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9. ABSTRACT

The mungbean was selected for intensive research by the Asian Vegetable Research and Development Center because it is an excellent source of high quality protein and could contribute substantially to closing the protein gap. Use of the mungbean as a simple, nutritious, low cost, protein and calorie source for children has long been recognized in the Philippines and development of outstanding varieties has been achieved. This document contains the fifty-four papers presented at the First International Mungbean Symposium where participants from sixteen countries gathered to exchange and expand current information about the mungbean. The utilization and economics of mungbean production focused on constraints limiting the use of mungbean as a major protein source in Asian diets. Papers on Management, protection, and varietal improvement explore ways to expand production of this important pulse. Problems requiring more study are pests and disease, poor plant architecture, irregular response to environment, and the numerous harvests required by pod-shattering and indeterminate growth habit. Low farm yield resulting from unimproved management practices results in low income to the farmer in spite of a relatively high unit price.

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The Ist International Mungbean Symposium

Foreword

This publication contains papers presented at the First International Symposium on Mungbean. Held between August 16-19, 1977 at the University of the Philippines, Los Baños (UPLB), the project was jointly sponsored by the University, the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), the Department of Agriculture of the Philippines, the Asia Foundation, the Philippine Council for Agriculture and Resources Research (PCARR), and the Asian Vegetable Research and Development Center (AVRDC).

More than 135 participants and observers from 16 countries and 45 research, educational, government, and private organizations gathered to exchange and expand current information about the mungbean. Mungbean production in various countries was assessed through country reports. The utilization and economics of mungbean production focused on constraints limiting the use of mungbean as a major protein source in Asian diets. Papers on management, protection, and varietal improvement sought ways to expand production of this improtant pulse.

The following notes apply to the papers published herein. All references to mungbean are to *Vigna radiata* (L) Wilczek. The metric system is used throughout the Proceedings and all currency is in US$ based on local currency equivalents. A Single asterisk (*) means significant at the 5% level; a double asterisk (**) means significant at the 1% level. Color photographs of the various mungbean diseases and insect pests is on page 157.

The editor and staff wish to thank the many people who assisted in the preparation of the Proceedings. As it should, the Symposium brought enthusiastic participation from workers and researchers alike. Special appreciation goes to all the helpers and assistants from the sponsoring agencies.

Introduction

The mungbean is an excellent source of high quality protein in Asian diets. As pointed out by Dr. J. D. Drilon, Director of SEARCA in his opening remarks at this Symposium, with at least 500 million people in the world undernourished, this crop could contribute substantially to closing the "protein gap". The crop was selected by AVRDC for intensive research for this reason. It was also chosen for examination and reporting in an international meeting because substantial progress has been made by the many national and international program scientists engaged in improving the mungbean.

The University of the Philippines at Los Baños was an especially appropriate location for the meeting because of the university's large group of scholars and teachers devoted to agriculture and rural development and particularly because of the outstanding results in mungbean breeding and improvement work going forward in its College of Agriculture. Chancellor Abelardo G. Samonte pointed out in welcoming us to his campus, that the association of the many national and regional institutions at UPLB is producing a synergistic impact of the many disciplines directed toward the improvement of food crops and nutrition and training of manpower for scientific agriculture.

Another of the co-sponsors, the Philippine Council for Agriculture and Resources Research, represented by Director-General Dr. J. C. Madamba pointed out that PCARR has emphasized legume protein production for the Philippines via their pivotal role in organizing and funding the national research program. One of the important results anticipated by the sponsors of the symposium is the formation of an international network of mungbean research and extension workers, who will extend this emphasis to other nations.

The welcome to the participants from Agricultural Secretary Arturo R. Tanco Jr., delivered by Assistant Secretary Jose P. Leviste Jr., emphasized the national commitment to improvement of agriculture, food production, nutrition and health.

Use of the mungbean as a simple, nutritious, low cost, protein and calorie source for children has long been recognized in the Philippines and development of outstanding varieties has been achieved.

Many problems remain; however, pests and disease, poor plant architecture, irregular response to environment, and the numerous harvests required by pod-shattering and indeterminate growth habit are recognized as limitations. Low farm yield resulting from unimproved management practices results in low income to the farmer in spite of a relatively high unit price.

This symposium owes much to the generosity of donors who supported the travel of Asian scientists to the meeting. Foremost among these is the Asia Foundation, who funded travel for scientists from nine countries. The Rockefeller Foundation, the United States Agency for International Development, the Tropical Agriculture Research Center of Japan, and the Ford Foundation also contributed to international travel. PCARR and the BPI supported the travel and expenses for Philippines scientists.

Our great thanks also go to Dr. Hyo Guen Park, AVRDC mungbean breeder, who corresponded at length with scientists around the world to organize the papers and the scientific subject matter for the symposium. The excellent staff help from SEARCA and the UPLB made local arrangements an efficient and attractive feature of the meeting. Special credit for this work goes to Drs. A.O. Gagin and R. Barba of SEARCA; Drs. I.C. Cagampang and F.C. Quebral of UPLB; and H.A. Custodio, F.B. Ballon, Ms. R. Tejam, and Dr. A. Palo of the Department of Agriculture. Our gratitude also extends to Robert L. Cowell, AVRDC's editorial associate who edited the manuscript to its present concise and attractive form by working with many scientists even before their papers were presented.

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Director

Production

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Mungbean Research and Production in Sri Lanka

N. Vignarajah

IMPORTANCE AND UTILIZATION

Mungbean is popularly known as green gram in Sri Lanka. It is one of the 6 major grain legumes cultivated in the country; the others being cowpea, black gram, soybean, groundnut, and pigeon pea. Of these, green gram was the most popular food in our diet until recently. However, it is now second to cowpea for which there are fewer production constraints.

Grain legumes are the major source of protein in Sri Lanka. Green gram, used either in the split form or to make curry spiced with chilis, is consumed with rice. Boiled, it is eaten with grated coconut for breakfast. And it is also used in making a variety of sweetmeats. In all these preparations, green gram is preferred to cowpea since it cooks easily and the people are used to it. However, the current cost of green gram is about twice that of cowpea.

Grain legumes were freely imported prior to 1970. Since 1970, foreign exchange difficulties and increasing world market price progressively reduced the import of grain legumes until now they have been discontinued altogether. This has given a boost to the local cultivation of green gram and other grain legumes. Consequently, production and research efforts have been intensified.

ECOLOGY

The total land area of Sri Lanka is 6.6 million ha. Divided into 3 agroclimatic zones namely, dry, intermediate, and wet - the dry zone comprises 4.7 million ha. Approximately half this area is available for agriculture.

The bi-modal rainfall pattern experienced in the dry zone creates 2 well-defined rainy seasons, the <u>Maha</u> and the <u>Yala</u>. The <u>Maha</u>, from mid-October to late January, is the major cultivation season. The <u>Yala</u> is the minor cultivation season and occurs from late March or early April to late May.

The wet, and some parts of the intermediate, zones are more suitable for the cultivation of plantation (perennial) crops and rice. The soil, climate, and other environmental characteristics of the dry zone (and some parts of the intermediate zone) make it both physically possible and economicaly feasible to grow a wide range of annual crops. Green gram is one of the major crops grown in the dry zone.

In summary, green gram is grown: -

1. as a <u>Maha</u> rainfed crop in the highlands;
2. as a <u>Yala</u> rainfed crop;
3. under lift irrigation; and
4. in paddy fields, during both seasons by using irrigation tanks when water is insufficient to grow rice.

DISEASES

The Mungbean Yellow Mosaic Virus BMYMV) and the Tobacco Ring Spot Virus (TRSV) are diseases that drastically reduce green gram yields. No sources of resistance have been identified in either virus disease. The plant pathologists suspect that the local strain of MYMV is different from that in India. *Cercospora* leaf spot (*Cercorspora canescens*) and powdery mildew (*Erysiphe polygoni*) occur to a lesser extent.

TRSV is seed-borne. There is no passage for the virus in black gram seed. A large number of interspecific crosses between green and black gram have been completed and selections are being made in segregating populations. Segregating populations of such interspecific crosses have also been obtained from AVRDC. Besides having resistance to TRSV, features such as resistance to moisture stress, shattering, and a wide range of pests (storage pests particularly) make it an ideal parent. However, we have not been able to bring about crosses with black gram as the female parent. This implies that if resistance to seed passage for TRSV is governed by extra chromosomal factors, this feature cannot be recovered from these crosses.

The population of white fly (*Bemisia tabaci*), which is the vector transmitting MYMV, peaks during the cooler months (Dec-Feb). A minor peak occurs in May-June. TRSV also seems to occur from December-February.

INSECT PESTS

The insect pests of economic importance are the beanfly (*Melanagromyza phaseoli*) and the pod borer (*Maruca testulalis*). The beanfly has only one peak, May-July; the pod borer has 2 peaks, December-February, and a minor peak in June. The bug complex, among which the Pentotomid bugs (*Nezara* sp.) and the Coreid bugs (*Riptortis* sp.) are the main pests, is likely to develop as a group of major pests. The Bruchids (*Callosobrochus* sp.), for example, cause enormous damage to stored green gram. The bug complex has only one peak, February-March.

CROP IMPROVEMENT

The leading varieties that have emerged from our crop improvement programs are MI 4, a variety bred locally, and Type 51, an introduction from India.

Our breeding objectives are formulated in consultation with extension and production personnel. The objectives include selecting different plant types and maturity groups to suit Sri Lanka's broad ecological niches. A relatively indeterminate plant type is considered appropriate for cultivation under <u>Maha</u> rainfed conditions where the levels of management will be low. In this case, the farmer will not risk investing in pest control (including disease and weed control) since he will be dependent on rainfall which might fail.

Other important objectives[a] are:

1. resistance to MYMV and TRSV. (We are intensively pursuing this objective through interspecific hybridization with black gram);
2. insensitivity to photoperiodism;
3. better plant architecture (moderate height obtained by a reduction in internode length without a reduction in node number, reduced leaf size and angle to allow greater light infiltration, and a rigid stem);
4. location of pods to present maximum exposure over leaf canopy;
5. determinate growth habit with synchronous flowering and maturity combined with non-shattering to reduce the number of harvests;
6. optimum response to moisture and fertilizers;
7. active nodulation under a wide range of edaphic conditions;
8. large glossy green seeds; and
9. acceptable cooking quality and palatability.

PRODUCTION

Cowpea, black gram, and soybean are grain legume crops that compete with green gram. Production for 1974-1976 is given in Table 1. There have been no increases in area and production for either soybean or green gram. Soybean was unpopular among farmers due to its limited demand. Now, however, demand for soybean has increased and production is expected to expand considerably. Additional factors affecting competition are: (1) soybean, cowpea, and black gram are less affected by virus diseases, and (2) soybean and black gram can be stored without damage from pests. However, black gram, the least affected by pests, is in limited demand.

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[a]Objectives 2-5 will not apply to the relatively indeterminate types we are seeking.

Table 1. Production of green gram and competitive grain legumes in Sri Lanka, 1977.[a]

Year	Green gram area[b] sown	Green gram total harvest	Cowpea area[b] sown	Cowpea total harvest	Soybean area[b] sown	Soybean total harvest	Black gram area[b] sown	Black gram total harvest
		--mt--		--mt--		--mt--		--mt--
1974	10.69	5266	2.99	2138	1.58	1235	1.42	581
1975	9.27	5321	8.75	6783	1.50	1403	2.03	931
1976	8.34	4540	19.24	10746	0.89	839	5.10	2216

[a]Compiled by S. Williams, INTSOY Economist, from reports received from the Ministry of Agriculture, Sri Lanka. [b]1000 ha.

CONCLUSION

Intensified research and production efforts on green gram are of recent origin. Formerly, the most popular grain legume in Sri Lanka, it has been relegated to a secondary position because pests, particularly virus diseases, are serious constraints to production. If these constraints are overcome, green gram is likely to regain its position. Research efforts are being strengthened to overcome these constraints.

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Mungbean Production in Thailand

Arwooth Nalampang

Mungbean has a long production and utilization history in Thailand. It is believed to be one of the crops cultivated since the beginning of civilization. Old literature on ceremonies often make mention of the beans. Furthermore, they are frequently found as one of the ingredients in a number of local food preparations still in use.

In the past, mungbeans were grown in small plots throughout Thailand for local consumption. Any surplus supplies were sold to neighbors. Large scale production was not practiced due to the limited market demand. But, this situation has changed in recent years as mungbeans became an important export commodity. Both area and production increased substantially as the farmers discovered that they could add to their income by growing mungbean. Some production statistics are given in Table 1.

Table 1 shows that area, production, and farm price increased considerably from 1962 to 1975. In 1976, the price jumped abruptly from US$0.19-US$0.35/kg due to strong demand in foreign markets. If this price persists, there will undoubtedly be a large future expansion in both area and production.

Table 2 illustrates the export condition of mungbeans. Japan is the leading importer while the Western countries and the Middle East are beginning to import Thai mungbeans in significant quantities. However, the bulk of Thai mungbean exports end up in nearby Asian countries.

For many years mungbeans were treated as a minor crop, and only planted when land and time were available. The best land was devoted to other major crops such as rice, corn, and cassava. Furthermore, only minimum inputs and management practices were provided which resulted in relatively low yields ranging from 600-1,000 kg/ha. In recent years, yields of 2 mt/ha have been reported from several farms using proper cultural and pest management practices.

PLANTING TIMES

As a short season crop, mungbeans can be grown throughout the year but as generally practiced, 3 crop seasons are normal. The early season crop starts in April or May as the first monsoon rains fall. Mungbeans are planted both in upland and lowland paddy fields and harvest is completed before the arrival of the heavy rains. A second planting season is practiced near the end of the rainy season, (Sept - Oct), but only in the upland regions, especially the corn belt of the Central Plain. The land is prepared immediately after corn harvesting and mungbean seeds are broadcast. The crop is usually harvested only a few times, thus the late maturing pods are lost to rats and other pests. About two-thirds of the production comes from this planting. The third cultivation method is practiced in the paddy fields after the rice is harvested and is primarily confined to the lower Central Plain where planting starts in January or February. The residual moisture in the lowland paddy fields is sufficient to produce yields of 600-800 kg/ha. Planting times in the North and Upper Central Plain regions are delayed until March or April in order to avoid low temperatures that frequently occur in January and February. In this case, some supplemental irrigation is necessary to establish the crop before the early monsoon rains arrive.

VARIETIES

Research on mungbean varietal improvement is of recent origin. The old local varieties are mostly of "Indian types" and possess such undesirable characters as uneven flowering and pod setting, and shatter easily. If maximum yields are to be obtained, several pickings are necessary and involve considerable labor and time. The identification of several newly introduced varieties show promise from the standpoint of uniform pod setting and maturity. One of these, M-7 A, a "Philippine type," has been released and named U-thong 1. In addition to high yield, large seed size, and shiny seed coat, this new variety requires only 1-2 pickings. It is rapidly gaining in popularity among both farmers and consumers. A mungbean hybridization program is also in progress in the Department of Agriculture. Close cooperation with AVRDC and UPLB have been established in order to exchange materials and information.

CROP MANAGEMENT

Weeds are one of the main factors responsible for low yields. Research work has shown that yields can be doubled if the crop is kept free of weeds for 30 days after seedling emergence. Unfortunately, most farmers employ the broadcasting method which makes hand-weeding impossible and also results in variable stands which encourage weed growth. At present, chemical weed control is considered impractical from both an economic and a practical standpoint.

PESTS

Because of hot and humid conditions, diseases are common especially during the rainy season. *Cercospora* leaf spot (*Cercospora canescens*) appears to be the most serious problem. A breeding program for resistance has been initiated. Root and collar rots are also important in the poorly drained soils, while mungbean mottle virus and powdery mildew are often noticed but do not cause damage.

Beanflies (*Melanagromyza phaseoli*) are widespread but vary in severity of infestation. In some areas, all the seedlings are destroyed. Systemic insecticides such as Dimethoate spray are recommended immediately after seedling emergence for effective control. Screening for resistance to this insect does not appear promising at this time. In addition, the grain borer causes serious problems to the stored grain. Large quantities of mungbeans are rejected and destroyed annually by importing countries due to residual insecticides applied during storage and transportation.

OTHER ASPECTS

Fertilizers and inoculum are seldom used by farmers. Root nodulation is not a problem since *Rhizobium* occur naturally in the soils and are sufficient. Fertilizer residues from previous crops also benefit the mungbean plants to some extent. Rotation with other major crops has been practiced for a long time. A seed multiplication program has been established by the Department of Agricultural Extension in cooperation with the Market Organization for Agriculturists and the Department of Agriculture. The objective is to supply farmers with an ample quantity of high quality improved varieties.

BLACK GRAM

A close relative of mungbean, black gram (*Vigna mungo*) is also grown in Thailand but to a lesser extent. This crop has not been popular due to its inferior palatability. Farmers generally sow black gram at the end of the rainy season (Oct-Nov), for use as a cattle feed and to improve soil fertility. Only a small quantity of seeds are saved for planting because it has not been considered of much economic importance.

However, in recent years, Japan has placed a strong demand on black gram for her bean sprout industries. This pressure has resulted in the rapid expansion of area and production. We estimate that about 100,000 ha are presently devoted to black gram. Table 3 shows that a large part of black gram exports go to Japan. Although total production is far less than for mungbeans, the market price in 1976 was such that growers will be encouraged to increase production.

Table 1. Mungbean production in Thailand; Bangkok, 1976.

Year	Area planted	Yield	Production	Value	Local farm price
	---1000 ha---	-kg/ha-	--1000 mt--	-US$1000-	------US ¢/kg-----
1962	49.6	1,081.3	53.7	-	-
1967	132.8	925.0	122.6	16.12	13.2
1972	205.4	931.3	191.1	24.56	12.8
1973	233.1	825.0	191.7	25.69	13.4
1974	206.9	906.3	187.9	33.26	17.7
1975	163.5	737.5	120.6	22.55	18.7
1976	222.8	562.5	124.8	43.93	35.2

Table 2. Thai mungbean exports to major markets.

Year	Japan		All Asian		European		Total	
	(mt)	(US$)	(mt)	(US$)	(mt)	(US$)	(mt)	(US$)
	----------------	----------------	----------------	----------------	1000	----------------	----------------	----------------
1972	1.18	234.8	33.51	5,729.3	2.51	560.7	36.62	6,290.0
1973	1.81	375.5	51.36	8,611.3	4.54	1,068.5	55.90	9,679.8
1974	1.25	346.8	43.79	10,425.7	3.88	1,187.2	47.67	11,613.9
1975	1.09	365.5	37.16	9,983.6	1.531	582.0	38.69	10,565.5
1976	13.20	7,397.5	45.24	20,305.5	4.58	2,262.2	49.82	22,567.7

able 3. Black gram export statistics, Thailand.

Year	Total exports		To Japan		Price/t
	amount	value[b]	amount	value[a]	
	--mt--		--mt--		--US$--
1972	47,852	7.64	30,242	4.83	159.67
1973	36,238	8.23	25,069	6.64	227.10
1974	37,147	9.32	25,796	7.41	250.88
1975	40,782	11.36	29,184	9.16	278.71
1976	30,642	21.26	29,110	20.50	693.86

[z] million US$.

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Mungbean in West Malaysia

Abu Kassim b. Abu Bakar
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INTRODUCTION

West Malaysia stretches between latitudes 1^{O}N and 7^{O}N. The climate is equatorial, characterised by humidity above 60%, abundant rainfall (2000-3000 mm/yr), temperatures ranging between 22° and 31^{O}C throughout the year, and daylength of about 12 hours.

Mungbean was experimentally introduced into the country around 1917 (3). Since then it has been neglected and there is limited knowledge of the crop. Studies on mungbean's potential were only revived a few years ago.

Production is negligible. Only about 70 ha were planted to the crop in 1973 and the mean yield was 450 kg/ha (4). Although difficult to estimate domestic demand or consumption of the pulse, it is available nearly everywhere in both urban and rural markets. Therefore, it probably forms a sizeable proportion of the imported pulses (excluding soybean and peanut), which amounted to about US$5.6 million for 1976 (6). Mainly consumed as vegetable sprouts, bean curds, and in boiled forms, it is also utilized in various festive recipes.

AGRONOMY

Most of the research undertaken has been evaluation of varietal and line performance. Sources of these materials are mainly from Taiwan and the Philippines. From recently imported germplasm of some 30 varieties and lines, 10 were selected for yield evaluations. The most promising appear to be E.G. Glabrous No. 3 and CES 55, achieving about 3 t/ha each (1).

The mungbean crop is raised under rain fed conditions and the rainfall patterns normally allow 2 crops each year in most parts of the peninsula. Soils range from sandy loam to clay loam and pH is around 5.0. Land preparation generally consists of one ploughing and 2 rotovations. In newly cropped areas or where soil pH is below 5.0, one t/ha of lime is incorporated just before the final rotovation.

Fertilizers are applied along the rows during planting at the rate of 34 kg N, 56 kg P_2O_5, and 56 kg K_2O/ha. Recent trials involving combinations of N levels of 0, 40, and 80 kg/ha with 40 or 80 kg/ha of P_2O_5 and 30 or 60 kg/ha of K_2O seem to indicate that treatments with 80 kg/ha P_2O_5, 60 kg/ha K_2O, and 40 kg/ha N gave maximum yields. No *Rhizobium* inoculation has been attempted but some nodulation occurs.

The plant spacings currently adopted are combinations of 50 or 75 cm by 5 or 10 cm. Weed-infestions are generally controlled by pre-emergent treatment with alachlor and 1-2 rounds of manual weeding before the crop commences flowering. The ripe pods are picked in 3-5 rounds and the maximum experimental yield recorded is 3.9 t/ha (Table 1).

PESTS AND DISEASES

Ooi (8) noted 6 important insect pests of the mungbean: *Melanagromyza phaseoli* Coq., *Prodenia litura* F., *Lamprosema diemenalis* Guen., *Apogonia* spp., *Pagria* sp., and *Riptortus linearis* F. Those considered of minor importance were *Aserica* sp., *Elimaea* sp., *Homoeocerus serrifer* Westw., *Coptosoma* sp. and *Bothrogonia ferruginea* F. In the same study a *Plutarchia* sp. was found to parasitise the beanfly while *Lamprosema diemenalis* was parasitised by an *Apanteles* sp.

In experimental plantings of the crop at Serdang MARDI station, Selangor, beanfly and pod-borer were among the most constant serious problems. Very little research on their control has been conducted. Current control of the beanfly involves treating seeds with endrin before planting and spraying seedlings with dimethoate early in the unifoliate stage. Ibrahim (5) reported that dimethoate was the most effective of 5 insecticides (malathion, heptachlor, alicarb, carbofuran, and diemthoate) tested against the beanfly. Applications of carbaryl beginning at the first signs of damage is the general practice for control of pod-borers.

One severe incidence of defoliation caused by caterpillars (*Anticarsia irrorata* F.) was observed in early 1976 at Serdang MARDI station (2). In a planting this year, heavy foliage damage of seedlings by the beetle, *Pagria* sp. was seen. Minor insect damage is caused by leaf-mining caterpillars (*Acrocercops* spp.) and certain hairy caterpillars.

Johnson (7) recorded *Cercospora* leaf spot and leaf rot due to *Corticium solani* (Prill. & Delacr.) Bourd. & Galz. Severe *Corticium* (=*Rhizoctonia*) leaf blight has been observed in plots of the crop at Serdang MARDI station (1,2). Little research has been undertaken. However, applications of benomyl beginning at first appearance of symptoms are generally made to reduce spread. Occasionally, scattered occurrences of stem rot incited by *Pythium* sp. and leaf rot caused by *Sclerotium rolfsii* Sacc. were also found.

In 1975, a yellow mottling disease presumably caused by a virus was seen in variety M 350 at Serdang MARDI station. In a study of its host range by sap inoculation to legumes (*Cassia occidentalis* L., peanut, soybean, cowpea, and mungbean M 350), and non-legumes (*Gomphrena Globosa* L., *Nicotiana glutinosa* L., and *Ocimum*

Table 1. Summary of yield data, yield components, and other traits of 8 mungbean varieties at MARDI Serdang Station, Selangor, 1975.

Varietal name	Yield	100 seed wt	Days to harvesting	Plant height
	-t/ha-	--g--		- cm -
E.G. Glabrous No. 3	3.98	9.33	82	50
M - 101	3.29	8.11	80	34
CES 55	3.02	9.27	82	58
CES 28	2.91	8.7	82	65
CES 87	2.68	9.23	82	57
Siwlik	2.64	6.22	90	73
CES	2.31	9.48	82	66
Dau Mo Long Khanh	1.78	7.85	82	62
LSD 5%	1.00	0.73	-	8
CV (%)	24.00	6.00	-	10

basilicum L.), no reaction was observed except on M 35G, which reproduced the symptoms observed in the field. A sample of about 150 seeds from the infected plants were tested for seed transmission of the virus but no positive evidence was obtained (2). There has been no further recurrence of the disease since then.

Other pest damages include rodents and birds.

CONCLUSION

Mungbean does not receive emphasis equal to peanut or soybean in Malaysian research. Currently, MARDI, RRIM (Rubber Research Institute of Malaysia), and the Department of Agriculture are among the main organizations involved with the crop. Outcome of the limited research undertaken so far suggests a potential worth exploiting. Farmers are showing an interest in incorporating mungbean into their cropping systems or patterns. Therefore, an intensive and accelerated research to support this move is evidently needed.

