delete "of".

Page 20: In the 4th paragraph of the 2nd column, it should read "595 were in the F_1 generation with the remaining 307 in the F_2. In addition, 129 F_3 families derived from 25 crosses originally made in the Philippines are included in our program." instead of "671 were in the F_1 generation, 332 in the F_2, and 129 in the F_3."

Page 21: In Table 4, the first note (*) should read "accessions 2182 through F_3#20" instead of "accessions 2182 F_3#20".

Page 23: The caption under the photo should read "cooperation with INTSOY" instead of "cooperation INTSOY".

Page 30: In Table 12, the double column under "CK" should read "0" (zero) instead of "o" (outdoor).

Page 38: In Table 20, the subscript "a" should be placed beside "tuber yield".

Page 45: In Table 29, the "Important Horticultural Attributes" of AVRDC accessions #233 through #264 (Neabeng Bulam #3 through Sum Chunri) should read "High yielding, resistant to soft rot and mosaic" instead of "Heat-tolerant, resistant to mosaic, early".

Page 46: The caption under the photo should read "methods than the hand-" instead of "methods that the hand-".

Page 48: In Table 32, for "Lasso", the last reading on its "Phytotoxicity" should be "0" (zero) instead of "6".

Page 52: The photo caption in the 2nd column should read "1973" instead of "1974".