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Mungbean in Nepal

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BACKGROUND OF NEPAL

The area of Nepal is approximately 141,000 km^2 with a cultivated area of approximately 2.4 million ha.

There are 4 physiographic regions which extend roughly in parallel bands along the northwest to southeast axis of the country. These are: (1) Tarai along the southern border, (2) Inner Tarai to the north, (3) the Hills ranging in elevation from 750 to roughly 4000 m, and (4) the Himalayas to the far north, above 4000 m.

Annual rainfall ranges between 2,000 mm in the east to less than 1,000 mm in the west with 85% falling during the monsoon period from June-November. Temperature ranges from the subtropical heat of the Tarai (up to 46°C in June) to the extreme cold of the Himalayas.

GRAIN LEGUMES

The area under grain legumes is estimated to be 70,000 ha with an average production of 500 kg/ha. Commonly grown grain legumes include chick pea (*Cicer aurietinum*), lentil (*Lens esculenta*) pigeon pea (*Cajanu cajan*), and chickling veteh (*Lathyrus sativus*) in Tarai and Inner Tarai; soybean (*Glycine max*), black gram (*Phaseolus mungo*), cowpea (*Vigna sinensis* and *V. catjang*), horse gram (*Dolichos biflous*), and several species of beans are grown in the Hills.

The importance of grain legumes mainly lies in their relationship to cropping systems as a mixed crop, an intercrop, or a catch crop with rice, maize, and wheat. Some of these crops occupy the waste portion of cultivated land like paddy bunds (soybean in the Hills and pigeon peas in Tarai). Furthermore, the high protein content of grain legumes and their inclusion in nearly every meal has contributed to meeting the protein requirements of an average Nepalese.

The exact area under mungbean production is not available; however, it is a relatively new crop and covers the least area compared with other grain legumes. Prior to 1970, mungbean was little grown in Tarai and Inner Tarai but it is becoming popular now as a catch crop during spring following the wheat harvest and before transplanting paddy rice in summer. The estimated production is 500 kg/ha. The price for mungbean is approximately 200% higher than for cereal grains, thus providing extra income to farmers when grown as a catch crop. Mungbean is mainly consumed as a thick soup (dal) like other grain legumes, and as bread made from either its flour alone or mixed with wheat flour. This bread is of two types: one like pancake (bara), another like crisp bread (papad).

VARIETAL IMPROVEMENT

The National Pulse Improvement Program was started in 1973 to improve grain legumes through research and varietal improvement. Indigeneous strains were collected and exotic strains were introduced from various sources. Cooperation with various regional and national research organizations in India, and with international organizations, such as AVRDC in Taiwan and ICRISAT in India, were established. Preliminary study on adaptation of mungbean strains revealed better adaptation in Tarai and Midhill. However, the adaptation was limited to areas under 2000 m, suspected to be due to lower temperatures at higher elevations. Varietal testings were conducted at several locations. The yields of strains included in testing are presented in Table 1. Pusa Baishakhi, an early maturing strain (70-80 days) developed by the Indian Agriculture Research Institute, yielded consistently highest for the 3 years. It was recommended for general cultivation in Central Tarai in 1975. Popularity of this strain among farmers is increasing as reflected by increasing demand for the seed. However, Pusa Baishakhi was found to be susceptible to *Cercospora* leaf spot.

Table 1. Yield for local and exotic strains of mungbean averaged across locations for 3 years; Nepal.

Strain	1974	1975	1976
	kg/ha		
Pusa Baishakhi	627	1041	912
Type 1	575	550	800
Type 44	452	605	508
Go 65[a]	462	780	406
Go 091[a]	257	885	398
Go 222[a]	127	-	341
Go 334[a]	-	-	462
Go 111	-	-	284
M 317	-	-	638
M 475	-	-	595

[a] Local strains; the rest are exotic strains.

Nepal has been receiving International Mungbean Nursery (IMN) sets since 1974-75. However, the Fourth and Fifth IMN sets were received late and were consequently planted late. Heavy monsoonal rain damaged nurseries and data couldn't be completely collected or properly evaluated. However, the general observations of the entries, especially with respect to disease reaction and uniformity in maturity, indicated the superiority of entries M 317, M 333, M 374, and M 374. The sixth IMN set has been planted and we hope for an encouraging result.

CULTURAL PRACTICES IMPROVEMENT

The main cropping system consists of rice or maize in summer and wheat or barley in winter, depending upon physiographic region. Rice is common in Tarai and the lowland areas of Midhills (elevations ranging from 600-2100 m), and maize is common in the upland areas of Midhills and Inner Tarai. In Tarai and Inner Tarai, the fields remain uncultivated for 90-100 days following wheat or barley harvest in February-March and before transplanting paddy rice in June-July. In the Hills, maize is commonly intercropped with soybean, fingermillet, and beans.

It was realized that mungbean's potential lies in culturing it as a catch crop and/or intercrop, and that time of planting is a critical factor in this goal. In a preliminary study on planting dates, researchers found that the spring-planted mungbean yielded higher than the summer-planted crop. In a further study on the date of planting, with Pusa Baishakhi at Parwanipur representing Tarai and Khumaltar representing the Hills, the best dates of planting were found to be the fourth week of March and the first week of April for Parwanipur and Khumaltar, respectively. Yields at those dates were 1433 and 850 kg/ha. for Parwanipur and Khumaltar, respectively. Yield losses for later dates were associated with waterlogging, and higher incidence of diseases and insects. Furthermore, the harvesting and post-harvesting operations were easier in the spring season crop. Farmers have adopted this technology and now mungbeans are planted in March in Tarai as a catch crop.

In a study on intercropping soybean, fingermillet, and mungbean with maize, it was found that mungbeans, intercropped with maize and then followed by relay cropping with fingermillet, gave the highest gross monetary return compared with other intercropping combinations. The yield of mungbean alone was as high as 1160 kg/ha. This high yield, combined with its higher price, was a factor contributing to the monetary return. This result was highly encouraging as an extra crop of mungbean with the benefit of an extra income could be enjoyed by the farmers. Other studies on intercropping mungbean with crops like sugarcane are under way now.

ECOLOGICAL CONSTRAINTS

Nepal's geographical position and mountainous terrain combine to produce climates ranging from hot in the lowlands to cold in the highlands. The adaptation of available strains is limited to the lowlands and the midhills. Another ecological limitation includes low moisture levels in the soil for early planting and excess moisture for late planting. Future research activities will be directed to screening strains for wider adaptation and relatively more drought tolerance.

GENETIC CONSTRAINTS

Available mungbean strains were found to be susceptible to *Cercospora* leaf spot and virus (unidentified) diseases in varying degrees. Although some of the strains have revealed more uniformity in maturity, most high yielding strains need 3-4 pickings. In general, these two genetically limiting factors account for yield losses of up to 30%. Identifying strains with more resistance to diseases and uniform maturity will be another research aspect.

AGRONOMIC CONSTRAINTS

Research on the following aspects will permit an important increase in mungbean yield:

a) proper time of planting relative to specific strains and different agro-climatic regions;

b) planting methods for both mono- and mixed cultures;

c) fertilizer use;

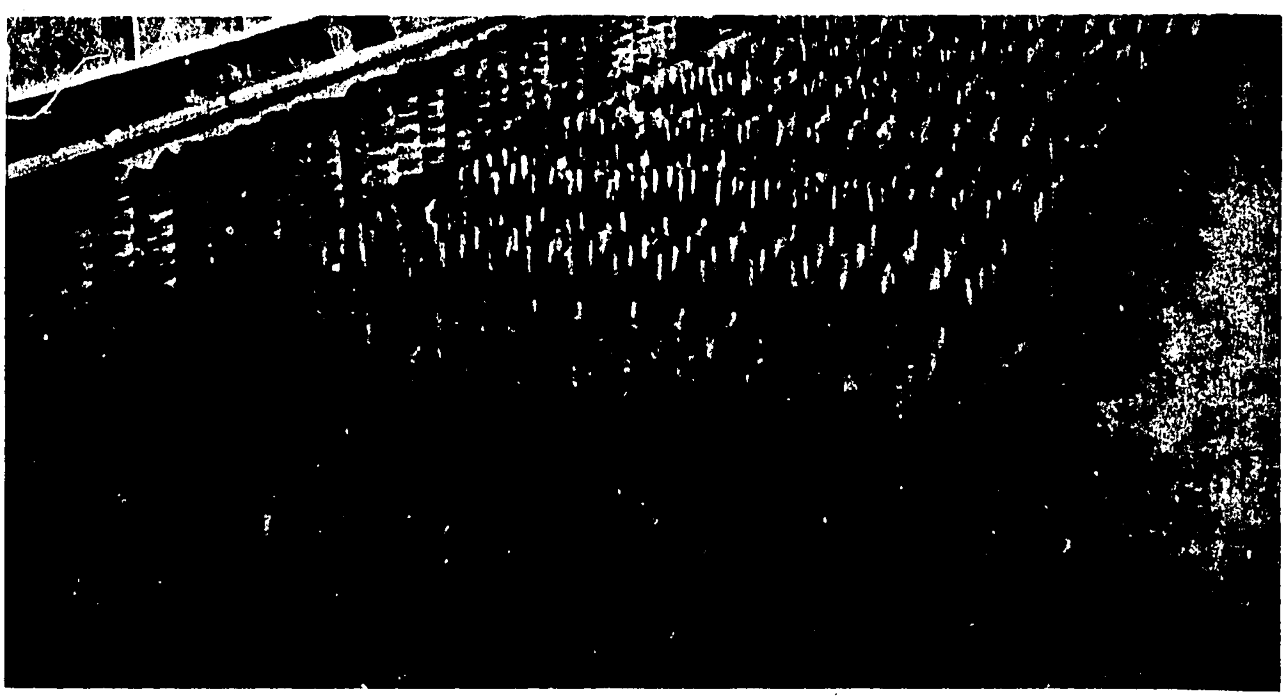
d) compatible symbiosis of mungbean and *Rhizobium* strains;

e) population density; and,

f) weed control.

SEED PRODUCTION AND DISTRIBUTION

Popularity among farmers has led to increasing demand for mungbean seeds. There is no seed growing company in Nepal. The limited land on government farms is used for producing the seed of major crops. Production of foundation seed on government farms and certified seed on a contract basis on farmers' fields could be a feasible way to overcome this constraint.



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Mungbean Cultivation in Bangladesh

MD. Ashraful Islam

INTRODUCTION

Bangladesh is situated between 20.50^{o} and 26.50^{o}N latitude, and 88.50^{o} and 92.50^{o}E longitude with an area of about 142.800 km^2 in the tropical monsoon region. Except for the Chittagong hill tracts and the Sylhet district, the land is a level plain less than 61 m above sea level. Its annual rainfall varies from 1700-2000 mm. Temperature during summer and winter ranges between 21^{o}-32^{o}C and 10^{o}-21^{o}C respectively. The climatic conditions of the country are favorable for growing rice, jute, pulses, oilseeds, sugarcane, fruit, vegetables, tobacco, and wheat on the plain, and tea in the hills.

Among the crops grown extensively in Bangladesh, rice occupies the largest area and highest production, jute is second, and pulses are third. Table 1 shows production data for the various pulses grown in the country.

During the year 1974-75, the total area under pulse cultivation was 309,804 ha and only 13,229 ha were under mungbean. The percentage distribution is shown in Table 2.

Mungbean is regarded as a quality pulse in Bangladesh for its excellent protein, high digestibility, and freedom from the flatulent effects associated with other pulses. It is generally used as dahl or soup, and often fed to babies and convalescents. However, since mungbean is susceptible to water-logging and competes with other major food and cash crops, its cultivation is limited.

ADAPTATION

Cultivated both in summer (Apr-Jun) and late autumn (Sept-Nov), mungbean is best adapted to a warm climate. The crop is grown with limited rainfall by utilizing residual moisture from the soil. When grown in the rainy season, the vegetative growth tends to be excessive, the plants are affected by rainstorms or heavy wind, there is less formation of the pods, and seeds in the pod may germinate or mold.

Mungbeans are generally cultivated on red loams, light red alluvial clays, and other soils, but it is best suited to alluvial soil in Bangladesh.

CULTIVATION

The field is prepared by ploughing followed by laddering. Nothing more than a rough

Table 1. Area and production for different pulses: 5 yr average; Bangladesh, 1970-1975.

Pulses	Area	Production	Yield
	--- ha ---	--- mt ----	-- kg/ha --
Grass pea	97,224	57,501	780
Lentil	67,898	48,031	717
Chick pea	63,330	45,781	753
Black gram	51.670	41,261	809
Pea	20,157	14,631	730
Mungbean	15,204	10,081	667
Pigeon pea	3,074	2,281	752
Cowpea	1,907	1,451	772

Table 2. Percentage distribution of land and production for different pulses; 5 yr average; Bangladesh, 1968-1973.

Pulses	Total land	Total production
	------------ %	------------------
Grass pea	26.1	26.9
Lentil	19.9	18.5
Chick pea	19.2	19.5
Black gram	15.0	15.7
Pea	6.3	6.2
Mungbean	5.5	4.9
Pigeon pea	0.9	0.9
Cowpea	0.6	0.6
Others	6.5	6.8

is attempted. In some areas, cultivators sow mungbean on the mud after the recession of flood water, or without tillage on moist rice land a few days before the rice is harvested.

Seeds are broadcast at the rate 15 kg/ha. In about a week or 12 days the plants are up and the braids are well seen. No intercultural operations are done in Bangladesh. In 70-80 days the pods are dry and the crop is ready to harvest. The plants are harvested by cutting the stem at ground level. Taken to the threshing floor and piled for a week, they are then threshed by beating with a stick or trampling under the feet of bullocks. The residue is preserved as fodder inside a straw stack.

FERTILIZATION

Mungbean does not generally need nitrogenous fertilizers. Their nitrogen needs are met by the fixation of atmospheric nitrogen in the plant root nodules. In areas where mungbean has been cultivated for a long time, nitrogen-fixing bacteria may be available in the soil. But in new areas, the seeds should be inoculated before planting with a suitable *Rhizobium* culture. In Bangladesh, no mungbean seeds are inoculated with any type of *Rhizobium*. And, generally, no NPK fertilizers are applied by the farmers. However, researchers have observed that the application of 40-50 kg/ha of P_2O_5, and 25-30 kg/ha of K_2O produces a higher yield. The fertilizers are spread before broadcasting and incorporated by ploughing.

DISEASES

The major diseases of mungbean are

Cercospora leaf spot (*Cercospora canescens* and *Cercospora cruenta*, Sacc.), powdery mildew (*Erysiphe polygoni*), and root rot fungi (*Fusarium solani*). To control diseases, spraying is recommended 2-3 times with Dithane M-45 (5 lbs/ha), or with copper oxychloride (7-9 lbs/ha) at 15 days interval.

INSECT PESTS

Mungbean is attacked by a number of insects. Beanflies (*Melanagromyza* Sp.) kill the young seedlings and damage the mature plants; leaf caterpillar larvae (*Anthena servula*, Brury) feed on leaves; pod borers severely damage mungbean pods; and aphids (*Aphis madicagenis*) suck sap from leaves. The most serious pest, the weevil (*Callosbruchas chinensis*), is principally a storage pest.

Insects are generally controlled by spraying locally available insecticides such as Diazinon (50 E.C.), Heptachlor (14.7% E.C.), and Lebaycid (50 E.C.). Storage pests are controlled by dusting the seeds with a disinfectant like 10% Sevin or Malathion. Sunning is also done to prevent storage pests.

PRESENT STATUS OF MUNGBEAN RESEARCH

The Bangladesh Agricultural Research Institute has started research to improve mungbean production. Twenty-seven mungbean germplasms have been collected from indigenous and exotic sources. Selection is made on the basis of different yield contributing characters, insect and disease resistance, indeterminent flowering habit, and nonshattering of pods. To increase per hectare production, immediate steps have been taken to conduct trials on agronomical problems with the existing recommended varieties.

RECOMMENDATIONS

During October 1976, the First National Workshop on Oilseeds and Pulses in Bangladesh recommended the improvement of pulses, including mungbean. They recommended that the Bangladesh Agricultural Research Council (the coordinating body for all agricultural research in Bangladesh) should establish a coordinated research project on pulses, including:

1. a survey and collection of available germplasm in Bangladesh;
2. the introduction of germplasm of suitable pulses from other Asian countries;
3. the development of high yielding, disease and insect resistant, and non-shattering varieties, and testing of the varieties under different agroecological conditions;
4. a survey of indigenous cropping and intercropping practices for pulses;
5. trials with improved soil and crop management practices, including intercropping, irrigation, and plant protection measures;
6. the development of crop rotation using pulses as a short term crop; and,
7. a survey of the status of nitrogen-fixing *Rhizobia* under different soil and hydrological conditions.

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Yield Potential of *Vigna Radiata* and *Vigna Mungo* in Summer Rainfall Cropping Areas of Australia

R. J. Lawn

INTRODUCTION

Green gram mungbeans have been grown commercially in Australia on a very minor scale for several decades. Prior to 1976-77, the total area sown annually was less than 2,000 ha. In that year the area planted to green gram rose to approximately 10,500 ha with a further 1,500 ha being sown to black gram (*V. mungo*). Most of the commercial production is currently centered on the tableland area west of Brisbane in Queensland, and on the northwest slopes and plains of New South Wales. All of the commercial cultivars available are direct introductions from overseas, and only recently have initiatives been taken to develop locally bred and adapted material.

However, despite the current minor nature of mungbean production in Australia, there is much interest in the potential for both green and black grams as grain legume crops. There is a recognized need both for diversified cropping, and for the inclusion of leguminous crops into the cropping systems where possible.

Currently, the potential of green and black grams for summer rainfall cropping areas is being examined, with emphasis on those areas where summer rainfall is too marginal and/or variable for other grain legumes such as soybeans.

YIELD TEST RESULTS

Comparative yield tests involving several sets of green gram and black gram accessions have been carried out over the last two decades at 8 sites ranging over latitudes 15°-29°S. In the lower latitude regions, the potential exists for irrigated cropping in the dry season. However, in the higher latitude regions, mungbeans are restricted to the summer growing season by low temperatures at other times.

The results of these studies are summarized in Table 1. In general, grain yields were quite variable, depending on prevailing environmental conditions, particularly moisture availability. For example, average seed yield for green gram accessions ranged from approximately 200-800 kg/ha dryland, and 760-1300 kg/ha irrigated. Average yields for black gram accessions ranged from around 400-1500 kg/ha dryland, and 1900-2200 kg/ha irrigated. Within the dryland tests, much of the yield variation was associated directly with differences in rainfall. Thus notwithstanding their reputations as drought tolerant species, both the green and black grams revealed marked response to moisture availability.

Table 1. Summary of yield tests for *V. radiata* and *V. mungo* accessions at 8 locations, Australia.

Site	Latitude (S)	Year	Irrigation status	*V. radiata* M[a]	*V. radiata* H[b]	*V. mungo* M	*V. mungo* H
				kg/ha			
Crooble	29° 16'	1961	Dryland	376	670	392	835[c]
Redland Bay	27° 37'	1972	Irrigated	1305	1759	2202	2633[d]
Lawes	27° 33'	1961	Dryland	496	1119	730	1401[e]
		1973	Irrigated	1108	2262	2113	3171[f]
		1974	Dryland	682	2564	1496	1961[g]
		1974	Irrigated	762	1695	2022	2551[g]
Dalby	27° 11'	1974	Dryland	232	485	465	683[g]
		1974	Dryland	367	716	467	663[g]
Narayen	25° 04'	1974	Dryland	555	840	715	715[h]
		1975	Dryland	821	1040	1235	1235[h]
Rodd's Bay	24° 02'	1961	Dryland	449	920	585	1019[e]
Clermont	22° 98'	1961	Dryland	565	885	539	765[c]
Ord River	15° 42'	1975	Irrigated	747	1277	1947	3852[i]

[a]M - mean yield. [b]H - highest accesion yield. [c]R.J. Williams. [d]Hibberd, et al. [e]Mungomery et al. [f]J.S. Russell. [g]R.J. Lawn. [h]D.B. Coates. [i]D.F. Beech.

Within tests, the black gram accessions were higher yielding on the average than the green grams (Table 1). Similarly, the highest yielding cultivar in each test was almost invariably a black gram accession. Furthermore, the black grams were more responsive to the more favorable environments (Fig. 1).

YIELD COMPONENTS AND YIELD POTENTIAL

In an attempt to analyze the underlying basis for the differential responsiveness of the green and black gram groups to environment, individual plant data were collected for 4 of the tests listed in Table 1. Mean seed yields over all accessions for these 4 environments varied from 360-1455 kg/ha, almost entirely as a direct response to moisture availability. Means for several plant attributes for the green and black gram accessions within each environment are summarized in Table 2.

Differences in yield over the 4 environments are related primarily to differences in the number of nodes/plant and the number of pods/node. The number of seeds/pod and individual seed weights within each species group were relatively stable over environments with seed size greater in the black grams and seeds/pod greater in the green grams.

Mean number of nodes/plant and the number of pods/node were higher, and also generally more responsive to environment, for the black grams. This was particularly the case for the number of pods/node.

These differential responses appear to reflect general differences in flowering and podding habit which characterized the green and black gram accessions used in these studies. In general, the green grams were determinate in flowering habit, with racemes and pods clustered around the terminal 4-6 nodes of the stem

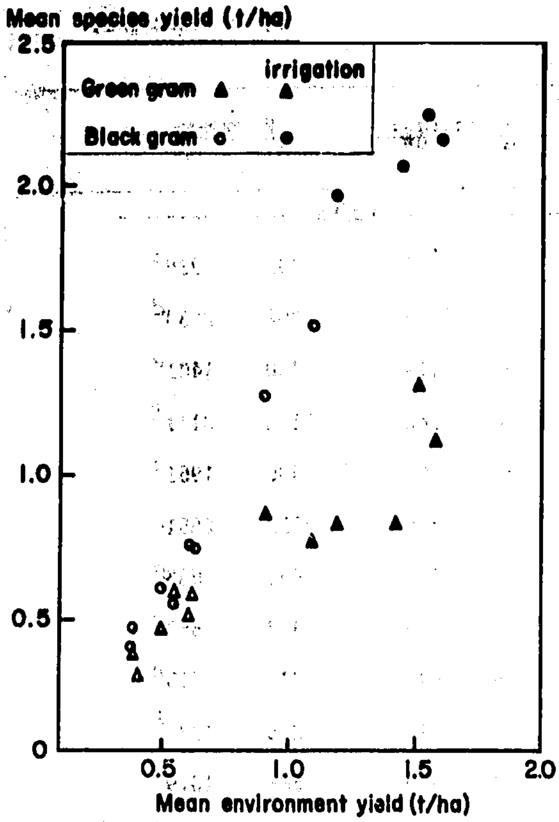

Fig 1. Relationship between mean yield of green and black gram accessions and mean environmental yield; Australia.

(Fig. 2). Vegetative growth of the stem usually ceased shortly after flowering. By contrast, the black grams were somewhat more indeterminate, with racemes dispersed at nodes along the stem and branches. Vegetative growth in the black grams occurred for some time after the start of flowering depending on prevailing environmental conditions.

Thus, in conditions unfavorable for growth (e.g. limited moisture availability), we would expect differences between the green and black grams to be minimal. However, in conditions favorable to growth, the number of nodes produced would be greater in the black grams. Furthermore a higher proportion of these nodes under better environmental conditions may be expected to be fertile, whereas with the green grams, further node production would be likely to result merely in the accumulation of sterile nodes lower on the stem.

The ability of the black grams to respond to favorable environmental conditions by producing more fertile nodes is clearly illustrated by a set of data from a study of the effect of plant population on plant morphology (Table 3). In this study, population was varied by altering row width while maintaining within row plant density constant at 20 plants/m. At high plant populations, the number of nodes/plant was rather similar for both green and black grams. However, as plant population was reduced, the number of nodes/plant for the black grams doubled, whereas that for the green grams increased by only one-half. Furthermore, the number of fertile nodes in the black gram increased almost three-fold as plant population decreased, compared with less than two-fold for the green grams.

Thus 35% of the extra nodes accumulated by the green grams in the lower plant populations were effectively sterile, compared with only 25% for the black grams.

As a consequence, other attributes such as

Table 2. Variation in yield and several plant attributes over 4 environments for 9 green gram (G) and 11 black gram (B) cultivars; Australia.

Attribute[a]	Environment 1		Environment 2		Environment 3		Environment 4	
	G	B	G	B	G	B	G	B
Yield (kg/ha)	232	465	367	467	682	1496	762	2022
Nodes/plant	12.00	17.80	11.80	13.20	22.10	23.20	20.90	24.10
Pods/node	0.55	0.89	0.62	1.13	0.72	1.39	0.77	1.28
Seeds/pod	7.40	4.40	6.30	3.70	5.20	4.00	6.30	4.40

[a]Mean over cultivars.

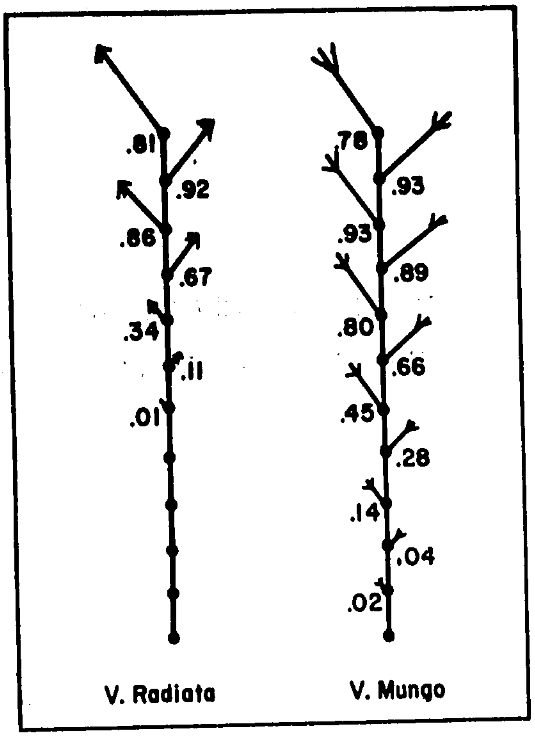

Fig. 2. A comparison of probabilities of fertility for the terminal 12 nodes on the stems of green and black gram. Data for each species are based on a sample of 480 plants (20 plt/plot for 3 replications of 2 cultivars grown in 4 plant populations.

pods/plant, pods/node, and percentage fertile pods increased more markedly with lower populations for the black than for the green grams. However, the number of pods/fertile node was relatively stable over the plant population for both groups.

These comparative data seem to suggest 3 options for breeding for higher yield in green gram.

1. Selection for indeterminancy along the lines that already exist in black gram. This option introduces the problems attendant upon the indeterminate growth habit (e.g. uneven maturity).

2. Selection for enhanced podding at nodes more distant from the terminal node (i.e. higher proportion of fertile nodes on the plant).

3. Selection of short season genotypes which accumulate minimum sterile lower nodes, for high population-narrow row culture.

CONCLUSIONS

1. Results of yield tests of green and black gram accessions indicated that high yielding accessions of both species are available for a range of latitudes and environments in Australia.

2. Both species responded markedly to availability of moisture during growth, despite their reputations as drought tolerant species.

3. The black grams were generally higher yielding than the green grams and were more responsive to favorable environments.

4. The greater responsiveness of the black grams appeared to be related to their indeterminate growth habit and the tendency to bear pods at a higher proportion of nodes than for the green grams.

Table 3. Variation in several plant attributes in response to plant population for green gram (G) and black gram (B) cultivars; Australia.

Attribute[a]	Row width (cm)							
	25		50		75		100	
	G	B	G	B	G	B	G	B
Nods/plant	9.6	13.1	12.9	22.1	14.6	24.2	14.4	28.4
Fertile nodes/plant	3.6	6.8	5.4	11.3	6.6	14.4	6.7	18.2
Pods/node	1.0	1.1	1.1	1.1	1.3	1.4	1.3	1.5
Pods/fertile node	2.6	2.1	2.7	2.1	2.8	2.3	2.9	2.4
% fertile nodes	37	52	41	51	43	60	46	65

[a]Mean for 2 cultivars.

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Production Protential of Mungbean and Gaps Limiting its Productivity India

Chokhey Singh & B.S. Yadav

INTRODUCTION

Pulses have been the mainstay of Indian agriculture, enabling the land to restore fertility so as to produce reasonable yields of succeeding crops and providing proteinaceous grain and nutritive fodder. With scientific advancements in agriculture, there has been a significant increase in the availability of cereals but also a considerable fall in the availability of pulses.

This dismal situation is due to stagnation in the expansion of pulse cropping areas, and complete absence of breakthroughs in the productivity of all pulses. According to prospective planning, India would need 18.6 and 22 million t of pulses during 1980 and 1990, respectively, against the present production of 13.4 million t from 23.0 million ha. Raising pulse production to this level may seem difficult but it is not impossible.

Mungbean, which ranks third to gram and red gram, is extensively grown on all types of soil and under varying climatic conditions.

Being of short duration and having wide adaptability, mungbean is grown all year round as a pure crop in double and multiple cropping systems, and as an intercrop. Under most adverse arid and semi-arid conditions where other crops almost fail, mungbean can grow successfully. Unfortunately, its average yield is only 212 kg/ha in *Kharif* (July-Nov.) and 395 kg/ha in *Rabi* (Sept.-Jan.). With the improvement in varieties and production technology, yields of 600-700 and 1200-1500 kg/ha of the pure crop under rainfed and irrigated conditions, respectively, are not uncommon on the research farms. On farmers' fields and as an intercrop, its productivity reaches 500-700 kg/ha. Various constraints limiting its production in India are:

1. Major growing areas are confined to marginal and sub-marginal lands inherently poor in plant nutrients. Little is grown in better soils amenable for double and multiple cropping.

2. Mungbean is mainly grown where moisture is so low that it becomes the primary limiting factor to increased yields.

3. Maintenance of plant populations is generally much below optimum. Adequate quantities of good quality seed of the elite varieties is not available.

4. There is an absence of varieties with potential for high yield, uniform maturity, and yield stability under varying agro-climatic conditions.

5. Little care is taken in protecting the crop from pests, diseases, and weeds.

6. There is little impact of improved technology as a package on large areas. This is the most important factor limiting its production in the country.

In spite of all these gaps and constraints, mungbean has a bright future in Indian agriculture. Production as a pure crop and as an intercrop is increasing in both irrigated and rainfed areas. Moreover ample evidence exists that mungbean yields in relatively unfavorable areas and climatic conditions can be substantially increased through improved production technology. Further advancement in varietal improvement and production technology is essential to make mungbean production competitive economically with other crops having higher yields.

VARIETY

Varieties which fit well in the various multiple and intercropping systems and give stabilized high yields are required. A large number of varieties of different durations, growth habits, and high yields have been developed, and cultivators now have a wide choice from which to select varieties according to soil and season.

However, there is still a great need for varieties with genetic potential for high yield with tolerance to pests, diseases, and environmental stress. Varieties must be bred with uniform maturity; adaptability for wider ranges of soil, climate, and production practices; and stable yields.

SOWING TIME

Sowing at the optimum time is an important factor to obtain high yields. In north India, sowing summer mungbean on or about April 15th gave the highest yield. Similarly in *Kharif* and *Rabi*, late-sown crops generally gave lower yields.

PLANT POPULATION, PLANTING PATTERN AND SEED

The plant population has a direct effect on yield. Spacing of 30 cm between rows, and 10-15 cm between plants has been found optimum. In summer, row spacing of 20 cm has been found to give the highest grain yield.

To attain this stand, a seed rate of 20-25 kg/ha should be used in varieties having medium size seeds and 25-30 kg/ha in varieties with bold seeds. Cultivators generally use a much lower quantity of seed than optimum, thereby producing low yields. Maintenance of the optimum plant stand will possibly increase productivity by 30-40% over present levels.

The seed production of elite varieties is generally not available to growers on a large scale. Improvements in seed production are needed immediately to benefit large area production, an essential prerequisite for raising mungbean's overall production.

THINNING, INTERCULTURE, AND WEED CONTROL

Thinning of excess seedlings 10-15 days after germination is an essential operation to get the balanced growth and fruiting of individual plants.

Mungbean in the initial growth stages is vulnerable to weeds. Effective weed control in the initial stages has been found to increase yields. The effectiveness of herbicides in controlling weeds in mungbean has not been studied extensively; however, studies at Hissar indicate that lasso at 1 kg/ha was comparable to handweeding.

FERTILIZER USE

Mungbean producing 1500-1600 kg/ha removes only 98 kg N, 25 kg P_2O_5, and 85 K_2O/ha, yet studies made in recent years invariably show that a supply of nutrients, particularly phosphate and nitrogen in adequate quantities, is essential to high yields. Though mungbean fixes nitrogen through a symbiotic process, applications of 10-30 kg/ha N as a starter dose at planting have been reported to increase its yield. A dose of 30-80 kg/ha P_2O_5 have been recommended by various workers in different situations.

The cost-benefit ratio of phosphate has been found favorable at 30-45 kg/ha P_2O_5. Nitrogen at 10, 20, and 30 kg/ha has been found to give response up to 5.4, 4.2 and 3.2 kg of grain/kg N, respectively. The soils being inherently poor, application of nitrogen with phosphate according to soil tests, variety, and production practices is essential to step-up its yield in different situations. Placement of fertilizer a few cm below the seed gives the maximum benefit.

RHIZOBIUM INOCULATION

Inoculation with efficient strains of *Rhizobium* have been reported as an important component in the high production of pulses including mungbean, and efforts have been made to isolate efficient cultures.

Still, the identification and development of more efficient strains suitable for different soils, and study on their quality control, proper storage, distribution, and suitable technology are essential for increasing yields and maintaining greater economy in nitrogen use.

For the proper functioning of the *Rhizobium* strains in highly alkaline and acid soils, pelleting with $CaCo_3$, or $CaSO_4$ has been studied.

WATER MANAGEMENT

Mungbean is mostly grown as a rainfed crop under arid, semi-arid, and sub-humid conditions. Due to its extensive deep root system, it is tolerant to drought conditions; however, most varieties respond to suitable water management. In studies made in summer and winter, irrigations at 50% available moisture have been found to increase yield over no irrigation, or over irrigation either in the pre- or post-flowering stages. Efficient water management in relation to critical periods of moisture stress is essential to raise the yield.

Mungbean cannot tolerate water-logging. During periods of heavy rainfall, water-logging becomes quite serious. Therefore, an efficient drainage system is essential to get high yields.

DAMAGE BY INSECTS, PESTS, AND DISEASES

This crop is severely damaged by the galarucid beetle and the jassids. Much loss is caused by stem fly and white fly, the latter also acts as the vector of yellow mosaic, a serious virus disease particularly during *Kharif*. Application of systematic insecticides at sowing, and one spray of contact insecticide at 30-40 days have been found to boost yield.

INTERCROPPING

Intercropping mungbean in widely spaced and initially slow-growing crops like cotton, jute, sugarcane, pigeon pea, maize, sorghum, castor, and sunflower, has been the age-old practice, but the total productivity in the traditional system of intercropping generally was not high. In recent years planting the economically dominant crops in paired row and skiprow patterns, and inserting quick growing crops like mungbean as an intercrop, has opened new vistas in intercropping to increase the total productivity of land in time and space with a higher cost-benefit ratio. By this method of intercropping, 500-700 kg/ha of mungbean can be obtained without adversely affecting the yield of the principal crop.

To get still greater yields, elaborate studies on planting patterns, plant populations, and fertilizer schedules for the principal crops, particularly high yielding varieties, and the mungbean intercrop, are needed for rainfed and irrigated conditions in the different agro-climatic regions.

MUNGBEAN IN MULTIPLE CROPPING

Development of early varieties suitable for cultivation in summer after the harvest of wheat, potato, sugarcane, barley, gram, and paddy, has been the most significant research achievement. Multicropping mungbean during summer utilizes the fallow land between *Rabi* and *Kharif* crops, provides gainful employment, better utilizes the irrigation water, improves soil fertility, and gives good economic returns. In high intensity cropping systems, input costs for summer mungbean is almost negligible as it utilizes residual nutrients applied to the preceding crops.

All these practices if adopted as a package in all mungbean areas, will raise productivity and make mungbean economically competitive with other crops. Thus, it has bright future in Indian agriculture, both in horizontal and vertical expansion.

Discussion

Calkins: Dr. Arwooth, Table 1 in your paper shows a declining yield pattern for 1962-1976. What is the reason for this trend?

Arwooth: The declining trend in yield could be due to a lack of technical knowledge or experience in mungbean production among the farmers who have recently decided to grow mungbean. We should also consider that mungbean is usually intercropped with, for instance, kenaf or cassava.

Tsou: Dr. Arwooth, Table 2 of your paper shows that the Japanese now import from Thailand ten times as much mungbean as compared with 1975. I also note that the price in 1976 has increased from 0.7 to 1.5 times higher than in 1975. Could you cite any reason for this tremedous expansion in price and volume?

Arwooth: The Japanese used to import from Burma, but because of recent political developments there, they now import mungbeans from Thailand.

Ramanujam: Dr. Arwooth, you might consider several new varieties of mungbean which have been developed in India. These are earlier maturing and more uniform in maturity. Some mature in 60-65 days and can be harvested by cutting the crop at the end of this period. Of course, their behavior might vary in different environments but they are worth testing in your program. Sources of field resistance to several diseases limiting mungbean production, such as yellow mosaic, leaf spots (*Cercospora* and *Canthoniones*), and powdery mildew, have been identified and used in our breeding programs. *Melanogromyza* can be controlled by systemic insecticides, such as disulfabon. Weed control using herbicides (Lasso, TOR E25) can be very paying if the chemicals are not washed away by the monsoon rains.

C.Yang: When you say "laddering", do you mean "terracing," Mr. Islam?

Islam: "Laddering is an intercultural operation usually done after ploughing which serves to break the clods and level the land

C.Yang: Concerning the root rot disease mentioned in your paper, did you merely identify the fungus as *Fusarium*, or was the root rot disease experimentally tested?

Islam: It was a *Fusarium* root-infecting pathogen, not a root rot fungus disease.

Hajar: In Bangladesh, are mungbeans normally grown in the highlands?

Islam: Summer (April-June) is the sowing time for mungbean in Bangladesh. Since heavy rain occurs during this period and sometimes causes water-logging, mungbean is sown only in the highlands. Additionally, in late autumn (September-November), standing water is found in low and medium elevations due to heavy rainfall during early autumn. Again, mungbeans are sown in the highlands.

Grewal: Was the low yield in non-irrigated mungbean during different years due to water scarcity, or were diseases and pests responsible to some extent? Can you recall diseases affecting mungbean and blackgram in Australia?

Lawn: The major differences between years within locations were related to moisture availability. Fortunately, at this point there appear to be no serious disease problems of mungbeans in Australia. We do occasionally find attacks of powdery mildew but the disease usually occurs too late in the life of the crop to significantly affect yields. However, there are insect problems, particularly with pod-sucking and pod-boring insects.

Calkins: As a result of your studies, do you recommend blackgram over mungbean for commercial production in Australia? If so, what conditions might make mungbean more competitive?

Lawn: The question as to whether farmers grow blackgram or green gram depends mainly on the availability of markets, and prices. In the marginal rainfall areas where mungbeans are grown in Australia, the yield differential between black and green grams is not large, except in those seasons with better than average rainfall after flowering.

C.Yang: Dr. Kassim, is the *Corticum* (=*Rhizoctonia* Leaf blight the same leaf blight on mungbean as that caused by *Thanatephoru cucumeirs*?

Kassim: Yes, I think so.

Utilization and Economics

- Continued -

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The Importance of Legumes as a Protein Source in Asian Diets

INTRODUCTION

The vegetable legumes are concentrated sources of protein and, in human nutrition, assume particular usefulness as fortifiers of cereal grains for the very young. During infancy and early childhood the cereal grains are inadequate in protein to support normal growth and development. For older children and adults, cereal-based diets generally satisfy protein requirements given the usual pattern of eating cereals with varying amounts of animal protein. In populations where low-protein starchy roots provide the major food source, the use of vegetable legumes may become the major dietary protein source.

PRODUCTION OF LEGUMES AND AVAILABILITY

Table 1 shows production figures for legumes in Asia (including Mainland China) as compared to world production.

Table 2 reveals that there are distinct population preferences for the major legume crop and also significant differences in availability of legumes for human consumption. Ground nuts, soybeans, and dry beans appear to be universally available but in varying quantities. Usually soybeans grown in Asia are directly consumed by man while in other major production areas, such as the United States and Brazil, soybeans are generally processed into oil and the oil meal is used mainly as animal feed. In Taiwan, because of the popularity of soybeans, the availability of legumes is nearly 75 g/capita per day. The lowest availability level is the Philippines with less than 5 g/capita per day. It is obvious, then, that the opportunity exists for expanding production and increasing the availability of legumes for human nutrition in Asian countries.

NUTRITIONAL QUALITY OF LEGUMES AND POTENTIAL FOR INCREASED USE

Table 3 summarizes the protein value of selected legumes. Most legumes contain 20-25% protein. The soybean is unique with 38% protein. Coconut, a fat rich food, is shown for comparison. It contains only 6.6% protein because of its high oil content. When the oil is removed, the coconut meal residue is equal in protein to the legumes (about 20-22%). PER, BV, and NPU are various methods of expressing the nutritional value of protein in legumes. Whole egg is shown for comparison because it is generally recognized to contain proteins that are almost completely utilized. Generally, the legume proteins are mediocre by themselves as shown by the relatively low values when compared to egg protein.

Table 4 summarizes the essential amino acid content of various legumes. Again whole egg is shown for comparison. Legumes are unique in that they contain lysine in quantities equal to that found in the highest quality protein, egg protein. The proteins of cereals are generally low or deficient in lysine. Since Asian diets are predominantly cereal based, the legume proteins and cereal proteins complement one-another. This results in better protein utilization than would be expected from either cereals or legumes alone. It should be noted that mungbeans are unusually rich in lysine. The legumes are much lower in methionine and cystine than egg protein but these amino acids are usually more abundant in cereals, thus again revealing the complementary effect.

Table 1. World production of legumes, 1973.

	Production world	Production Asia	Asia as % of world production
	---1000mt---		
Dry beans	11,010	3,908	35
Broad beans	5,286	3,510	66
Dry peas	10,731	4,331	40
Chick peas	7,415	6,530	88
Pigeon peas	1,648	1,548	94
Cowpea	1,146	27	2
Soybean	52,712	12,740	24
Ground nut	16,532	8,495	52

Collaborative studies conducted at the Virginia Polytechnic Institute, and the Food and Nutrition Research Institute (FNRI), Philippines, confirmed that a rice/mungbean diet greatly enhanced the protein value of rice alone (1). Such a combination is the basis for "nutripaks" (nutritious food packets for nutritional rehabilitation in infants and young children), and as a weaning food (2,9). The FNRI has formulated a high protein bread (pan de sal) using mungbean and wheat flour (6). An excellent review of the nutritive value of legumes points out the contributions they can make toward improved Philippine dietaries (5). Twelve varieties of beans were evaluated for their nutritive qualities (3).

Table 5, shows the quantities of various legumes that would have to be consumed daily to satisfy one-sixth of the protein or amino acid requirement.

To achieve this would require a considerable increase from the present consumption level of legumes (about 4.8 g/day) in the Philippines. However, several Asian countries consume 30 g or more per capita per day (Table 2) so there is the potential for considerable improvement in the Philippines. I see several ways to accomplish this not only in the Philippines but in other Asian countries as well; first, extensive promotion of legume-rice porridges as weaning foods; second, blending of bean flours with wheat flour and; third, more extensive development of legumes as extenders of meat dishes, such as pork and beans.

Table 2. Availability of legumes, selected Asian countries, 1973.

Country	Dry beans	Broad beans	Dry peas	Chick pea	Pigeon peas	Cow-peas	Soybean	Ground nuts	Others	Total
	g/capita/day									
India	8.1		3.8	20.4	8.2		7.6	10.6	11.6	50.4
Indonesia							7.6	10.6	11.6	29.8
Malaysia							5.5	1.0	8.9	15.4
Philippines	0.6						0.5	1.1	2.6	4.8
Thailand		0.9					1.5	3.9	6.6	12.9
Sri Lanka			5.9	2.9		0.5		1.0	11.1	21.4
Taiwan	7.6						58.5	8.3		74.4
Vietnam	2.3						1.0	1.5	4.2	8.9
Cambodia	7.6						0.6	3.9		12.1
Laos								0.7	10.8	11.5
South Korea	1.5		0.1				13.7	0.4	0.4	16.1

Table 3. Protein value of selected legumes and nuts, 1973.[a]

	Protein in dry beans	PER[b]	Digestibility	BV[c]	NPU[d]
	%		----------------	%	----------------
Dry beans	22.1	1.48	73	58	38
Dry broad beans	23.4		87	55	48
Dry peas	22.5	1.57	88	64	47
Chick peas	20.1	1.68	86	68	62[e]
Pigeon peas	20.9		78	57	52
Cowpeas	23.4	1.41	79	57	45
Coconut	6.6	2.14	80	69	55
Soybean	38.0	2.32	91	73	61
Ground nut	25.6	1.65	87	55	43
Mungbean	23.9	2.12	81	70	46[e]
Whole egg	43.0	3.92	97	94	93

[a](7). [b]PER - Protein efficiency ratio. [c]B.V. - Biological value. [d]NPU - Net protein utilization.
[e](8).

Table 4. Amino acid content of legumes (mg/g nitrogen), 1973.[a]

	Isoleu	Leu	Lys	Meth cyst	Pola	Threo	Tryp	Vol.
Dry beans	262[b]	476	450	119	326	248	63	287
Dry broad bean	250	443	404	96	270	210	54	275
Dry peas	276	425	470	127	287	254	56	294
Chick peas	277	468	428	139	358	235	54	284
Pigeon peas	194	394	481	93	517	182	35	225
Cowpeas	239	440	427	141	323	225	66	283
Coconut	244	419	220	196	283	212	68	339
Soybean	284	486	399	162	309	241	78	300
Ground nut	211	400	221	150	311	163	64	261
Mungbean	223	441	504	77	306	209	50	259
Whole egg	393	551	436	362	358	320	93	428

[a](7). [b]Column chromatography method, except trytoplane, which is the microbiological method.

Table 5. Grams of legumes required daily to supply 1/6 the essential amino acid requirement of an adult male.[a]

	Dry beans	Broad beans	Dry peas	Chick peas	Pigeon peas	Cow-peas	Soy-bean	Mung-bean	Average
Isoleucine	18	18	17	19	26	19	9	19	18
Leucine	16	16	17	17	20	16	8	16	16
Lysine	12	13	11	14	12	12	7	10	11
Methionine cystine	62	73	58	59	85	50	24	89	63
Phenylalanine	23	26	25	23	15	22	13	22	21
Threonine	14	15	13	16	20	14	7	15	14
Tryptophan	27	30	30	35	51	24	23	31	31
Valine	19	19	18	21	26	18	10	19	19

[a]Assumptions: That the diet contains adequate total protein from the following sources, 1/6 from legumes, 1/6 from animal sources, 4/6 from other plant sources, and that the biological value is about 70% that of an ideal protein.

PROBLEMS AND PRODUCTION POTENTIAL FOR LEGUMES

There are several problems that must be considered when one examines the nutritional value of food legumes and their impact on programs for improving the nutritional status of vulnerable populations (4). Vegetable legumes very often are produced in competition with cereal grains and their yields, in terms of energy production per hectare, are usually low. Therefore, it is often difficult to convince the producer to increase his production.

Because of low yields, the producer often needs a high price to break even or to earn a profit. This, in turn, increases prices the consumer must pay. In the Philippines, the most popular vegetable legume, mungbean, has in recent years been more costly as a protein source than some animal products such as dried fish or shellfish.

Generally, vegetable legumes have low digestibilities compared to cereal grains or animal protein sources such as meat, egg, or milk.

Most of the legumes have a hard seed coat which means that the time and energy required for cooking is considerably longer than that for cereal grains. This can be partially overcome by pre-soaking in water. However, under tropical temperature conditions, sprouting may begin even with only overnight soaking, as may happen with mungbeans under Philippine conditions.

Most vegetable legumes contain anti-enzymes or other mildly or moderately toxic components and, therefore, require varying degrees of heat treatment to destroy or inactivate the harmful agents. The mungbean is somewhat unique in that it appears to be quite low in such toxic components or anti-enzymes.

To insure appropriate attention to quality, legume breeders might consider the following guidelines to overcome the above-mentioned problems:

1. increase yield (to be competitive with cereals, without sacrificing protein content);
2. increase methionine and cystine content;
3. reduce anti-enzymes or toxins;
4. raise protein digestibility; and,
5. reduce seed hardness or reduce cooking time.

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The Potential Roles of Mungbean as a Diet Component in Asia

Samson C.S. Tsou and M.S. Hsu

FAO reported that the 1975 world production of legumes was 133.4 million mt, including pulses, soybean, and groundnuts (6). Of this, about 0.3 million mt of mungbeans were produced on 1.4 million ha in Southeast Asia (11). Table 1 compares the average yield and total production of mungbean with those of soybean, groundnut, dry peas, and chick peas in selected Asian countries. The calculated average yield of protein nutrition, based on the protein chemical score, is also listed. The amount of mungbean produced in this area is limited, so the yield of protein nutrition is very low. There are 3 possible ways to increase the protein nutrition yield of mungbean: yield improvement, protein content, and protein quality. Yield improvement is the first priority and most important approach; however, this paper deals with the other two possibilities.

MUNGBEAN PROTEIN

In 1974, AVRDC screened 1,658 mungbean lines. The protein content ranged from 19.5-28.5%, which is comparable to the observations of Yohe and Poehlman (14). The genetic variability is not very broad. Experimental results show that environmental conditions significantly affect the mungbean protein content. It seems, therefore, that there is not much potential for improving mungbean protein content through a traditional breeding approach.

Protein quality of most legumes is limited by the sulfur-containing amino acids (methionine and cysteine) and their digestibility. Figure 1 shows that when mungbean protein is supplemented with methionine, the protein efficiency ratio (PER) can be significantly improved. Ninety-one mungbean lines from a crossing block at AVRDC in 1976 were analyzed for their methionine content. The methionine content per unit weight of protein varied from 0.282-0.402% (Fig. 2). Black gram (*Vigna mungo)* has a higher methionine content than that of mungbean. The progeny of AVRDC's interspecific breeding program is between mungbean and black gram.

Mungbean is usually considered easily digestible and free from flatulence-inducing substances (11). The digestibility and biological value of mungbean and soybean fed at a 10% protein level in rat diets are shown in Table 2. There is no significant variation between the two mungbean lines for digestibility, biological value, or net protein utilization. A rapid screening technique on digestibility study needs to be developed in order to study varietal differences. The nature of flatus production is not fully understood although it is a field of concern to many food scientists and nutritionists. Murphy showed that mungbean has a certain effect on gas formation, although among the legumes, it is considered the least flatulent (9).

Table 1. Relative protein production efficiency of legume in some Asian countries.[a]

Crop	Selected country	Products	Avg. yield	Average protein content	Chemical score[b] (% of egg protein) legume	Chemical score[b] (% of egg protein) mix[c]	Protein content nutritional coefficient legume	Protein content nutritional coefficient mix[c]	Actual Avg. yield protein nutrition legume	Actual Avg. yield protein nutrition mix[c]
		1000T	t/ha	%					t/ha	
Soybean				38	62	78	23.6	29.6		
	India	120	0.750						0.177	0.222
	Indonesia	560	0.737						0.174	0.218
	Philippines	1	0.464						0.109	0.137
	Sri Lanka	1	1.000						0.236	0.296
	Thailand	140	0.892						0.210	0.264
	Taiwan	61	1.495						0.353	0.443
Groundnut				25.6	69	72	17.7	18.4		
	Bangladesh	35	1.400						0.248	0.258
	India	6600	0.917						0.162	0.169
	Indonesia	541	1.300						0.230	0.239
	Philippines	22	0.611						0.108	0.112
	Sri Lanka	17	1.867						0.330	0.344
	Thailand	260	2.167						0.384	0.399
	Taiwan	91	1.427						0.253	0.263
Dry peas				22.5	50	76	11.3	17.1		
	India	550	1.050						0.119	0.180
Chick peas				20.1	53	76	10.7	15.3		
	Bangladesh	44	0.730						0.078	0.112
	India	1818	0.716						0.077	0.110
	Pakistan	1	0.623						0.067	0.095
Mungbean				23.9	32	72	7.6	17.2		
	Bangladesh	14	0.800						0.061	0.138
	India	494	0.400						0.030	0.069
	Indonesia	17	0.600						0.046	0.103
	Sri Lanka	6	0.600						0.046	0.103
	Taiwan	3	0.700						0.053	0.120
	Thailand	190	0.800						0.061	0.138

[a](6,2). [b](1). [c]Based on a mixture of 75% and 25% protein from rice and legume, respectively.

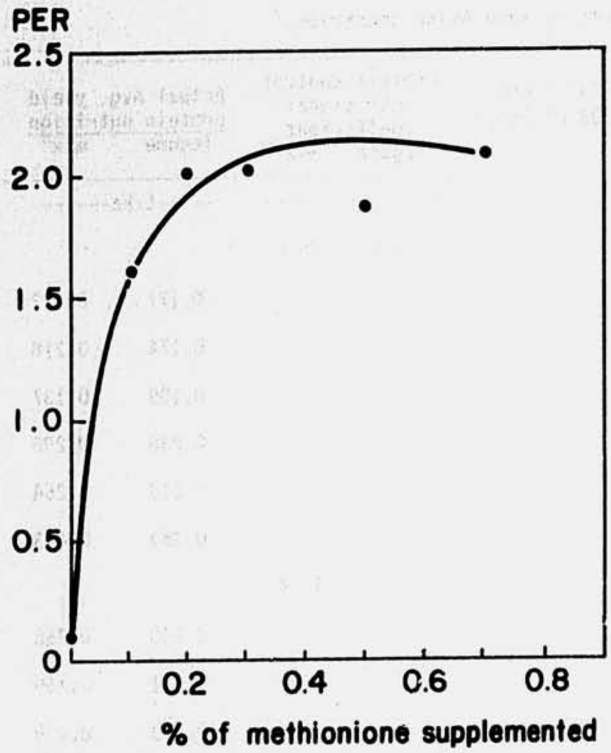

Fig. 1. The effect of methionine supplementation on PER; protein level, 10%; 28 day old Long-Evens strain rats; experimental period, 4 wks; AVRDC.

MUNGBEAN AS A SUPPLEMENTAL PROTEIN SOURCE FOR A RICE DIET

Any agronomic and nutritional improvement in legume foods must take into consideration the nutritional role they play in mixed diets based on cereal grains and starchy foods (5). The chemical scores for a rice-legume mixed diet are given in Table 1. The actual protein nutrition yield of mungbean significantly increases under this condition. A rat feeding experiment showed that the PER of a mixed diet is much higher than that of one using mungbean protein alone (3). The PER of the rice protein is improved from 1.97 to 2.44. Although the calculated chemical score of the mixed mungbean-rice diet is limited by sulfur-containing amino acids, the rat feeding experiment showed that the addition of methionine alone did not improve its PER (Table 3). However, when lysine and methionine were used simultaneously, the PER improved significantly.

These results indicated that mungbean is an excellent supplemental protein source for a rice diet. The protein quality of the present cultivars are probably good enough to serve this purpose. However, when mungbean is not eaten with rice or is eaten with starchy food low in sulfur-containing amino acids (sweet potato, cassava), a more nutritionally balanced mungbean will be needed.

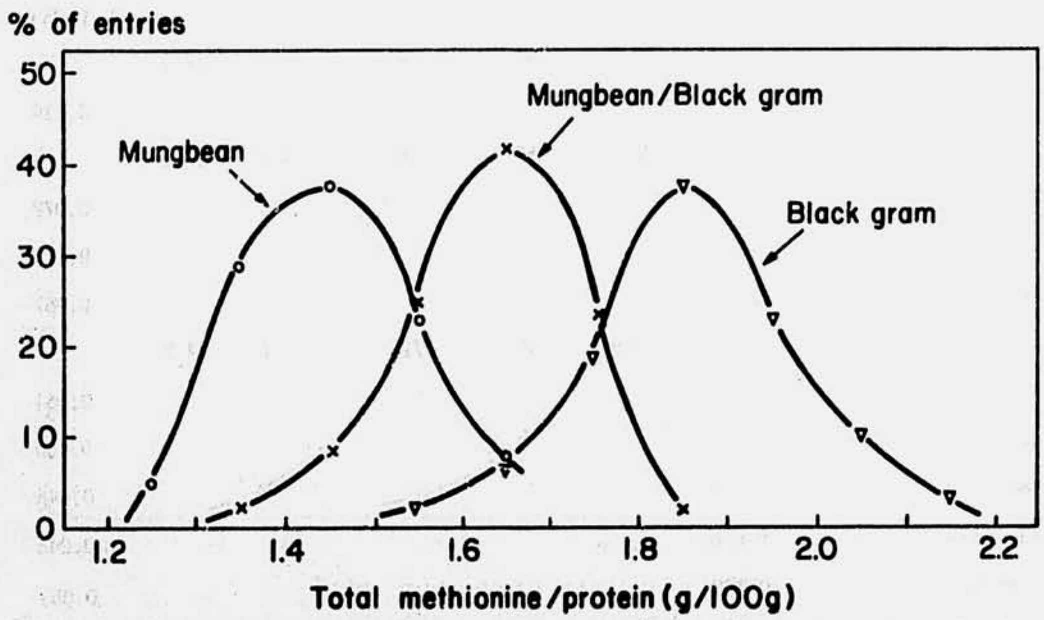

Fig. 2. Methionine distribution curve of mungbean, mungbean/blackgram, and black gram (the methionine content was analyzed by microbiological assay using *Streptococcus zymogenes* NCDO-592); data are from 91 mungbean cultivars; 172 mungbean/blackgram crosses, and 128 blackgram cultivars; AVRDC, 1976.

Table 2. Nutritional quality of some mungbean and soybean cultivars; AVRDC, 1976.[a]

Crop	Variety	Apparent Digestibility	True Digestibility	Biological value	Net protein utilization
Mungbean	M 0304	71.9 a	81.9 a	80.7	66.1 a
	PHLV 18	65.4 a	73.3 a	81.5	59.7 a
Soybean	AGS-2	76.5 b	84.6 a	76.3	64.5 a
	Shih-Shih	73.4 ab	81.2 a	84.2	68.4 a
Casein		91.9 c	99.9 b	91.1	91.0 b
LSD 5%		10.64	12.10	NS	16.02

[a]Protein level: 10%; with Long-Evens strain 12 weeks old rats; experimental period: Protein-free diet: 11 days ; Test diet: 7 days; Data followed by same number not significantly different.

OTHER NUTRIENTS

Protein is not the only nutrient which mungbean can contribute to a rice diet. Table 4 summarizes the nutritive constituents of mungbean and mungbean products. Mungbean sprouts are very popular in Chinese and Japanese cooking. Even in the United States, about 10.2 million kg of mungbean are used annually for sprouting (11). Mungbean sprout become a high quality vegetable not only because their protein content is high but also due to their vitamin C content, attractive appearance, and texture. Genetic variations of the vitamin C contents of bean sprouts can be detected. A range of 9-20 mg/100 g fresh wt of vitamin C was observed in our study.

MUNGBEAN AS OFF-SEASON VEGETABLE

Mungbean sprouts add variety to the Chinese vegetable list, and help fill in when other vegetables are off-season. In Taiwan, fewer vegetables are available in the summer monsoon season than during the rest of the year. After a typhoon, the vegetable supply is a serious problem and mungbean sprouts become the most reliable vegetable. The technology for prepar-

Table 3. Protein efficiency ratio of mungbean and rice mixture supplemented by amino acids; AVRDC, 1976.[a]

Protein distribution	Amino acid added	Average wt. gain	PER
----------- % -----------		------- g ------	
Mungbean 25 + Rice 75	0.2% Lys	41	1.64
Mungbean 25 + Rice 75	0.05% Met	45	1.83
Mungbean 25 + Rice 75	0.2% Lys + 0.05% Met	61	2.36
Mungbean 25 + Rice 75	0.2% Lys + 0.05% Met + 0.05% Thr	85	2.59
Mungbean 25 + Rice 75	None	44	1.67
Casein	None	66	2.22

[a]Protein level: 10%; with Long-Even strain 28 days old rats; experimental period: 4 weeks.

Table 4. The nutrition constituents of mungbean and mungbean products.[a]

Mungbean products	Cal.	Moisture	Protein	Fat	Ash	Fiber	N-free ext.	Mineral Ca	Mg	P	Fe	Na	K	Vitamins A	B_1	B_2	Nia.	C
		%	g					mg %						I.U.	mg %			
Taiwan																		
Seed, raw	320	11.1	22.9	1.1	3.6	4.2	56.9	86		320	4.9			70	0.52	0.29	3.10	0
Starch	346	14.4	0.2	0.1	0.2	+	84.7	15		30	2.3			0	0.15	0	0.20	0
Sprouts	15	95.2	1.8	0.1	0.2	0.8	2.0	11		28	0.5			+	0.08	0.10	0.10	19
India																		
Seeds, raw	334	10.4	24.0	1.3	3.5	4.1	56.7	124	171	326	7.3	28	843	157	0.47	0.39	2.10	0
Dhal	348	10.1	24.5	1.2	3.5	0.8	59.9	75	189	405	8.5	27.2	1150	82	0.72	0.15	2.40	0
Philippines																		
Seeds, raw	356	6.1	24.4	1.0	3.9	4.3	64.6	125		340	5.7	6	1141	130	0.66	0.22	2.40	10
Seeds, boiled	150	60.0	11.0	0.3	1.6	1.3	27.1			209	2.6			40	0.14	0.06	0.60	2
USA																		
Seeds, raw	340	10.7	24.2	1.3			60.3	118		340	7.7	6.2	1030	81	0.38	0.21	2.60	
Sprouts	35.3	88.8	3.8	0.2			6.6	19		63.8	1.3	4.8	223	19	0.13	0.13	0.76	19
Sprouts boiled	28	91.0	3.2	0.24			5.2	16.8		48	0.88	4	156	24	0.09	0.10	0.72	6.4

[a](7,10,8)

ing bean sprouts is relatively simple and appropriate to both rural and urban location. Little space is needed. One producer near Shanhua produces 1 ton of bean sprouts/day in a 7 x 10 m room. During typhoon season he doubles his production. Since mungbean can be easily

Table 5. Expenditures on mungbean products compared to vegetable and general food expenditure, Taiwan.

Year	Mungbean products seed	sprout	noodle	total	Veg. exp.	Food exp.	Mungbean products/ veg. exp.	Mungbean products/ food exp.
	NT$						%	
1973	56.4	105.6	97.2	259.2	4,251.6	33,639.6	6.1	0.77
1974	74.4	152.4	139.2	366.2	7,962.0	46,215.6	4.6	0.79
1975	97.2	145.2	184.8	427.2	8,608.8	50,876.4	5.0	0.84
1976	86.4	114.0	151.2	351.6	8,380.8	52,878.0	4.2	0.66
Average							5.0	0.77

stored, transported, and produced in the urban area, mungbean sprouts are an ideal vegetable under emergency conditions or for those areas where vegetable transportation is a problem.

Nutrition is not the only factor which needs to be considered when we discuss the role of secondary foods. Acceptability and variability of preparation may be even more important when housewives are writing thei purchasing list. For Chinese, bean sprouts and mungbean noodles are the most common forms in which mungbean is prepared. Dry beans are usually prepared as soup or with sugar as a snack or dessert. Sometimes mungbeans are boiled in rice soup during the summer. The products made from mungbean are limited compared with the number made from soybeans. A consumption survey indicated that mungbean products account for only 0.77% and 5.0% of total food and vegetable expenditures of a Chinese family in Taipei city (Table 5). New products will be needed to promote further mungbean consumption. In this respect, the Institute of Food Research and Product Development of Kasetsart University in Thailand and the National Nutrition Council and Nutrition Center of the Philippines use mungbean as the supplemental protein source in their products for baby foods (4, 13). This type of research will certainly help promote mungbean utilization in Asia, and should be encouraged.

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Mungbean and its Utilization in Thailand

Amara Bhumiratana

PRODUCTION OF MUNGBEAN IN THAILAND

Plant seasons

Generally, mungbeans can be grown in Thailand three times per year: early rainy season, late rainy season, and in the rice field after harvest. Production depends largely on climate. Mungbean can be planted in the early rainy season, usually during May or June. Although production will be delayed because of the extended period of plant growth, the plants will receive plenty of water and the yield will be far better than that of other crops in any other season. One disadvantage in growing mungbeans during this season is that the harvest must take place during the late rainy season. Storing and drying of the mungbean become a problem. Spoilage from micro-organisms or insect infestation reduce quality and, thus, lower the price.

Planting mungbeans in the late rainy season is the most common practice in central Thailand. Although the yield is usually lower than that of the early rainy season, the farmers do not have problems in harvesting and storing the beans. Since harvest for this season will occur around November, the beans will be relatively dry and of good quality - which can be sol at a high price. Furthermore, during this season the farmer can crop mungbean after corn and receive additional income.

Planting mungbean in the rice field after harvest is a practice of farmers in the central and northern part of Thailand where irrigation is good. The farmer will start planting during January or February and harvest the crop before the rainy season starts in April or May.

Types of mungbeans

Mungbeans are generally divided into 4 types, based on the appearance of the seeds: dull, shiny, golden, and black. As far as the price of mungbeans is concerned, large beans receive a high price.

Growing area of mungbean

Mungbean production and area for 14 years are shown in Table 1. During 1975, mungbeans utilized approximately 163,500 ha of irrigated land. The total production was 120,600 mt or 737 kg/ha. It was estimated that 42,206 mt of beans, or about 35% of 1975 production, was exported, and the remainder was locally consumed. From 1975 and 1976 surveys, it was found

Table 1. Mungbean production in Thailand; Bangkok, 1976.[a]

Year	Area planted	Average yield	Production	Net exports	Exports as % of product
	1000 ha	kg/ha	---------- 1000 mt	------	
1962	49.6	1081.3	53.7	21	39
1963	100.8	1150.0	116.0	20	18
1964	101.1	1087.5	110.2	33	30
1965	120.5	1037.5	124.8	44	36
1966	136.0	968.8	131.8	33	25
1967	132.8	925.0	122.6	23	19
1968	200.0	918.8	184.0	27	15
1969	207.5	818.8	169.8	51	30
1970	238.9	618.8	148.5	48	33
1971	147.7	950.0	140.0	38	27
1972	205.4	931.3	191.1	40	21
1973	233.1	825.0	191.7	59	31
1974	206.9	906.3	187.9	53	28
1975	163.5	737.5	120.6	42	35

[a]Agriculture Statistics of Thailand: 1975-1976. Document No. 54, Division of Agriculture Economics, Secretariat Office. Minister of Agriculture and Cooperative; Bangkok, Thailand, 1976.

that most of the mungbeans are grown in the northern part of Thailand. The central region was the next highest, whereas the southern and northeastern regions contributed very little. Petchaboon province is the largest producer of mungbeans. Sukothai, Nakornswan, and Lopburi also have substantial production. The total mungbean area in these 4 provinces is approximately 66.3% of the total production area for Thailand.

Price of mungbeans

The price of mungbeans showed yearly increases of US$179.20/mt in 1973, US$254.55/mt in 1974, and US$291.90/mt in 1975. The increase of mungbean price stimulated more farmers to grow the product; however, the yield of mungbean is still very low.

PREPARATION AND UTILIZATION OF PROTEIN ISOLATES FROM MUNGBEAN

Close to 85% of the mungbeans are consumed as food in Thailand. The remaining 15%, which is exported, results in a net income of approximately US$10 million/yr.

Beside using mungbean directly for preparation of various types of food products, large amounts are used to obtain substantial quantities of starch and protein. Table 2 represents the quantitative differences of various properties of protein isolates and mungbean flour when whole bean and dehulled bean are used as the starting material.

The protein isolate from mungbean has been used extensively as a protein supplement in many types of food products. The method used for preparation of protein isolate from mungbean is as follows:

1. 120 kg of whole mungbean split into halves;
2. clean and soak in water at room temperature 8-10 hrs;

3. rinse well to separate the hulls, remove water;

4. crush by using a mill or rietz, and disintegrate;

5. add water and mix well; and,

6. pass the mixture through a Bird centrifuge to obtain:

   a. the water portion containing protein material. Heat this portion at 80°C for 20 min. Adjust pH to 4-5 with glacial acetic acid (1-2 ℓ). The protein will precipitate and can be collected by filtration. Wash the protein once or twice or rinse away the remaining acetic acid.

   b. The second portion contains a residue with high starch content. The starch can be separated by adding 3 volumes of water. Filter through a cheese cloth, and wash 2-3 times. Water-soluble residue will remain in the filter while the water-soluble starch will be in the filtrate. The starch can then be made to precipitate by sedimentation in 1-2 hrs using gravity. The water is then poured out. The process is repeated once or twice to obtain a whitish colored starch. The starch is then dried in a cabinet dryer a 60°C for 5 hrs.

Table 2. Recoveries of starch and protein from whole mungbeans and dehulled mungbeans; Thailand, 1976.

Properties	Whole mungbean	Dehulled mungbean
Protein isolated from 100 g mungbean	17.75	11.80
Starch obtained from 100 g mungbean	20.85	13.00
Protein recovered from 100 g mungbean protein	77.17	51.30
Starch recovered from 100 g mungbean starch	45.33	30.22

The chemical composition of protein isolated from mungbean appears in Table 3. The corrected PER values of protein isolate and ANRC casein are 1.19 and 2.5, respectively.

The protein isolate is used to supplement many food products to increase the level of protein content. Mungbean protein has also been used in preparation of "Kaset Protein," which is one of the high protein-low cost products produced by the Institute of Food Research and Product Development in Thailand.

Table 3. Chemical composition of mungbean protein isolate; Thailand, 1976.[a]

	Protein isolate (dehydrated)	Protein isolate (wet)	Starch (dehydrated)	Residue (dehydrated)
Moisture %	2.97	87.60	7.31	8.39
Protein (N + 6.25), %	78.90	8.61	0.67	15.80

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The Potentials of Mungbean as a Protein Supplement for Child Feeding

Estelita M. Payumo

INTRODUCTION

There is increasing evidence that severe dietary deprivation early in life limits the physical as well as the mental development of the individual. Nutrition surveys conducted in the Philippines show that, nutritionally, the pre-school child is the most vulnerable group in the population (10). Only 20% of this population group is within the normal weight range and the rest suffer from mild to severe forms of malnutrition, particularly calorie-protein deficiency. Low body weights may be traced to the lack of supplementary foods which should be given in infancy and/or the poor nutritional quality of weaning foods. Other contributory factors are: low economic status, lack of information on the food needs of the growing child, too many family members, and poor hygiene and sanitation. Traditionally, when a mother finds that her supply of breast milk is inadequate to satisfy the baby, the alternative food most often provided is a sweetened and diluted form of processed cow's milk or a thin rice gruel. This diet could probably satisfy the energy needs but does not supply the quantity of protein essential for growth and maintenance. Commercial infant foods which have found their way onto the grocery shelves are expensive in terms of local purchasing power. Rice supplemented with animal protein offers the best solution but is limited by availability and high cost. The protein intake may, therefore, be improved by the consumption of cheaper protein sources, which could be vegetable legumes.

NUTRITIONAL AND ECONOMIC VALUE OF MUNGBEANS

Among the vegetable legumes, mungbeans are widely available and commonly consumed in the Philippines. Mungbeans contain 20-25% protein, almost three times that of cereals, and yield as many calories per unit of weight as cereals. When allowed to sprout or germinate, ascorbic acid is synthesized. The amounts of riboflavin and thiamine are also increased.

Just like other legumes, mungbeans have adequate amounts of lysine but are limited in the sulfur-containing amino acids, methionine and cystine. As such they mutually supplement cereals, which are generally deficient in lysine. The protein quality of mungbeans is considerably improved when combined in the 70:30 rice to mungbean proportion (4). The protein efficiency ratio (PER) of the raw bean is relatively low (0.87 compared to 2.5 for casein) because of its low methionine content and the presence of a trypsin inhibitor (2,8). This anti-nutritional factor is, however, inactivated by common cooking procedures (16).

One of the problems associated with maternal acceptance of legumes for feeding young children is the production of intestinal gas or flatulence. It is suspected that the compounds

Table 1. Yield of protein by different crops; Philippines, 1977.[a]

Crop	Average yield	Maturity	edible portion	Production yield	production
	- mt/ha -	- days -	- g -	kg/ha	kg/ha/day
Rice	1.60	120	7.4	75[b]	0.63[b]
Corn	0.84	100	4.9	4	0.04
Mungbean	0.55	60	24.4	134	2.20
Peanut	0.57	110	14.1	41[c]	0.37[c]
Cowpea	0.40	60	20.4	82	1.40
Sweet potato	5.00	100	1.1	55	0.55

[a](16). [b]Based on 64% milling recovery. [c]Based on 51% edible portion.

in beans which play a major part in flatus production are the oligosaccharides, raffinose and stachyose (5). Studies on flatus production in children fed legume diets (9) showed that among the legumes, mungbeans were the least flatulent and most easily digestible.

In most developing countries protein yield per hectare of land is important. Table 1 shows that mungbean gives a higher protein yield per hectare than cereals or rootcrops. Furthermore, protein from mungbeans is cheaper compared with that of animals (Fig. 1). They provide more proteins for the money spent than do animal sources.

PROCESSING AND UTILIZATION

Filipinos eat a relatively small amount of beans. Regarded as socially inferior food, beans are not normally served during special celebrations. Traditionally, mungbeans are cooked, either whole or sprouted, as a vegetable dish in combination with meat, shrimp, or fish. Snacks and desserts are also prepared from the boiled beans. Mungbean starch is also prepared into traditional oriental noodles.

In general, the major disadvantage in the utilization of beans is the extended cooking

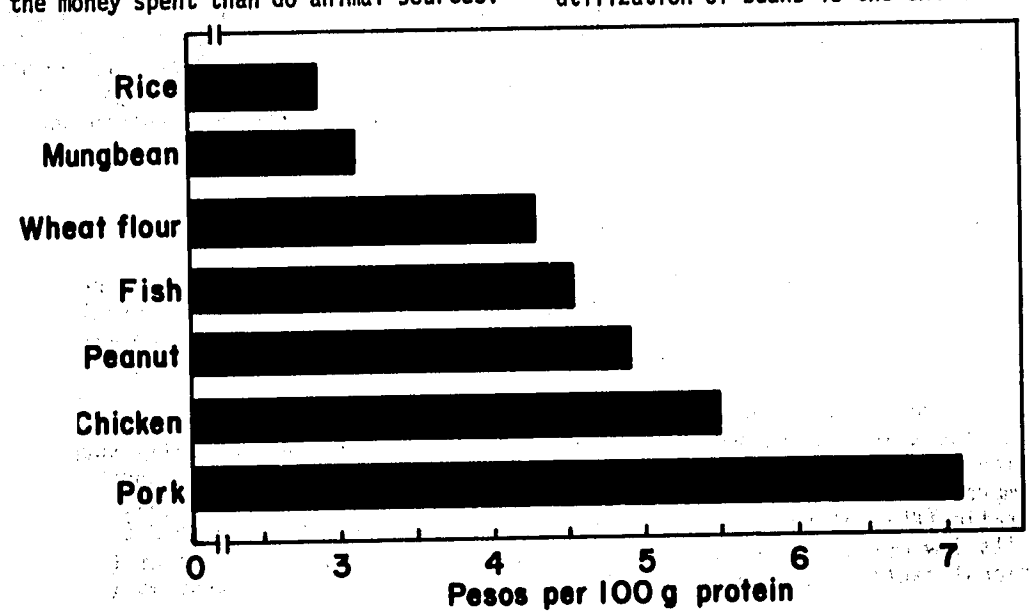

Fig. 1. Relative cost of protein from selected raw material sources (based on Manila retail prices, July 1977; ₱7.35 = US$1.00); Philippines, 1977.

time needed to achieve the desired palatability and digestibility. For infant feeding, the boiled beans must be further mashed and sieved to remove the seed coat for maximum digestibility. The length of time required for such preparation influences the attitude of the busy mother towards its use for child feeding. In order to alter the image of beans and pulses from that of a "poor man's food," as well as to increase the overall acceptance and reduce cooking time, legumes are processed into powder or flour.

The procedures for mungbean flour preparation range from the simple household method of toasting-cracking or soaking-drying-cracking to the more highly mechanized fine dry milling and sifting to remove the seed coat (3, 6, 12, 18, 19). Removal of the seed coat reduces the crude fiber from approximately 5% to 0.75% and increases the protein content by about 8% of the whole bean value.

Realizing the urgency of solving malnutrition, weaning and supplementary foods for the young child based on blends of legumes, oilseed meal, and cereals were developed. Fish, mini-shrimp powder, or dried skim milk are added, depending on availability. Some selected local formulations using whole mungbean or flour are shown in Table 2.

Table 2. High protein food supplements utilizing mungbeans and other indigenous raw materials; Philippines, 1977.

Category	Form	Basic ingredients	Protein (%)	Calories (per 100 g)
Weaning food	Porridge	Mungbeans, "am" (boiled rice broth), sugar[a]	4.4	105
		Mungbeans, rice, milk, sugar[a]	4.4	111
	Dry mix	Mungbean flour, coconut flour, skim milk powder[b] (MCM)	25.0	364
		Mungbean flour, rice flour, coconut flour, fish protein concentrate[b] (MRCF)	24.0	383
		Mungbean grits, ground rice, skim milk powder, oil (Nutri-Pak)[c]	12.0	388
		Rice flour, mungbean flour, full fat soy flour[b]	22.8	422
	Drum-dried flakes	Coconut protein isolate, mungbean flour, skim milk powder[b]	22.0	398
		Mungbean flour, rice flour, fish protein concentrate, coconut skim milk[b]	25.0	370
		Mungbean flour, coconut protein isolate, rice flour, fish protein concentrate[b]	25.0	370
Snack food	Deep fried crunchies	Mungbean flour, coconut flour, corn meal[b]	17.0	484
	Cookies	Mungbean flour, cowpea flour, rice flour, wheat flour[a]	7.2	290
	Breakfast bun "pan de sal"	Mungbean flour, bread flour (30:70)[b]	12.0	295
Noodles	Dry	Mungbean flour, rice flour (50:50)[b]	17.5	362
		Wheat flour, coconut flour, mungbean flour[b] (50:30:20)	22.0	368

[a](3) [b](1) [c](11)

The porridge-type weaning food prepared from boiled, mashed, and sieved mungbeans with added cereals and sugar (with or without milk) was fed to infants 6-18 months old. Studies showed that the infant supplements were readily accepted and no evidence of diarrhea or gastro-intestinal disturbance of any kind was detected (3).

MCM, which is a blend of 80 parts mungbean flour, 15 parts coconut flour, and 5 parts skim milk powder, was well accepted and tolerated by children aged 1-3 years (1). After 6 months of feeding, results showed a significant increase in weight in the MCM plus rice-fed children compared to the control group who were fed with the usual nursery food of rice with some broth, ground meat, and vegetable for lunch and supper. Similarly, MRCF fed to children 1-6 years of age showed no untoward signs or symptoms attributed to intolerance. A growth test conducted over a 3-month period showed that MCRF is as good a source of protein as the more expensive animal proteins.

"Nutripak" contains individual packets of ground rice, a protein-rice food, which is either mungbean grits, mini-shrimp powder, or "dilis" (anchovy) powder with skim milk powder and cooking oil. The ingredients are cooked into porridge as directed, with salt or sugar added to taste (11).

The drum-dried flakes were rated highly acceptable and comparable to the imported product of the same type by a panel of tasters composed of young mothers (13, 14).

A popular type of breakfast bun locally known as "pan de sal" was prepared by substituting 30% of the wheat flour with mungbean flour. The resulting bread was well accepted, had good volume, fine uniform grain, and soft crumbs which remained so for 3 days when stored in polyethylene bags at room temperature (7). The protein content was increased by approximately 39% over that of the all-wheat commercial formula. The other types of snack foods were likewise highly accepted.

Wheat and rice-based noodles prepared partially with mungbean flour were rated very acceptable even after 6 months storage of the dry noodles in polyethylene bags at room temperature (12, 15).

CONCLUSION

The potential for increasing the utilization and consumption of mungbean as a protein supplement especially for child feeding is evident. With the present breakthrough in production as well as improved processing technologies, the role of mungbean in improving the nutritional status of a large number of people living in developing countries cannot be ignored.

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Economics of Mungbean Production and Trade in Asia

Peter H. Calkins

In order to plan further development of the mungbean industry in Asia, it is necessary to understand the region's current production and trade situation. Mungbean is notorious for both low and unpredictable yields, and great variability in export volumes. This paper takes an integrated approach in addressing these problems. Its specific objectives are to:

1) consider production and trade in 3 representative countries: Thailand, the Philippin and Taiwan;

2) investigate the climate, cropping systems, reasons for planting, disposition of the crop, and detailed production budgets for samples of mungbean farmers surveyed in representative producing regions of these 3 countries; and,

3) evaluate the appropriateness of existing technologies in their economic production environment.

PRODUCTION AND TRADE OF MUNGBEAN IN ASIA

FAO and other data (3,4,9,10) from the Asian region suggest that India is the primary mungbean producer. Yields, however, are highest in Thailand, which is Asia's second largest producer and, given a much smaller domestic consumption than India, is also the origin of most of the export trade in Asia. Moreover, Thailand is the only country which has shown both a consistent increase in annual production and resistance to export instabilities.

Figure 1 shows the breakdown of exports from Thailand. Major importers are Japan, Taiwan, Malaysia, and Hong Kong in that order.

THE MUNGBEAN INDUSTRY IN THREE ASIAN COUNTRIES

Three countries were selected for study to determine why Asian producers face production and trade instabilities for mungbean, and how these may be overcome. Thailand represents a success story of annually increasing production and trade. The Philippines is a minor consuming country with a large area planted, but low yields. And, Taiwan, a major consuming country, is endeavoring to increase domestic supply capability. Figure 2 gives the comparative levels of planted area and exports for these 3 countries.

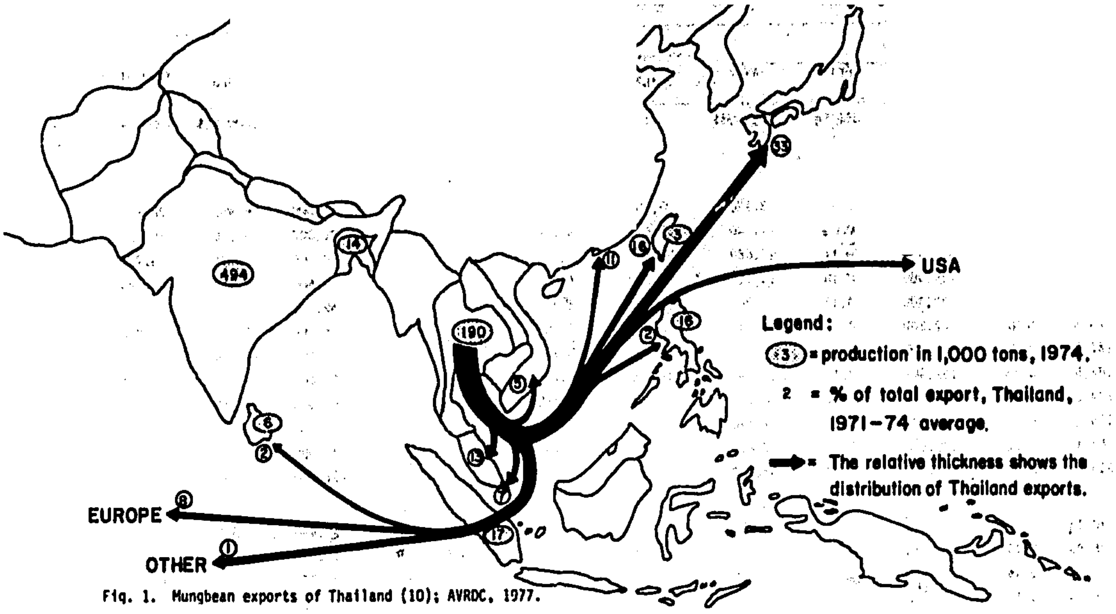

Fig. 1. Mungbean exports of Thailand (10); AVRDC, 1977.

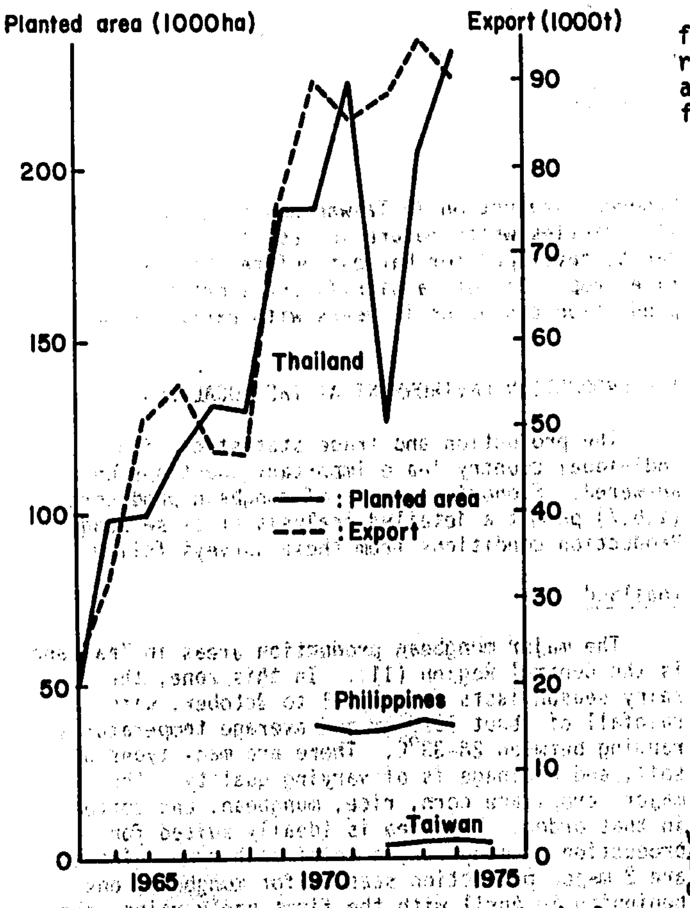

Fig. 2. Mungbean planted area and exports in 3 Asian countries (10); AVRDC, 1977.

The production, trade, and consumption figures for each of these countries for all recent years in which statistics are available are shown in Table 1. Thailand exhibits the following characteristics:

1) steady and dramatic increase in planted area;

2) a tendency to declining yield, suggesting that new land brought into production is not as suitable for mungbean, and that there have been no widely-adopted improvements in production technology or genetic material;

3) price fluctuations which suggest that farmer income is subject to considerable risk in mungbean;

4) steadily increasing production and exports with no history of imports; and,

5) large fluctuations in domestic supply accompanied by a steady increase in population so that large fluctuations also occur in per capita consumption. Such fluctuations are a major deterrent to increased use of mungbean in the Thai diet should exports deteriorate.

Thailand's problems of declining yield and variability in production and consumption can be improved through plant breeding and improved crop management.

Figures on the Philippines show:

Table 1. Production, import & export of mungbean in Thailand, Philippines, and Taiwan.[a]

	Production					Trade				Domestic supply		Population	Consumption
						Export(FOB)		Import(CIF)					
	area	yield	quantity	price	value	quantity	value	quantity	value	quantity	value		
	1000 ha	t/ha	-- t --	US$/kg	1000 US$	-- t --	1000 US$	-- t --	1000 US$	-- t --	1000 US$	1000 persons	per capital kg/person
Year													
Thailand													
1962	49.1	1.08	53,700	0.15	8,130	20,700	2,950			33,000	4,950	20,884	1.14
1963	98.9	1.15	116,200	0.12	14,700	33,400	4,200			82,800	9,936	29,792	2.78
1964	99.7	1.09	110,300	0.11	12,680	50,700	5,900			59,600	6,556	30,774	1.94
1965	118.2	1.04	124,900	0.10	13,110	55,300	6,550			69,600	6,960	31,740	2.19
1966	131.2	0.98	132,000	0.12	16,960	46,900	6,100			05,100	10,212	32,781	2.60
1967	129.3	0.92	122,800	0.16	20,440	46,700	6,600			76,100	12,176	33,866	2.25
1968	187.5	0.92	184,000	0.14	26,490	76,800	10,750			107,200	15,008	34,993	3.06
1969	187.5	0.78	152,400	0.17	14,740	89,800	12,750			62,600	10,642	36,161	1.73
1970	224.2	0.62	148,500	0.12	19,010	85,600	12,750			62,900	7,548	37,368	1.68
1971	126.4	0.97	125,600	0.11	14,440	88,300	13,850			37,300	4,103	38,612	0.97
1972	205.4	0.92	190,500	0.17	33,810	95,200	18,700			95,300	16,201	39,891	2.39
1973	233.1	0.82	191,700	0.20	39,490	90,000	21,600			101,700	20,340	41,204	2.47
Philippines													
1970	38.13	0.42	15,990	0.21	3,495	207	25	207	30	15,990	3,358	38,114	0.42
1971	36.90	0.44	16,253	0.23	3,738	135	44	1,419	237	17,487	4,022	39,422	0.44
1972	37.86	0.44	19,440	0.23	4,690	6	3	3,290	681	22,724	5,227	40,797	0.56
1973	33.98	0.44	19,120	0.27	5,290	8	4			19,112	5,160	42,243	0.45
1974	37.48	0.42	16,060	0.40	6,480	90	41	231	68	16,201	6,480	43,760	0.37
Taiwan													
1972	3.13	0.42	1,320	0.41	540	42	20	15,212	2,283	16,490	6,761	15,289	1.08
1973	4.33	0.65	2,810	0.35	950	199	97	19,324	3,067	21,635	7,572	15,565	1.39
1974	4.70	0.67	3,160	0.38	1,220	65	44	22,126	4,682	25,201	9,576	15,852	1.59
1975	4.30	0.66	2,840	0.36	1,030	3	2	20,738	5,065	23,575	8,487	16,150	1.46

[a](3,9,10), and Monthly Bulletin, Bank of Thailand; MFAC, Export Potentials for Mungbeans.

1) a fairly constant planted area, yield, and quantity produced;

2) an increasing price trend, which however is not closely related either to the export-import situation or to the level of domestic per capita consumption; and,

3) no clear-cut trends in trade and consumption. Thus, there is tremendous potential in the Philippines if technology and germplasm can be introduced to elevate yields on a planted area now almost equal to that of Thailand in 1962.

The statistics from Taiwan reveal:

1) an increase in area planted, yield, quantity produced, domestic consumption, value of production, and quantity of imports from 1972-1974, followed by a decline in all of these in 1975;

2) price instability, posing risk to the farmer; and,

3) a general pattern of declining exports which in any case are insignificant compared with the volume of imports.

Mungbean production in Taiwan has great potential if varieties which mature in less than 70 days can be developed for harvest before the summer rice crop. If not, a significant short-fall in production can occur in years with early monsoons.

THE PRODUCTION ENVIRONMENT AT THE LOCAL LEVEL

The production and trade statistics of an individual country leave important questions unanswered. Economic surveys of mungbean producers (1,6,7) permit a detailed analysis at close range. Production conditions from these surveys follow.

Thailand

The major mungbean production areas in Thailand is the Central Region (11). In this zone, the rainy season lasts from April to October, with rainfall of about 1370 mm and average temperatures ranging between 28-33°C. There are many types of soil, and drainage is of varying quality. The major crops are corn, rice, mungbean, and cotton, in that order. The area is ideally suited for production of mungbean, a chief cash crop. There are 2 major production seasons for mungbean, one beginning in April with the first early rains, and the other beginning in August and ending in January.

Thus, mungbean production occurs for almost 9 months.

By far the major use for mungbean is cash sales. Among the main reasons for growing mungbean, price is by far the major consideration, with less labor and lower capital intensity as secondary reasons. Only 1% of the Thai farmers mentioned higher yields as a reason for growing mungbean, suggesting that much work can be done on yield improvement.

In comparison with other crops, mungbean uses more labor than sorghum and black gram but less than cotton and soybean, and so, for Thai upland crops, may be considered of medium labor intensity.

Philippines

The Ilocos region of the Philippines (northwestern coastal Luzon) has 3 seasons: hot-dry (Mar-May), with average temperatures between 23°-35°C; hot-humid (Jun-Oct), with a temperature range of 21°-28°C; and cool-dry (Nov-Feb), with temperatures ranging between 18°-30°C. Almost all rainfall occurs during the hot, humid season, when over 50 mm may fall each day (2).

In this region, mungbean is usually planted after harvesting the monsoon rice during the last half of Decmeber (7). Harvests are most frequent in the first half of March. Farmers (65%) grow the crop on irrigated lowland, and it is sometimes followed by corn or early rice.

The average total production in 1976 for the region was 341 kg/farm, or 355 kg/ha. The disposition of the crop was as follows: landlord 27%; harvest labor 18%; next-year's seed 12%; and, operator 43%. The rate of cash sales was 33%, with up to 37% sold on high-yield farms.

Between 1975 and 1976, similar samples of mungbean-producing farmers in the Ilocos Region registered an increase in mungbean planted area from 0.56 ha to 1.02 ha on a total average farm size of 1.58 (7). Thus, there seems to be great supply elasticity in the Ilocos region, especially if the current low yields can be raised. Even the high yielding farms only average 537 kg/ha. Thus, improved breeding lines and cultural practices stand to make a large impact on Philippine production.

Taiwan

In Taiwan, over 96% (1975) of the total harvested mungbean area is concentrated in the southwestern counties of Tainan, Chiayi, and Yunlin. However, the mungbean crop occupies only 9% of all hectare-months cropped even on mungbean-producing farms (6).

The annual precipitation in Tainan County, which may be taken as representative of the region, is 1324 mm, with average temperatures between 22°-31°C. There are 3 production seasons: the hot-dry (Mar-May), with temperatures ranging between 20-30°C; the hot-humid (Jun-Sept), with a temperature range between 25°-33°C; and the cool-dry (Oct-Feb), with temperatures between 16°-26°C (8).

Farmers in Taiwan plant 80% of the mungbean area during the hot-dry season, before the monsoon rice crop. Although mungbean can be cultivated in every season, it cannot yet assure a high or sufficiently stable level of return to be competitive. Farmers choose to grow mungbean for its short growth period and the chance of better income with relatively low labor costs. It is often preferred to sesbania, sorghum, and seed melon. However, the very shortness in its production period, which is its greatest asset, also throws it into the greatest danger of not being harvested. If rains come early in a given year, the crop must be abandoned to ready the field for rice.

As for the disposition of the crop in Taiwan, about one-seventh of the farmers did not sell their crop, consuming about 61% and giving away 39% as gifts. The farmers who sold mungbean, on the other hand, consumed only 49% of the mungbean they did not sell, giving away much of the remainder.

PRODUCTION TECHNOLOGY AT THE LOCAL LEVEL

The climatic factors in the 3 areas, especially northern Luzon and southern Taiwan, are quite similar. Therefore, we may hypothesize that major differences in production technology are due to economic, rather than agronomic factors. The data given in Table 2 compare the information from 4 separate farm-level surveys of mungbean production.

The area planted to mungbean on each farm is much smaller in Taiwan than in the Philippines, which in turn is smaller than in Thailand. Yield, however, follows the opposite trend. A possible explanation for this phenomenon is that, as field size increases, the ability to supply necessary production inputs/unit area decreases. Indeed, this is the case, as shown by the labor hours and material and, labor costs/ha in Table 2. It is evident that the whole level of production technology used in Taiwan is higher than that in either the Philippines or Thailand. Because of this higher level of technology, farm income (defined as value of the crop minus cash costs), is also the greatest in Taiwan. Net return, which further subtracts an imputed value for owned assets, tends to follow this pattern as well, except for the case of the Philippines where major non-cash expenditures result in a negative net return.

Table 2. Comparative mungbean production cost structure/ha in several Asian agroclimates; AVRDC, 1976.

	Thailand Phra Buddhabat[a]	Philippines Ilocos[b]	Taiwan Tainan[c]	 Yunlin, Tainan, Chiayi[d]
	1974 (n=108)	1975-76 (n=161)	1975-76 (n=10)	1974 (n=73)
Field size (ha)	2.14	0.79	0.20	-
Yield (kg/ha)	268	334	672	800
REVENUE ($US)	40.2	154.0	464.1	453.7
TOTAL EXPENSES ($US)	37.7	191.6	470.3	435.5
Labor (%)	21.9 (58)	55.9 (29)	273.3 (58)	285.7 (66)
Materials (%)	8.4 (22)	45.1 (24)	109.9 (23)	56.7 (13)
Other capital (%)	7.4 (20)	90.6 (47)	87.1 (19)	93.1 (21)
NET RETURN (US$)	22.5	-37.6	62.0	18.2
FARM INCOME (US$)	34.1	43.0	301.0	109.1
Labor (hrs/ha)	200.1	318.3	679.3	651.0
Wage (US$/hr)	0.11	0.18	0.41	0.41
Capital (US$/ha)	17.8	135.7	197.0	149.8
Interest (%/yr)	15	15	13	13

[a](1). [b](7). [c]AVRDC Farming Practices and Cooperative farmer projects. [d](6).

In addition to the *level* of technology, it is also important to consider the *balance* among material, labor, and other costs (i.e. irrigation fees and land taxes). Notably, material costs occupy about the same percentage of total costs in all agroclimates under consideration. However, labor costs are the greatest cost component in Taiwan, while other costs are the greatest in the Philippines and Thailand. This suggests that although mungbean is considered a non-labor intensive crop, it still requires some 600 hr/ha in order to become truly profitable.

APPROPRIATE FACTOR RATIOS

Appropriate technology best reflects the relative costs of inputs in deciding their relative magnitudes in the production mix. Figures 3 and 4 demonstrate the results of such analysis for mungbean production in three Asian countries. The ordinate in Figure 3 shows the wage rate for each country, while the abscissa shows the interest rate. In Figure 4, the ordinate represents capital inputs which are defined as material

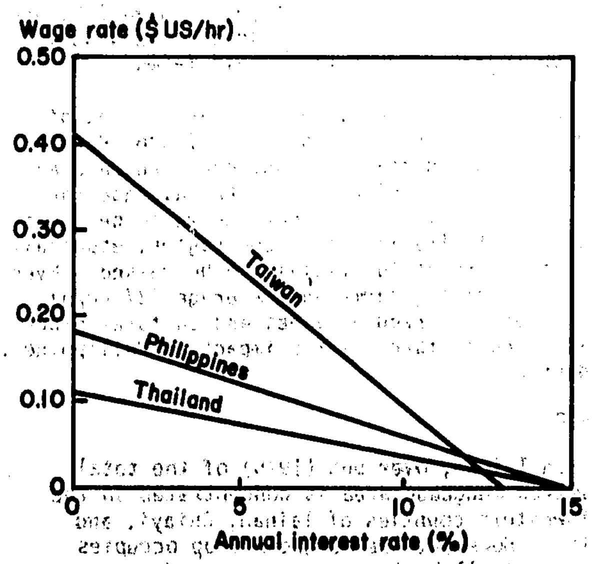

Fig. 3. Factor costs in 3 Asian countries (5,9,10); AVRDC, 1977.

and other nonlabor costs; while the abscissa represents labor costs. By connecting the levels on both axes for a given country, a line is determined with a definite slope. The theory of economic efficiency - or, in other words, appropriateness - suggests that the slopes of the capital/labor price lines, (i.e. the wage rate to the interest rate), will follow the same sequence as that of the lines connecting the levels of capital and labor used.

Figure 3 shows that:

1) the level of wage rates declines as one goes from Taiwan to the Philippines to Thailand;

2) interest rates, however, are lower in Taiwan than in either of the other countries; and,

3) thus, the factor cost slope is greatest in Taiwan, intermediate in the Philippines, and gentlest in Thailand.

Figure 4 shows that:

1) the level of overall production technology declines as one moves from Taiwan to the Philippines to Thailand; and,

2) the factor proportion slope is greatest in the Philippines, intermediate in Taiwan, and gradual in Thailand.

Because the order of slopes is not the same in both figures, we cannot accept the hypothesis that technology is appropriate in all countries involved. The Philippines, in which capital is as expensive as in Thailand, uses over 7 times as much of this input. In the Philippines, less capital and at least as much labor could be involved to produce a more appropriate technology for the country. If such a technology were used, then the order of factor proportion slopes in Figure 4 would follow that of the input costs in Figure 3.

The interest rate in Thailand is higher than in Taiwan. Logically, capital expenditures are very low. However, the low wage rate in Thailand would lead one to expect very labor intensive production of mungbeans, especially since, as we have seen, a minimum of 600 hr/ha seems to be essential for good profitability. Yet, land is more abundant in Thailand, so that labor must be distributed over a much larger area. A much lower level of farm income/ha is also acceptable. The statistics in Table 2 reveal that farm income/hr of labor worked is higher in Thailand than in Taiwan. Therefore, technology in Thailand, though apparently underdeveloped, may be the most suitable for the resource base. It is not surprising that Thailand is Asia's major exporter of mungbean.

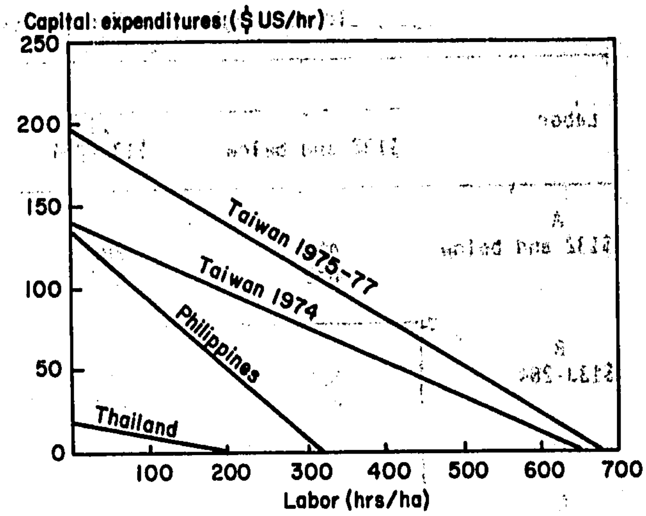

Fig. 4. Factor use levels for mungbean production in 3 Asian countries (refer to Table 2 for sources); AVRDC, 1977.

The interest rate in Taiwan is lower than in the other 2 countries and that, as a result, substantially higher capital expenditures are made per hectare. Also the wage rate is over twice that in either of the other countries. It would seem that Taiwan mungbean production would use much less labor/ha. Figure 4 shows that this is not the case. However, as with Thailand, the answer may be found in the man-land ratio. The average size farm in Taiwan is smaller than either the Philippines or Thailand, and the average field size for mungbean is a quarter that in the Philippines and a tenth that in Thailand. Thus it is more important to achieve high return per unit of land than high return per unit of labor. As shown by both net return and farm income/ha in Table 2, income is far greater in Taiwan than in the other 2 countries. Therefore, mungbean production technology in Taiwan may also be appropriate.

APPROPRIATE MUNGBEAN PRODUCTION TECHNOLOGY IN TAIWAN

So far we have considered only production indices which are *average* for each of the 3 farm samples. One sample from Taiwan will now be examined to test the profitability and efficiency of mungbean production on individual farms. Table 3 shows the distribution of a sample of 73 farmers by level of technological input(6). On the left side of the table, labor is divided into 5 increasing levels of investment value. The same is done for capital along the top. In each capital/labor technology level cell, so defined, the yield in kg/ha and the number of farms using this level are specified. The following observations may be made:

Table 3. Average yield to mungbean production (kg/ha) on 73 farms in Taiwan, 1974.[a]

Labor	Capital I $132 and below	II $133-264	III $265-395	IV $396-527	V over $527
A $132 and below	488 n=2	286 n=2			
B $133-264	826 n=7	909 n=16	817 n=10	672 n=3	1694 n=1
C $265-395	1080 n=2	1252 n=3	882 n=15	1454 n=2	640 n=2
D $396-527		1765 n=2	1280 n=1	1225 n=2	1145 n=1
Over $527				600 n=1	1020 n=2

[a](6).

1) If more than $264 of capital is employed, then at least $133 worth of labor expenditure is also made. Similarly, if more than $395 worth of labor is employed, then no less than $133 worth of capital will be employed. Thus it is clear that extreme imbalances in the ratio between capital and labor are not found in existing production technologies.

2) For every level of capital expenditure up to $395, added increments of labor result in higher yields. Above $395 worth of capital, however, the picture is very erratic. Hence, other things being equal, farmers should not invest more than $395.

3) Highest agronomic yield occurs in the technology cell II D. However, sample size for this cell is only 2 farmers and an inspection of individual farm yields in all cells shows considerable variability. For example, the average yield in cell II B is 909 kg; however, individual yields range from 336.5 to 1566 kg/ha. These findings demonstrate once again how variable the yield of mungbean can be.

4) The area in the table outlined in dark black, which encompasses 5 cells, does show consistent patterns of increasing yield with increasing input. This lends support to the assumption that technology level II D results in the highest yield under Taiwan conditions.

Yield, in and of itself, is not meaningful to the farmer unless it is accompanied by high economic return. Table 4 uses the same distribution of farmers to assess the profitability of increasing investments in capital and labor. The following points can be made:

1) Extremely low and extremely high levels of investment in capital and labor result in negative and/or erratic net return. Such technologies should not be adopted by most farmers.

2) The same block of 5 cells, outlined in

Table 4. Average net return to mungbean production ($US) on 73 farms in Taiwan, 1974.[a]

Labor	Capital				
	$132 and below	$133-264	$265-395	$396-527	Over $527
A $132 and below	-27	-107			
B $133-264	99	144	24	-15	426
C $265-395	149	190	5	162	-215
D 396-527		406	50	80	-68
E Over $527				-621	-664

[a](6).

black , shows consistent increases in net return and agronomic yield. Within this block, cell II D once again is the most favorable. Cell I B, with slightly higher return, lies in the erratic zone.

We may conclude that investments of $133-$264 in capital accompanied by investments of $395-$527 in labor yield not only the highest output of mungbean per unit area but also the best profit.

Now that we have determined the most appropriate level of production among the 73 farmers as a whole, it will be of interest to divide them into 3 production areas - Yunlin, Tainan, and Chiayi. Farmers in Yunlin did the best in producing mungbean, for they had the highest yield, revenue, net return, and farm income. How were they able to accomplish this? Table 5 shows that they invested less in capital and labor on both an absolute and percentage of total cost basis than the other two areas. However, such differences are not significant, and there is a striking similarity in total production costs across the 3 samples. The true differences in production technology can be found in the individual operations involved. Farmers in Yunlin used significantly more fertilizer than in the other areas and applied it all before planting. They also spent significantly less on pesticides, suggesting that they are often over-applied in Taiwan. Their harvesting techniques were also much more efficient, for they spent only US$0.11/kg versus $0.13 and $0.15 for Tainan and Chiayi, respectively. Thus, while it is important to determine the appropriate level of capital and labor inputs, it is just as important to apportion these costs to the most productive activities.

ASSESSING DEVELOPMENT PRIORITIES

The yield and market prospects for many vegetables can and should be developed. Two questions arise: "Which vegetable should be given development priority where government resources are limited?" and "Should production or marketing be emphasized?" Figure 5 shows a development priority grid which can be used as a tool to answer the above questions. Six vegetables are listed for Taiwan as examples. Other vegetables will be important in other countries. The ordinate shows adequacy of supply capability and the abscissa, the stength of current demand. Hence, a set of development priorities is determined for each quadrant. If more than one vegetable falls in a given quadrant their relative position on the grid determines which deserve~ more attention in marketing and/or yield stabilization. It is hoped that the participants in this conference will

Table 5. Mungbean production cost for Yunlin, Chiayi, and Tainan Areas; AVRDC, 1975.[a]

Item	Areas					
	Yunlin (N=11)		Chiayi (N=7)		Tainan (N=55)	
Yield (kg)	1,024		929		871	
Revenue (US$)	530.4		458.5		436.2	
	(US$)	(%)	(US$)	(%)	(US$)	(%)
Expense (per ha)						
Material						
Seed	24.5	6	25.7	6	18.8	4
Basal fertilizer	24.4	6	3.3	1	19.0	4
Top dressing fertilizer	0		1.9		0.8	
Pesticide	17.6	4	33.9	7	15.1	4
Irrigation	1.3		0		2.1	1
Subtotal	67.8	16	64.8	14	55.8	13
Labor						
Tillage	36.5	9	12.6	4	41.9	10
Planting[b]	39.8	10	30.3	6	41.3	9
Top dressing fertilizer	0		1.3			
Weeding & intertillage	62.3	15	59.9	13	48.9	11
Pesticide spraying	12.7	3	46.1	10	17.0	4
Irrigation	1.3		0		2.2	
Harvesting	110.4	26	139.2	30	117.3	27
Threshing	13.7	3	7.4		11.7	3
Transportation	2.1		0		0	
Subtotal	278.8	66	296.8	64	280.4	65
Others						
Water conservancy fee	0.7		0		0.4	
Land tax	17.0	4	25.5	6	23.3	6
Interest on capital	3.7	1	4.2	1	6.1	1
Interest on land	55.5	13	71.6	15	63.6	15
Subtotal	76.9	18	101.3	22	93.4	22
Total Costs	423.5	100	462.9	100	429.6	100
Farm Income	304.3		198.2		60.5	
Net Return	106.9		-4.4		6.6	

[a](6) sample of farmers whose rain damage loss was 30% or less. [b]Furrowing, applying, basal fertilizer, sowing, closing furrow.

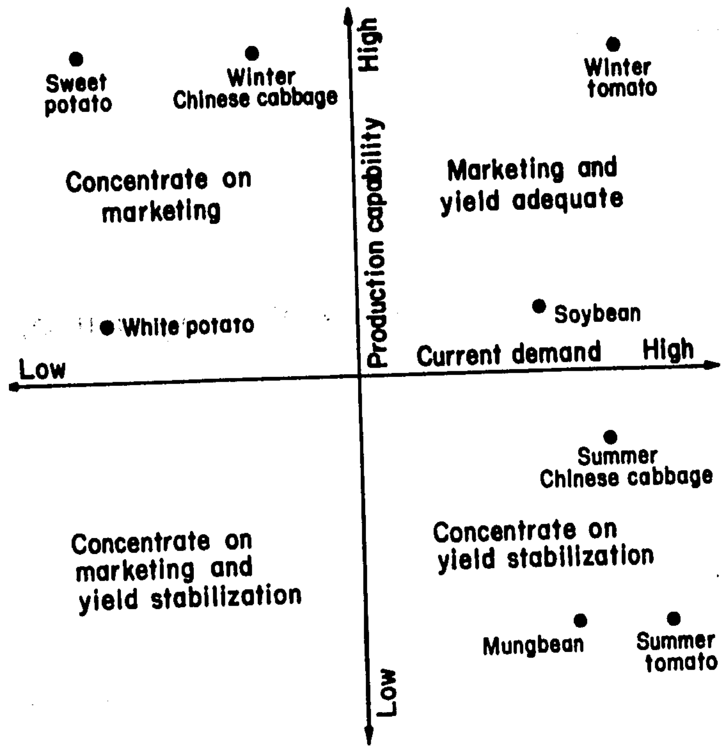

Fig. 5. Development priority grid for 6 vegetables in Taiwan; AVRDC, 1977.

construct such a grid for promotion of mungbean development in their countries. It is also imperative that more complete and more widespread surveys of the problems in current production technology at the farm level be conducted and compared.

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A Study of Mungbean Sprout Production

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INTRODUCTION

Mungbean sprouts are a very popular and common vegetable in China as well as in many other oriental countries. They can be produced all year round, require neither soil nor insecticide, and production takes only a few days. Therefore, when compared with other vegetables to which insecticides are widely applied, mungbean sprouts are considered one of the cleanest and most dependable of year-round vegetables. The nutrition value is high enough to compare with asparagus and mushroom (10). In addition to being used as fresh vegetables, they can be frozen or canned.

Many people think that mungbean sprout production is a simple germination process. But actually a commercial grower will always face at least 3 problems: (1) long roots and slender hypocotyl; (2) spoiling; and (3) anthocyanin formation in the cotyledons and hook region. Among these three, the most difficult is how to produce short-rooted and larger diameter sprouts.

Traditional production techniques among Chinese sprout growers and recent research (2,3) suggest that, if etiolated mungbean seedlings are grown under stress, ethylene is produced and acts to regulate the growth of the seedlings, producing short-rooted and larger-diameter hypocotyl sprouts. This information encouraged me to hypothesize that ethylene might be the most important factor involved in producing the short rooted, larger diameter sprouts; and the main purpose of this research is to test that hypothesis.

MATERIALS AND METHODS

Six grams of Thai green, medium-sized mungbean seeds were soaked in cold tap water for 14 hrs, and then transferred to 4" clay pots for germination. The pots were covered with a heavy hamper cloth to maintain darkness and high humidity. All the pots were put on trays. Tap water was added to the trays every 5 hrs during the day, and, at night, the water was decanted and the trays were kept dry. The next day the process was repeated. During the germination process, the following treatments were applied:

1. Temperature effect: both 20° and 25°C constant temperatures were compared.

2. Ethylene effect:

   a. 2,4-D, which is able to induce ethylene production from the plants (4), was applied in concentrations of 100, 150, and 200 μM.

b. Ethephon=Ethrel=2-chloroethyl phosphonic acid, which will also release ethylene from the sprouts (8) was applied in concentrations of 2.5, 5, 10, and 20 ppm.

The chemicals were applied to the sprouts after they soaked in water for 36 hrs, or when they were 1.5 cm in length - about the beginning of the most rapid growth (6).

c. 100, 200, 300, and 400 g of pressure was applied to each pot immediately after soaking the seeds. The amount of ethylene evolution in each treatment was measured by gas chromatography. We also recorded the effect of each treatment on the growth of sprouts.

3. Shear press value was measured by a Shear press TP-2 for the texture of hypocotyls (12).

4. Anatomical observation:

a. Hypocotyl tissues were fixed in TBA series, embedded in paraffin wax, and cut into 10 μ sections by a rotary microtome. Some sections were double stained with safranin and fast green for light microscopy, and the others were stained with cotton blue for fluorescence microscopy (7).

b. Hypocotyl tissues were double fixed in Karnovsky's fixative (5) and osmium tetraoxide solution (11), dehydrated in ethyl alchol series, critical point dried, and coated with gold and carbon (1). Samples were examined by a JSM-35 scanning electron microscope.

RESULTS AND DISCUSSION

1. Temperature effect

Table 1 indicates that at 25°C, 5-day-old sprouts were ready to be harvested with much longer hypocotyl and roots than those at 20°C. However, 20°C had a significant effect on increasing the diameter of the sprouts. Both 5-day-old (25°C) and 8-day-old sprouts (20°C) had commercial value, but long roots among the latter remain a problem.

Morphological observation showed that anthocyanin formation was stimulated by higher temperature (25°C), and was closely related to varieties. Usually the anthocyanin was formed in the hook region and cotyledons.

2. Ethylene effect

Lin (6) pointed out that the growth curve of mungbean sprouts is a typical sigmoid curve and, therefore, the timing of chemical application is very important. We found that, at 25°C, the right time for both Ethephon and 2,4-D treatments was after soaking the seeds for 36-48 hrs. That was the onset of straight growth. When the chemical was applied too early the sprouts became distorted and little cell elongation occured. If the chemical was applied too late (about the end of straight growth), then there was no effect. Only when the chemicals were applied at the right stage would they produce the desirable sprouts.

The results in Table 2 suggest that Ethephon 10 ppm; 2,4-D 15 μM; and pressure at 300 g/50 cm^2 can produce sprouts with commercially closer desirable characteristics. The results also show that all treatments will result in shorter root and hypocotyl, and will increase the diameter of the hypocotyl. However, the dry and fresh weight of all chemical and pressure treated samples decreased to some extent.

Both Figure 1 and Table 2 show that treatments either release ethylene to the sprouts, (Ethephon), or induce the production of more endogenous ethlene (2,4-D, and physical pressure), and, thus, produce short-rooted and larger-diameter sprouts.

Table 1. Effect of temperature on the growth of mungbean spouts at different ages; Taiwan, 1977.

Age	Temperature	Measurements			
		hypocotyl length	hypocotyl diameter	root length	fresh wt.
- days -	--- °C ---	cm			g/150 pots
5	20	2.45	0.29	3.91	41.58
	25	8.66	0.25	5.42	61.89
8	20	7.54	0.31	8.99	75.90
	25	16.78	0.22	5.98	79.65

Table 2. Effect of chemical and physical pressure treatments on the growth of 5-day-old mungbean sprouts at 25°C; Taiwan, 1977.

Treatment	Measurements				
	hypocotyl length	hypocotyl diameter	root length	dry weight	fresh weight
	cm	cm	cm	g/150 pots	g/150 pots
Ethephon (ppm)					
2.5	4.30	0.25	3.70	6.70	60.50
5	4.05	0.27	3.51	6.41	58.62
10	3.53	0.28	3.15	6.12	54.23
20	2.84	0.30	2.50	5.72	50.21
2,4-D (µM)					
100	3.88	0.29	1.79	5.85	59.85
150	3.85	0.28	1.68	6.28	58.14
200	3.30	0.30	1.43	6.58	55.95
Pressure 100 g/50 cm²					
200	4.01	0.26	3.27	6.41	62.41
300	3.48	0.30	3.01	6.23	59.82
400	2.95	0.33	2.74	5.72	51.63
Check	4.55	0.23	3.78	6.92	63.03

3. Measurement of shear press value

Table 3 indicates that both chemical and pressure treatments resulted in the increase of toughness of hypocotyls. Since mungbean sprouts are normally very soft in texture, the increase of toughness is favorable.

Table 3. Shear press values of mungbean sprouts treated with Ethiphon; 2,4-D; and physical pressure; Taiwan, 1977.

	Treatment			
	check	ethiphon	2,4-D	pressure
		10 ppm	150 µm	330 g/50 cm²
Shear press value	0.91	1.85	2.59	2.57

4. Anatomical observation

Light microscopy showed that chemical and pressure treatments all induced an enlargement without any change in the number of hypocotyl cells (Fig. 2a-d); and, more protein-like substances in the vascular bundles (Fig. 2d, arrow). Therefore, the quality of sprouts was better than the control.

Fluorescence microscopy showed that the cell wall of the tracheary element became thicker and more lignified than the control (Fig. 3a and b). This result correlated well with the increase of shear press values, and shows why the sprouts became crispier. Sargeant et al (9) found that the orientation of microfibril of ethylene treated etiolated pea cell walls changed, and the thickness of the cell wall increased.

Scanning electron microscopy showed that chemical and pressure treatments induced the bulge formation of the hypocotyl, and increased the number of root hairs (Fig. 4a-b, 5a-b). Later the bulges formed lateral roots.

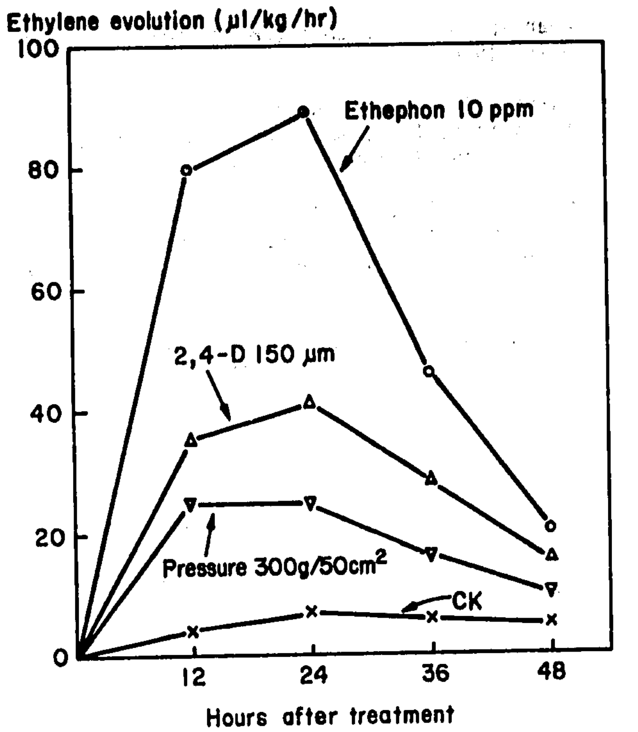

Fig. 1. Ethylene evolution from mungbean sprouts.

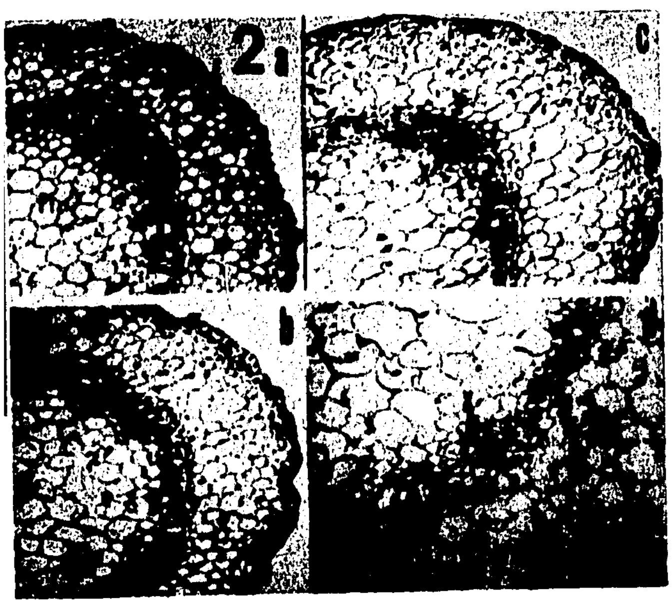

Fig. 2a-d. Cross sections of hypocotyl region of 5-day old mungbean sprouts. Note the enlargement of cortex cells with the increase of chemical concentration or pressure, and the presence of protein-like substances (arrow, Fig. 2d). a: CK; b-d: low to high chemical concentration or pressure treatments. (70 X). C: cortex; E: epidermis; P: phloem; Pi: pith; V: vascular bundle; X: xylem.

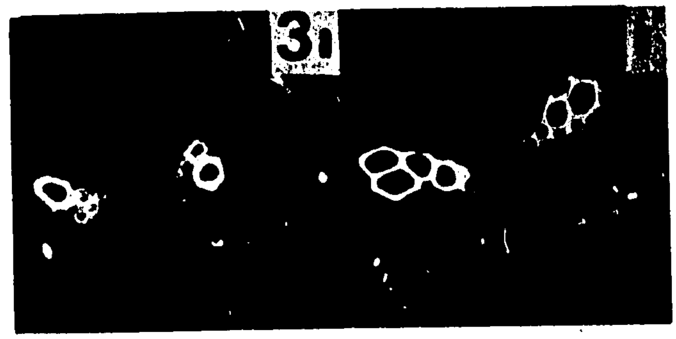

Fig. 3a,b. Florescence micrograph of vascular bundle of 5-day old mungbean sprout. Note the thicker and more lignified cell wall in the treated sample. a: CK; b: chemical and pressure treated. (170 X).

Fig. 4a,b. Scanning electron micrograph of hypocotyl of 5-day old control (a) and treated (b) mungbean sprouts. Note the bulge formation in the treated sample. (a: 200 X; b: 600 X).

Fig. 5a,b. Scanning electron micrograph of the roothair of 5-day old control (a) and treated (b) mungbean sprouts. Note the increase in number of treated root hairs. (240 X).

In conclusion, the results indicate that ethylene is one of the most important factors in the production of better quality sprouts. We suggest that commercial bean sprout growers pay more attention to the use or inducement of ethylene in their production process. However, if a chemical treatment is used the residue effect should be carefully considered.

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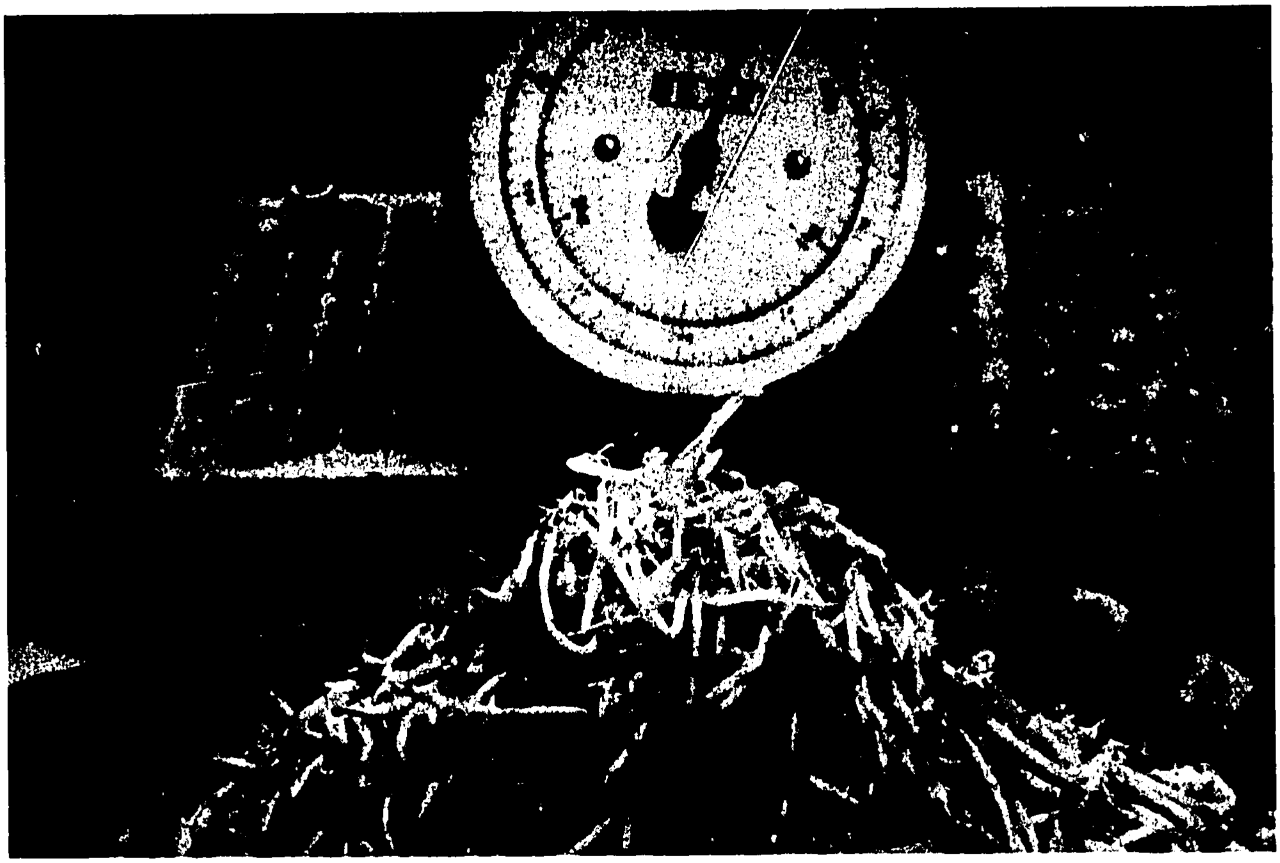

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Isolation and Functional Characterization of a Protein Isolate from Mungbean Flour

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INTRODUCTION

The nutritional and functional properties of many plant proteins are being investigated. Of available protein products, protein isolates offer the highest protein content (90% by dry wt), greatest solubility, and fewest extraneous materials. They are also the most expensive. Protein isolates have been prepared from soybean, northern bean, cottonseed, coconut, rapeseed, peanut, and sunflower. The purpose of this study is to extract a protein isolate from mungbean flour and to evaluate its nitrogen solubility, amino acid content, and the functional properties of buffer capacity, foamability, and gelation.

MATERIALS AND METHODS

Analytical Methods

Mungbean flour was analyzed for moisture, ash, crude fiber, and fat content by standard methods given in the Official Methods of Analyses of AOAC, 10th edition (1965). Non-protein nitrogen (NPN) was determined by tricholoracetic acid precipitation. The micro-Kjeldahl method was used for nitrogen determinations (Protein = % N x 6.25). Fat-free, acid-hydrolyzed samples of flour and isolate were analyzed on a Beckman Model 120C amino acid analyzer. Results were expressed as grams amino acid/16 g nitrogen. No analysis for tryptophan was done.

Isolate Production

Dried seeds of mungbean, variety MG50-10A, were supplied by the International Rice Research Institute, Philippines. A commercial flour mill used a laboratory Buhler mill to grind the seeds and separate the flour. The flour was used as the starting material because it contains the majority of the protein, is relatively soluble, requires little equipment, and produces few by-products.

Initial investigations compared aqueous, alkaline, and salt extraction methods. Dilute NaOH at pH 10.5 extracted the greatest amount of protein and was used for isolate production (3). Mungbean flour was mixed with dilute NaOH at pH 10.5 at a ratio of 20:1 (water:flour, v:w) and allowed to set for 1 hr with moderate mixing at 15 min intervals. Insoluble compounds were removed by centrifuging at 2,000 rpm for 30 min. To the supernatant liquid 0.5 N HCl was added to effect precipitation. Precipitation was considered complete when the solution reached pH 4.4-4.5. The precipitated protein was separated by centrifuging at 2,000 rpm for 30 min and washed 3 times with an acid solution of pH 4.5. The pH of the recovered protein isolate was adjusted to pH 6.8-7.0 with 0.5 N NaOH and the isolate was freeze-dried. Physical properties of the isolate were: beige color, granular texture, and mild "beany" odor and taste. The protein content was 92.8% (dry wt).

<u>Nitrogen Solubility</u>

Nitrogen solubility was determined using Mattil's method (7). Two grams of isolate were dispersed in distilled water of the appropriate pH. Dispersions were stirred continuously with a magnetic stirrer for 30 min and pH was maintained using 0.5 N NaOH or 0.5 N HCl. The final volume of 40 ml gave a solvent:isolate ratio of 20:1 (v:w). The supernatent extract was centrifuged at 3,000 rpm for 30 min, filtered through Whatman No. 1 filter paper and analyzed for total nitrogen by the micro-Kjeldahl method. Results were expressed as percent soluble protein.

<u>Buffer Capacity</u>

The protein isolate was dispersed in 100 mℓ distilled water to form a 0.5% protein concentration (w:v). The initial pH was determined and the dispersions titrated to pH 3.0 with 0.1 N HCl or to pH 10.0 with 0.1 N NaOH. The buffer capacity (BC) was calculated for each 0.5 pH change by the equation (9):

$$BC = \frac{\text{meq titrant}}{\text{wt of protein (g)} \times \Delta\ \text{pH}}$$

<u>Foamability</u>

Sufficient isolate was added to distilled water to give 8.0% protein (w:v). Solutions were adjusted to pH 7.0 and mixed gently. A 10-speed General Electric M69 electric household mixer was used for 5 and 10 min of vigorous whipping. Egg white served as the control.

Volumes were recorded before and after whipping and the percent volume increase calculated (6):

$$\%\ \text{vol increase} = \frac{\text{vol after whipping} - \text{vol before whipping}}{\text{vol before whipping}} \times 100$$

Weights were taken before and after whipping and the specific volume calculated (1):

$$\text{Specific volume} = \frac{\text{vol after whipping (m}\ell\text{)}}{\text{wt after whipping (g)}}$$

Foam samples were inverted and allowed to drip through a wire screen into weighed beakers (1,8). The weight of liquid released from the foam after 20, 30, 60, and 120 min was determined and calculated as percent drip.

$$\%\ \text{drip} = \frac{\text{wt of liquid released from foam}}{\text{original wt of foam}} \times 100$$

<u>Gelation</u>

Sufficient isolate was dispersed in distilled water to make 100 mℓ of total volume and protein concentrations of 2-12, and 14% (4). The pH was adjusted to 7.0 with 0.5 N NaOH. Mixtures were placed in a blender at high speed for 2 min followed by centrifugation for 15 min at 3,000 rpm. Ten mℓ aliquots were distributed into test tubes and evaluated for gel formation by the Least Concentration Endpoint (2). Samples were heated in an 80°C water bath for 10 min and cooled in an ice bath at 0°C. The lowest protein concentration that formed a stable gel (remained in an inverted test tube) was considered the gelation endpoint.

RESULTS AND DISCUSSION

<u>Proximate Analyses</u>

The proximate analyses for mungbean flour were: ash 3.3%, crude fiber 1.2%, crude fat 0.8%, protein 28.0%, and carbohydrates (calculated by difference) 66.7%. The flour contained 9.9% NPN.

<u>Amino Acids</u>

The amino acid composition of mungbean protein isolate was similar to that of the flour (Table 1). Methionine and cystine were the limiting amino acids in both samples. Most amino acids were present in greater amounts in the isolate but these variations were small and the general amino acid pattern remained unchanged. Flour contained only 0.37 g cystine/16 g nitrogen. Isolate cystine was not recovered in sufficient quantity for measurement. Circle and Johnson (4) attributed the destruction of sulfur-containing amino acids to partial protein hydrolysis by alkali. Wolf (12) reported decreased amounts of essential amino acids in soybean isolate were due to fractionation of protein during isolate preparation.

<u>Nitrogen Solubility</u>

The percent soluble nitrogen in the mungbean protein isolate was determined at 7 pH values (Fig. 1). Greatest solubility occurred at pH values far removed from the isoelectric point. Tests ran at pH 2, 8, and 10 yielded the highest percent soluble protein with 84.1, 98.6, and 98.8% respectively. Lowest solubility was recorded at pH 4-5. This was expected as the isolate proteins were precipitated at their isoelectric point of pH 4.5.

Although the shape of the solubility curve proved consistent, a wide range of values was

Table 1. Amino acid composition of mungbean flour and its protein isolate (g/16 g N), Philippines, 1977.

Amino Acid	Mungbean flour			Mungbean isolate		
	1	2	mean	1	2	mean
Alanine	4.39	4.35	4.37	4.75	5.39	5.07
Arginine	6.76	6.86	6.81	6.94	7.07	7.01
Aspartic acid	11.80	11.90	11.85	10.40	9.94	10.17
Cystine	0.32	0.41	0.37	-	-	-
Glutamic acid	17.90	18.20	18.05	19.20	19.80	19.50
Glycine	3.86	4.01	3.94	3.48	3.71	3.60
Histidine	2.59	2.58	2.59	2.57	2.40	2.48
Isoleucine	4.71	4.86	4.79	5.30	5.63	5.47
Leucine	7.80	8.00	7.90	9.04	9.62	9.33
Lysine	6.68	6.69	6.69	6.67	6.96	6.82
Methionine	1.17	1.27	1.22	1.28	1.30	1.29
Phenylalanine	5.39	5.60	5.50	6.60	6.97	6.79
Proline	3.80	4.25	4.03	3.82	4.29	4.06
Serine	4.32	5.40	4.85	2.83	2.11	2.47
Threonine	2.62	3.01	2.82	1.87	1.67	1.77
Tyreonine	2.84	3.02	2.93	2.95	3.02	2.99
Valine	5.87	6.03	5.95	6.48	6.96	6.72
Ammonia	3.98	3.41	3.70	3.86	4.31	4.09
% Protein (% N x 6.25)	27.99	27.99	27.99	92.82	92.82	92.82

recorded for those isolates produced on different days. Variation in legume protein isolate solubility was noted earlier (10,11,13). The main explanation centered on the nature of the globulins, the major protein fraction. In soybeans a portion of the 7S and 11S globulins was shown to exist as aggregates. These aggregates appeared to grow with each step of isolate preparation and effected a corresponding decrease in protein solubility. The rate and extent of polymerization were highly variable.

Buffer Capacity

Aside from the high buffering capacity at the titration extremes of pH 3.0 and 10.0, the best buffering action was in the pH 5.5-5.7 range. The lowest values for buffer capacity were recorded at pH 4.0 and 8.0 (Fig. 2). More (9) attributed buffering action to the ionization equilibria involving protein carboxyl groups (pKa 1.8-2.5), citrates (pKa 3.08, 4.74, and 5.40), and phosphates (pKa 2.12, 7.21, and 12.67), and reported increased BC with mineral content.

Foamability

The specific volume and percent volume increase were calculated as an indication of air uptake (Table 2). Whipping for 10 min gave higher specific volume and greater volume increases than whipping for 5 min. Specific volume increased from 8.5 mℓ/g at 5 min to 9.3 mℓ/g at 10 min. Volume increase of 650% at 5 min rose to 727% at

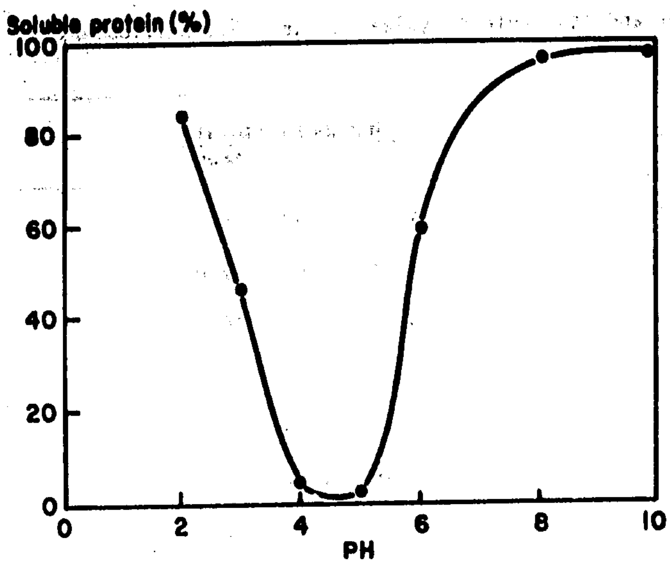

Fig. 1. Effect of pH on solubility of mungbean protein isolate; Philippines, 1977.

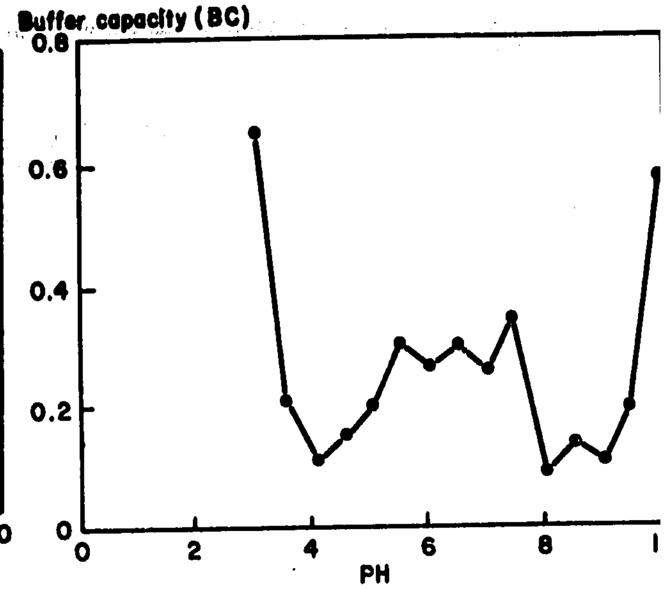

Fig. 2. Buffer capacity of mungbean protein isolate; Philippines, 1977.

10 min. Percent drip was inversely related to foam stability (Table 2). Foam stability was not significantly affected by shipping times. Half of the foam remained after 30 min; one-fourth after 2 hrs. While mungbean protein isolate showed good foamability, it did not equal egg white. Egg white was more stable, more brittle, and a brighter white. Mungbean foam was light beige and creamy.

<u>Gelation</u>

Protein concentrations of 10,12, and 14% consistently gelled upon application of heat (Table 3). Gels of 10% were softer than gels of 12-14%. A coagulum was formed at 8-9% protein concentrations but it was not strong enough to prevent gel disruption upon inversion of the test tube.

CONCLUSIONS

The same amino acid pattern was observed in both mungbean flour and its protein isolate. Cystine was destroyed during the isolation process, perhaps by alki-hydrolysis. This decreased the nutritional value but should not affect the functional value of the isolate. Nitrogen solubility at pH values less than 3 or more than 6 yielded 50% or more soluble protein. Low solubility of only 2-5% between pH 4-5 limits the isolate's usefulness in foods at these pH levels. Buffer capacity was not great and its influence when incorporated into other foods would be minimal. The isolate demonstrated good whippability although it did not equal whipped egg white. Gelation of mungbean protein isolate was found to depend on the protein concentration. Increased

Table 2. Whipping of mungbean protein isolate[a]; Philippines, 1977.

Sample	Whipping time	Volume increase	Specific volume	DRIP 20 min	DRIP 30 min	DRIP 60 min	DRIP 120 min
	---- min ----	----- % -----	----- mℓ/g ----	----------------		% -------------	
Isolate	10	727	9.3	23.97	49.22	71.76	79.36
Isolate	5	650	8.5	28.54	48.86	70.01	79.17
gg White	5	625	8.9	5.75	19.17	44.13	54.14

[a]Conditions of whipping: Dispersion of 8% protein in distilled water at pH 7.0 at room temperature.

Table 3. Effect of protein concentration of gelation of mungbean protein isolate[a], Philippines, 1977

% protein	No. of samples	Gelation	Appearance
2.0	2	-	Liquid
4.0	2	-	Liquid
5.0	3	-	Liquid
6.0	3	-	Liquid
7.0	3	-	Liquid
8.0	9	-	Viscous
9.0	6	-	Very Viscous
10.0	6	Gelation	Gel (LCE)[b]
12.0	3	Gelation	Firm gel
14.0	3	Gelation	Firm gel

[a]Conditions of gelation: heating protein solution of pH 7.0 at 80°C for 10 minutes and cooling to 0°C. [b]LCE - Least Concentration Endpoint, lowest protein concentration at which the gel remained in the inverted test tube.

gel rigidity occurred with increased protein concentration.

We concluded that mungbean protein isolate performed well in simple systems under laboratory conditions. However, practical testing in complicated food systems must be done to firmly establish its role as a nutritional and functional food component.

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Rice-Mung Cropping Patterns in Manaoag, Pangasinan: A Costs and Returns Study

L.M. Lavapiez, B. Duran, J. Nicolas, and E.C. Price

INTRODUCTION

Mungbean is one of the most popular leguminous upland crops grown by farmers at the IRRI-BPI cropping system test site in Manaoag, Pangasinan. Results of the baseline survey conducted during CY 1974-1975 revealed that 2 widely adopted patterns involving mungbean were rice-mung and rice-mung-other crop, commonly either cowpea or corn. The total area planted to these patterns was estimated at 57 and 11%, respectively. During the following crop year, records of farmer cooperators showed that 24% of their total cropland was planted to rice-mung while 20% was under the rice-mung-corn pattern. Twelve plots planted to rice-mung under farmer-management gave a gross return of ₱4490/ha. On the other hand, experimental field trials of the same cropping pattern yielded a gross return of ₱5169 and ₱3832/ha for low and high tillage fields, respectively.

Generally, this study aims to determine the profitability of using these patterns in the test area:

1. To determine the yields, costs, and returns at various tillage levels for mungbean and rice-mungbean cropping patterns; and,
2. to compare the yields, costs, and returns for the rice-mungbean cropping pattern applied on farmer-managed fields, and in experimental trials.

PROCEDURE AND METHODOLOGY

Data for this study were taken from the farm record keeping project collected in 4 pilot barrios of Manaoag, Pangasinan: Anis, Caaringayan, Lipit, and Pao.

Of the 102 ha tilled by 46 economic cooperators during CY 1976-77, about 32 ha (31%) was planted to mungbean. Almost half of these cooperators planted this legume in 2 plots, totalling 67 plots for all cooperators (Table 1).

Analysis for rice-mung cropping patterns covered 37 farmer-managed plots. Data from 9 experimental trial plots of the same pattern were analyzed for comparison.

Table 1. Distribution of 67 field plots planted to mungbean under farmer's management by barrio and by tillage level; Manaoag, Pangasinan, 1976-77.

Barrio	Tillage level				Total
	zero	low	min.	high	
	Number of plots				
Anis	5	6	5	2	18
Caaringayan	4	8	2	6	20
Lipit	-	-	11	1	12
Pao	-	1	11	5	17

RESULTS AND DISCUSSION

Varietal use

The varieties of mungbean used by farmer cooperators were: Wonder, Lopog, Green mung, Yellow mung, Miracle mung, and CES 14. Of these, Wonder mung is the most popular.

Cultural practices

1. Level of tillage management. Based on farmer's methods, 4 levels of tillage management were identified:

   (a) Zero tillage - broadcasting followed by one harrowing to cover the seeds.

   (b) Low tillage - broadcasting followed by one plowing to cover the seeds.

   (c) Minimum tillage - one plowing and harrowing as formal land preparation; broadcasting followed by one harrowing to cover the seeds.

   (d) High tillage - 2 or more plowings and harrowings as formal land preparation (the first plowing either by tractor or draft animal); broadcasting followed by harrowing to cover the seeds.

2. Date of planting and harvesting. Planting dates for mungbean in the test area start from mid-October to mid-December, but 80% of the plots were planted late November to mid-December. Some farmers held the view that if mungbean is planted in early October, the chances of obtaining a lower yield are greater due to a disease which causes wilting.

   Harvesting dates generally extend from mid-February to mid-March, about 75 d.a.s.

3. Fertilizer and insecticides. Application of fertilizer on mungbean is not practices in the area. Not a single plot was fertilized. All farmer cooperators applied insecticides on mungbean (Table 2). The choice of insecticide depended on its availability and farmers' operating capital. On the average, the insecticide was sprayed only once at 6 wks after seeding. However, a few plots were sprayed twice, the first at 4 wks after seeding, and the second 2 wks later.

Table 2. Average amounts of seeds and insecticides used on farmer's mungbean, 67 plots; Manaoag, Pangasinan, 1976-77.

Barrio	Plots	Seeds	Insecticides				
			Azodrin	Folidol	Thiodan	Sevin	Others
		kg/ha					
Anis	18	34.2	0.080	-	0.021	0.069	Lannate (0.015) Eradex (0.037)
Caaringayan	20	33.4	0.053	0.089	-	-	Broadan (0.044)
Lipit	12	31.6	0.025	-	0.060	0.087	Gusathion (0.005) Endrin (0.010) Hopcin (0.039)
Pao	17	25.1	0.438	0.102	-	0.167	-
Average		31.0	0.158	0.054	0.016	0.088	

Table 3. Labor utilization by tillage level, and as percentage of total labor by type of farm operation, 67 plots; Manaoag, Pangasinan, 1976-77.

Tillage level	Type of farm operation				Total
	land preparation	seeding	insecticide application	harvesting threshing	
	Man-hours/ha (%)				
Zero	-	27(10)	9(3)	231(87)	267
Low	2(1)	54(16)	6(2)	265(81)	327
Minimum	42(12)	27(8)	18(5)	265(75)	352
High	112(32)	26(8)	11(3)	195(57)	344

Labor utilization

Labor input spent for various farm operations varied greatly for the 4 tillage levels (Table 3). Interestingly, for high tillage plots, only 57% was devoted to harvesting and threshing operations. This can be explained by the low weed populations present which reduced the time spent on harvesting and threshing operations, and the comparatively lower yields in the high tillage plots. The opposite was observed in terms of weed population and yield at the 3 lower tillage levels.

Production data

Farmers commonly measure their produce in one gallon cans, locally termed *limon*. From actual weighing, one *limon* ranges from 2.5-2.8 kg. (2.6 kg average) depending on the variety used.

Table 4 and 5 show average yields. The poor yield performance of high tillage plots may be attributed to a low seeding rate estimated at 27 kg/ha. The highest seeding rates, 33.5 and 31.0 kg/ha, were observed on low and minimum tillage plots, respectively. Zero tillage averaged 29.0 kg/ha. The recommended rate was 30 kg/ha.

Table 4. Average mungbean yields by tillage level, 67 plots; Manaoag, Pangasinan, 1976-77.

Tillage level	Plot	Yield
		-- kg/ha --
Zero	9	219
Low	15	251
Minimum	29	251
High	14	185
Average		233

Table 5. Average mungbean yields by barrio, 67 plots; Manaoag, Pangasinan, 1976-77.

Barrio	Plots	Yield
		kg/ha
Anis	18	280
Caaringayan	20	185
Lipit	12	223
Pao	17	264
Average		233

Costs and returns analyses

1. Variable costs. Table 6 shows the average cash costs spent for seeds and insecticides by each barrio.

2. Mungbean at various tillage levels. Table 7 shows the costs and returns analyses for mungbean at various tillage levels. The much lower yield obtained in the high tillage plots plus a high labor cost incurred in land preparation accounts for its low return.

   Table 8 shows the cost and return analysis of the rice-mung cropping pattern.

3. Rice-mung cropping pattern (experimental vs. farmer's management). Table 8 shows the costs

Table 6. Value of material inputs (pesos/ha) spent on farmer's mungbean 67 plots; Manaoag, Pangasinan, 1976-77.

Barrio		Inputs		Total
		seeds	insecticide	
		----- Pesos/ha[a] -----		
Anis	(18)	175	18	193
Caaringayan	(20)	172	26	198
Lipit	(12)	165	24	189
Pao	(17)	130	118	248
Average		161	47	208

[a]₱ 1.00 = US$.13.

and returns for the rice-mung cropping patterns between experimental and farmer-managed plots. Both rice and mungbean on experimental plots outyielded the rice and mungbean on farmer's plots, hence, gross returns are also higher on experimental plots.

Cost of labor for the experimental rice-mung pattern was almost twice that of farmer's plots. Material costs (seeds, insecticide, fertilizer) under the rice-mung trial was 4 times larger than that of the farmer managed plots. This was brought about by the larger input cost incurred on fertilizer and insecticide. In contrast, material items spent on farmer-managed rice-mung plots were much less because no fertilizer was applied to mungbean. Mungbean was sprayed only once.

The return to labor manhours for rice on farmer's plots was higher but lower for mungbean. However, on the whole, a similar return to labor of ₱2.80/manhour was accrued both by experimental and farmer-management fields.

Return to cash for the rice-mung pattern under farmer-managed plots was ₱2.40 greater than that of the similar pattern in experimental plots.

Table 7. Cost and return analysis for mungbean by tillage level, 67 plots; Manaoag, Pangasinan, 1976-77.

Item	Tillage level				All plots
	zero	low	minimum	high	
No. of plots	9	15	29	14	67
Gross return (₱/ha)	925	1062	1062	782	985
Total variable cost (₱/ha)	425	506	579	594	545
Material cash input (₱/ha)[a]	186	191	233	186	208
Labor (₱/ha)[b]	239	315	346	408	337
Net return (₱/ha)[c]	500	556	483	188	440
Return/cash material input (₱/₱)[d]	5.0	5.6	4.6	4.2	4.7
Return/labor man-hour (₱/man-hour)[e]	2.8	2.6	2.4	1.7	2.3

[a]Includes cost of seeds, insecticide; ₱1.00 = US$ .13. [b]Includes operator, family and hired labor cost. [c]Gross return - Total variable cost. [d]Gross return/cash material input.
[e]$\frac{\text{Gross return - cash material input}}{\text{Labor (man-hour/ha)}}$

Table 8. Cost and return analysis for rice-mung pattern by tillage level, 37 plots; Manaoag, Pangasinan, 1976-77.

Item	Tillage level zero	low	minimum	high	All plots
No. of plots	6	9	14	8	37
Gross return (₱/ha)	3414	2806	2432	3197	3091
Total variable cost (₱/ha)	1591	1983	1528	1868	1722
Material cash input (₱/ha)[a]	503	555	448	486	491
Labor (₱/ha)[b]	1088	1428	1080	1382	1231
Net return (₱/ha)[c]	1823	1823	904	1329	1368
Return/cash material input (₱/₱)[d]	6.8	6.8	5.4	6.6	6.3
Resturn/labor man-hour (₱/man-hour)[e]	3.8	3.2	2.3	2.6	2.8

[a-e]See footnotes Table 7; ₱1.00 = US$ .13.

Table 9. Comparison of costs and returns for the rice-mung pattern (experimental vs. farmer's plots); Manaoag, Pangasinan, 1976-77.

Item	1st crop (RICE)	2nd crop (MUNG)	Total/average
No reported			
Experimental plot	9	9	9
Farmer's plot	37	37	37
Yield (t/ha)			
Experimental plot	3.76	0.73	-
Farmer's plot	1.65	0.22	-
Labor cost (₱/ha)			
Experimental plot	1616	547	2163
Farmer's plot	903	328	1231
Labor input (man-hours/ha)			
Experimental plot	1723	400	2123
Farmer's plot	584	344	928
Material costs (₱/ha)			
Experimental plot	931	1141	2072
Farmer's plot	307	184	491
Total variable costs (₱/ha)			
Experimental plot	2547	1688	4235
Farmer's plot	1210	512	1722
Gross return (₱/ha)			
Experimental plot	4910	3107	8017
Farmer's plot	2159	932	3091
Return above VC (₱/ha)			
Experimental plot	2363	1419	3782
Farmer's plot	949	420	1369
Return to labor (₱/man-hours)			
Experimental plot	2.3	4.9	2.8
Farmer's plot	3.2	2.2	2.8
Return to material cash (₱/₱)			
Experimental plot	5.3	2.7	3.9
Farmer's plot	7.0	5.1	6.3

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Traditional Utilization of Mungbean Starch

Hsi-Hua Wang

THE IMPORTANCE OF MUNGBEAN STARCH NOODLES

The Chinese use transparent noodles made with mungbean starch in their dishes. The noodles are called "Tung Fung" (winter flour) by the Chinese and "Haru-Same" (spring rain) by the Japanese.

The mechanical properties of producing mungbean noodles were proposed by Schock and introduced by Honbo (1): the refrigeration, which is in the traditional process before drying the moist noodles, makes the finished noodles less soluble in hot water.

The noodles are tasteless, good looking, transparent, semi-instant or easily cooked, and easily packed. In addition, the noodles are not easily attacked by digested enzymes because of the insolubility and staleness of the noodle starch (2). Therefore, it seems safe to forecast that the noodles have great potential as a world wide food.

ENVIRONMENTAL CONTROL FOUND IN CHINESE TRADITIONAL WET PROCESS FOR MUNGBEAN STARCH MANUFACTURE

The traditional process for separating mungbean starch by the wet process has been done for many years in Taiwan (Fig. 1). During the process, many starch granules are lost in the steeping water which is squeezed off by hand with scoops. In order to improve the process, we have studied:

1. the structure of mungbean seeds: the size of starch granules and protein bodies existing in mungbean are 20-30 and 1-3 microns, respectively. Mungbean granules could be separated by a mechanical process such as the centrifugation in corn starch manufacture or the sedimentation in the traditional process.

2. the properties of the steeping water: microbial reaction of the steeping water is found to be homofermentative. There is no gas formation in the presence of glucose as a sole carbon source. The final pH of the steeping water is around 4.0:

   the microbial activities of the steeping water: twelve cultures of lactic acid bacteria are isolated from the steeping water. The cultures are characterized into 4 groups, which resemble *Leuconoctoc mesenteroids*, *Lactobacillus casai* var. *alactosus*, *Lactobacillus cellobiosus*, and *Lactobacillus fermentii*, respectively.

4. the isolation and identifcation of micro-organisms in the steeping water: a cell-separating enzyme and an acid proteolytic enzyme are not found.

5. the inhibitory effect of steeping water on amylolytic bacterial isolates: by disc assay, the steeping water shows an inhibitory effect on some amylolytic aerobes and anaerobes, even at pH 7.0.

6. the replacement of lactate fermentation with H_2SO_3: the starch products have more clarity when mungbean is treated with H_2SO_3 in pre-steeping, while the viscosity of starch is the same as when not treated with H_2SO_3 in pre-steeping. Since there are neither proteolytic activities nor proteolytic lactobacilli in the steeping water, it appears that lactate fermentation in the process of steeping is a tool for environmental control which represses the probable presence of amylolytic bacilli or clostridia in the steeping water. The control is analygous to the use of water activity or gas in the other traditional food process (3-6).

THE UTILITY OF STEEPING WATER IN THE WET PROCESS

As shown in Figure 1 there is a tremendous

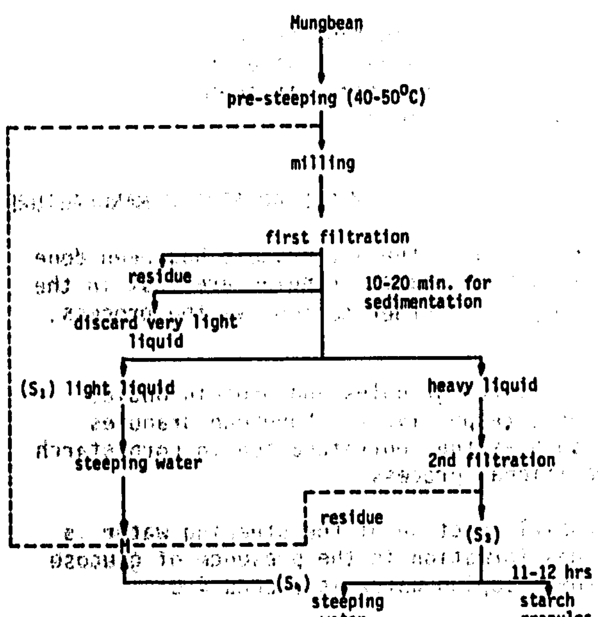

Fig. 1. Flow diagram of mungbean starch manufacture in Taichung Farm in Taiwan. No proteolytic and cell separating enzyme activities, none is S_3, very weak in S_1, S_2, and S_4. M: take a small part of S_2 and S_4, respectively, and mix together and store for further use; 1976.

volume of steeping water in the wet process of mungbean starch manufacture. The steeping wate contains many organic substances such as lactic acid. Table 1 shows the COD and BOD values of steeping water were as high as 35,000 and 18,00 ppm, respectively. During the course of anothe study on methane fermentation of swine waste, 1 *Rhodopseudomonas* strains of non-sulfur purple photosynthetic bacteria, were isolated from the effluent of the digestor. Among them, 4 strain were identified as *R. gelatinosa*, and the remaining 14 strains were *R. spheroides*. The steeping water was treated with the isolate *R. gelatinosa* M-1. Shaking the steeping water fla at the rate of 130 rpm at 30°C in the dark was the best treatment. Under these conditions, th COD and BOD decrements after 3 days were 58 and 70% respectively. (Fig. 2).

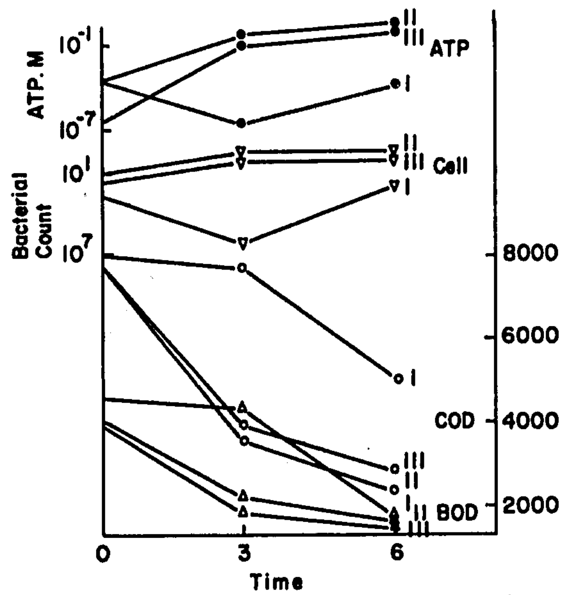

Fig. 2. Increase of bacterial count and cellular ATP content accompanies with COD and BOD reduction. I, with gentle heating (60°C for 10 min); II, with gentle heating and the inoculated isolate M-1; III, with gentle heating, then sterilization, and the inoculated isolate M-1. Taiwan, 1977.

The protein content and amino acid composition of the cells of *R. gelatinosa* M-1 and *R. spheroides* C-1 were assayed by an autoanalyzer to assess the feasibility of using the cells as feed. It was found that they contained 60% protein and their essential amino acid content was higher than the FAO reference. The methionine content was remarkably higher than other single cell protein, such as yeast. Besides, the Essential Amino Acid Indices for M-1 and C-1 are 0.90 and 0.85, respectively (7). (Table 2).

ble 1. Properties of waste steeping water; Taiwan, 1977.

Date	Sample	pH	A	BC	TN	TS	VS	SS	COD	BOD
			mg/ℓ	cell/mℓ	----------	----------	----------	mg/ℓ	----------	----------
Jul.2, 1974	I	5.9	1306	-	2660	26545	24265	-	34400	18280
	II	6.0	840	-	525	8825	8095	-	8010	5332
Jul. 19, 1974	I	6.0	1353	4.3 x 10^8	2408	-	-	-	33200	17400
	II	6.1	902	2.7 x 10^5	505	-	-	-	7870	5140
Aug. 7, 1974	I	5.9	1258	4.6 x 10^8	2520	25265	23660	-	37400	19430
	II	6.1	772	1.7 x 10^6	543	8515	7740	-	8210	6150
Aug. 28, 1974	I	6.1	1278	4.9 x 10^8*	2620	28170	26530	19360	38600	20680
	II	6.1	856	1.1 x 10^6*	490	9745	8935	1370	8510	6330
Nov. 6, 1974	I	4.0*	2234*	-	2800	27640	25375	18840	34800	17750
	II	4.0*	1573*	-	508	9585	8785	1280	8360	5323
Jan. 26, 1974	I	4.1*	2255*	-	2565	23965	22080	15520	31500	16650
	II	4.3*	1615*	-	484	8325	7410	1140	7170	4990
Feb. 5, 1974	I	4.0*	2395*	-	2589	27210	25745	17960	35200	18700
	II	4.0*	1650*	-	532	9250	8465	1120	8170	5636

A: acidity, BC: bacterial count, TN: total nitrogen, TS: tota, solid, VS: volatile solid, SS: suspended solid I: sample without pretreatment, II: the superratant of sample after heating at 60°C for 10 minutes. *- Tested after 6 hrs of sampling.

Table 2. Comparison of the essential amino acid content of the isolates of *Rhodopseudomonas* with that of wheat, egg, and some other microbes; Taiwan, 1977.

EAA	Isolate C-1	Isolate M-1	*S. cerevisiae*	*C. lipolytica*	Wheat	Egg
Lys	5.5	6.0	7.7	7.8	2.8	6.5
Thr	5.1	5.3	4.8	5.4	2.9	5.1
Met	2.0	2.7	1.7	1.8	1.5	3.2
Trp	-	-	1.0	-	1.1	1.6
Ileu	6.2	5.9	4.6	3.9	3.3	6.7
Leu	8.2	7.0	7.0	7.0	6.7	8.9
Val	5.4	6.7	5.3	5.9	4.4	7.3
Phe	5.5	5.6	4.1	4.0	4.5	5.8
EAAI[a]	0.85	0.90	0.80	0.79	0.58	1.0

[a]EAAI (Essential Amino Acid Index) = $\sqrt[n]{\frac{EAA_1(sample)}{EAA_1(egg)} \times \ldots \times \ldots \times \frac{EAAn\ (sample)}{EAAn\ (egg)}}$

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Discussion

Calkins: Dr. Amara, how would you compare the production costs of mungbean textured-protein with meat products? Would you say artificial meat is competitive at the present?

Amara: The cost of mungbean textured meat is 1/3 the cost of real meat in terms of protein content. The Thai government is working on a World Bank loan to set up a mungbean processing plant primarily to produce baby food and meat. Our production target aims to serve the needs of 1/3 million school children and about 2 million pre-school children.

Wang: Is the dry milling process being utilized already in Thailand and the Philippines for starch and protein separation?

Payumo: In the Philippines, we are still using the wet process. The dry process is used for hull separation.

Amara: The same is true in Thailand.

Wang: Is there any pollution control for the wet process in Thailand?

Amara: Yes. The most important method is to use the batch system and the proper clean-up. Prolonging the work overnight needs a lot of water in the system, and this becomes pollution.

Ramanujam: Do you consider cereal proteins alone are qualitatively adequate for adult humans, Dr. Engel?

Engel: Since there have been many studies showing that children do very well on diets containing essentially only cereal protein, certainly adults would come very close to meeting their protein needs qualitatively from cereals. But it depends on the cereal. While the quantity of protein is higher in wheat than in rice, the quality of rice protein is better. Corn protein is somewhere between these two.

Bharati: How does *Vigna mungo* compare with *Vigna radiata* in nutrient content?

Engel: I do not think there are any major differences in composition between the two.

Ramanujam: I question your statement that there is no difference between *Vigna radiata* and *Vigna mungo*. Cytogenetic studies carried out in India strongly demonstrate genetic isolation between the two. Organoleptic differences supported by biochemical characterisation of protein support this separation. The considerable similarily in phenotype can perhaps be traced to the broadly similar agro-climatic conditions under which the two species are grown. Interestingly, in *Pgaseolus sublobalin*, the presumable wild progenitor of the two species, there are two distinct types which can be differentiated on the basis of crossability with green and black gram.

C. Yang: You mentioned in your talk, Dr. Engel, that the softness of the mungbean seed coat is related to aflatoxin. Would you care to say where or at what stage the mungbean becomes prone to the *Aspergillus* infestation?

Engel: I did not state a fact. I speculated that in crops which have thin seed coats protecting the germ (corn, for example), the seed is very susceptible to *Aspergillus* infestation. Therefore, a thin-coat in mungbean might result in more *aspergillus* infestation. Generally, susceptible seed can become infested with *aspergillus* any time after it ripens if it is not properly dried. A moisture level above 9-10% leads to infestation, particularly in a warm humid climate.

Ballon: Dr. Tsou, what factors in mungbean breeding increase methionine content? What would you suggest to mungbean breeders for the development of a mungbean breeding program to enhance methionine content.

Tsou: We are working on this subject right now. We only know albumin contains more methionine than other protein fractions. There is also more albumin present in blackgram than in mungbean. Peptides may have some relationship with methionine content.
I suggest that breeders first study the mungbean consumption pattern in their countries to decide whether breeding is feasible. Then, they should work with chemists for protein quality improvement. Techniques for S-AA should be developed before seriously going into breeding.

Ballon: Can you tell us which breeding technique would be more efficient in improving the protein content of mungbean, interspecific or intergeneric breeding?

Tsou: I'll have to refer you to Dr. Park.

Park: In general, interspecific breeding would be more feasible than intergeneric. I would strongly recommend that all conventional breeding techniques be thoroughly exhausted before breeders seriously consider unconventional techniques such as mutation or interspecific breeding. Dr. Amara, can you use the by-products of processed mungbean directly?

Amara: There is no way to use the by-products of processed mungbean without subjecting them first to chemical or mechanical treatment. For instance, we have to practice dehydration to improve the absorption capacity of the material.

Ahmad: In all your preparation of mungbean products, the seedcoats are removed. Are the seedcoats of no nutritional value.

Amara: No. So far as I know, they are only crude fiber.

Ahmad: What is the chemical process occurring under high temperature (25°C) that leads to anthocyanin formation in the hook to cotyledon region of the sprout? How could this be overcome?

Chang: I haven't done much on this problem. From my experiments, we found that lowering the temperature to 20°C can reduce the anthocyanin formation. Other factors such as ethylene, CO_2, and light also affect anthocyanin.

Ahmad: What was the Calcium level of the water you used in experiments with the production of crispier sprouts?

Chang: One can make the sprouts crispier by spraying 100 ppm $CaCl_2$ solution on the sprouts. Further investigation is needed to determine if this has practical commercial value.

Engel: In the mungbean consumption data presented today, how much is consumed as starch and how much is consumed as whole grain? In the Philippines, most of the people eat the processed forms. Is this the case in Thailand also?

Amara: We consume a lot of cooked whole mungbean as desserts. Consumption in this form is quite substantial, but I would not know the precise percentage of consumption of whole mungbean.

Duangploy: Do they prefer black or greengram in Taiwan? Why do they prefer blackgram for bean sprouts in Japan?

Park: According to surveys conducted in Taiwan and Japan, blackgram is preferred because it is more stable to temperature fluctuation. In Taiwan, sprouted mungbean has to be sold within 5 days, beyond which the quality will deteriorate due to spoilage. The Japanese have asked us to study the effects of temperature stability on mungbean sprout production.

Zandstra: Dr. Calkins, in the comparative table you presented on yield performance of mungbean in Thailand, Taiwan, and the Philippines, you did not distinguish between the cost of harvest labor and capital. Differences in yield could greatly influence labor costs, is this not true?

Calkins: Your point is quite valid. The problem is that the data from Thailand and the Philippines were not categorized by operation. This makes a cross-country comparison of the effect of pre-harvest labor on mungbean yield quite difficult. I included the detailed data for Taiwan, however, for precisely this reason. There, the highest yield sample uses only 11 more hours of pre-harvest labor than the second yielder. Thus, for the Taiwan case it is not so much the level but the operational structure of pre-harvest labor which seems significant.

Ng: Can you tell us about the present production level and trade movement of blackgram?

Calkins: I don't know that such statistics exist. The FAO Production and Trade Yearbooks do show such patterns for the category "Dry Beans" as a whole and one may assume that blackgram follows these trends. As mentioned, the production and export volume of dry beans are erratic for all Asian countries, with the single exception of Thailand.

Wang: Dr. Calkins, how do labor costs figure in the total expenditure for mungbean production? In the farm family, what is the ratio between its own labor and the labor it employs? If its own labor is in the majority, it seems to me that farmers will be more interested in cultivating mungbean.

Calkins: Your first question is one of the definition in economic production cost accounts. Even if labor is hired, such costs are included in "labor" and not in "capital". This allows us to compare the aggregate levels of the two types of input. By this definition, then, labor represents a zero fraction of total capital costs. As for your second question, full utilization of family labor in the pre-monsoon season is indeed one of the main reasons why farmers grow mungbean in Taiwan. There is a negligible proportion of hired labor in mungbean production in our three district samples. This may be seen in the large difference between farm return and net return, as shown in Table 10. Net return inputes a wage to family labor and subtracts this from the value of output, while farm income does not. Even though net income is often quite low the farmer is contant with high farm income, which represents the overall return to his family from mungbean cultivation.

Park: Do you think that mungbean prices in the Philippines are still not high enough to induce more planting?

Calkins: According to the studies I reported, the price of mungbean received by farmers in the Philippines is about US$0.45/kg, which compared well with the price of US$0.14/kg received in Thailand. It is something less than the price of US$0.68/kg received by Taiwan farmers but Taiwan has a much more capital-intensive, competitive agriculture. Thus, I do not feel that output price is a serious problem in the Philippines, but rather that effective and stable production technology for input use has yet to be developed.

Cowell: In your talk, you made mungbean yield comparisons between Taiwan, Thailand, and the Philippines. Do these comparisons involve the same variety in each country or different varieties? Have you taken into account the mungbean's record as an erratic producer since production and environmental factors leading to an outstanding harvest in one country might produce a miserable failure in another?

Calkins: The yield figure for each country is a composite of the varietal yields achieved by all the sample farmers surveyed. Since in none of the three surveys were yield data recorded by individual variety, it is difficult to assess the impact of different environments on the yield performance of a given line. We do, however, have strong evidence that farmers are rational and choose the variety most suitable to them. Moreover, we noted that the environmental factors in each of the three study areas were quite similar. Thus, the erratic production you mention occurs just as much because of weather variability from year to year in the same country as from country to country in the same year.

Management

-continued-

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Some Studies on Production Management of Mungbean at UPLB-CA

I.C. Cagampang, O.F. Samson, and J.C. Micosa

INTRODUCTION

The current average mungbean yield in the Philippines of about 450 kg/ha is relatively low compared to achievable yield levels of more than one t/ha. Conveniently, this low-level output can be accounted for by a mixture of interrelated field variables, such as date-of-planting, plant population density, and row spacing.

The effects of date-of-planting on mungbean performance is poorly documented. Date-of-planting exerts influence through the effects of various climatic parameters, mainly temperature and insolation which are, in turn, affected by the photoperiod cycle. In the higher latitudes, the effect is more of temperature change so that too early or too late planting can bring about substantial yield reduction. Nevertheless, in a tropical, monsoonal climate like the Philippines, the influence is more on insolation which varies to a significant extent the year round. The effect of date-of-planting, however, is particularly marked in photosensitive crops, like mungbean, as it directly affects the plant's vegetative-reproductive physiology. Most of the commercially grown mungbean cultivars in the Philippines are moderately photoperiodic.

Research on plant population density shows that while there are no absolute population density requirements, there is an optimum density range for a given plant type of a given crop species (1,4,5).

Because of its photoreactive nature, mungbean tends to grow tall, which renders it susceptible to lodging. Reports are not consistent, but there is some evidence that 2, 3, 5-Triiodobenzoic Acid (TIBA), a well known growth regulator, enhances yield through increased flowering, pod setting, and reduced lodging (2,3).

This paper will report on 3 studies: month-of-planting mungbean in relation to row spacing and cultivar; plant density in relation to cultivar; and, foliar application of 2, 3, 5-Triiodobenzoic Acid (TIBA).

MATERIALS AND METHODS

Experiment 1

Three mungbean cultivars with row spacings of 50, 75, and 100 cm were planted in a split-split plot randomized complete block design in 3 replications. Month-of-planting served as the main plot, cultivar as the first subplot, and row spacing as the second subplot. The experimental unit size was 3 x 5 m. The number of rows/experimental subplot was 6,4, and 3 for the 50, 75, and 100 cm spacings, respectively.

We planted on the third day of the month starting from June, 1970 to May, 1971 (except July). The seeds were handsown in the furrow after application of the basal fertilizer (40 kg N/ha and 60 kg each P_2O_5 and K_2O. Thinning to 300,000 plants/ha was done 2 weeks after seedling emergence. The February, March, and April plantings were supplemented with 3 applications of irrigation water applied through an overhead sprinkler system at planting, 2 weeks after planting, and at mid-bloom.

Experiment 2

Six population density levels were tested (200, 300, 400, 500, 600, and 700 thousand plants/ha). The experiment was conducted in a randomized complete block design, arranged in split-plots, and replicated 4 times. The cultivars (CES-55 and MG 10A) served as the main plot while the population density served as the subplots. The experimental unit measured 3 x 6 m divided into 4 rows, spaced 75 cm during the wet season planting, and 2 x 6 m with 4 rows, spaced 50 cm during the dry season.

A fertilizer mixture of 40 kg/ha each of N, P_2O_5, and K_2O was applied basally just before planting. The dry season crop was seeded on October 13, 1972, while the wet season planting was done on May 22, 1973. To insure that a more accurate population count would be achieved, 50% more seeds were sown than the estimated requirement. The desired population levels were then corrected by thinning the seedlings 10 days from emergence.

Experiment 3

We tested the rate of TIBA application and growth stage of the mungbean. The TIBA rates used were 0, 25, 50, 75, and 100 g/ha in the wet season, and 0, 15, 30, 45, 60, 75, 90, and 105 g/ha in the dry season. The growth stages at time of application were second trifoliate (2TF), fourth trifoliate (4TF), and mid-flowering stage. The experiment was laid out in randomized complete block design, in split-plot manner, with 4 replications. The TIBA rate was the main plot while the stages of growth served as the subplot.

The TIBA was thoroughly dissolved in 5 mℓ of 0.1 N NaOH for rates below 50 g/ha and 10 mℓ for rates higher than 50 g/ha and mixed with

Table 1. Mean values of agronomic variables of mungbean as affected by month-of-planting across 3 mungbean cultivars and 3 row spacing; UPLB, 1970-71.

Month	Yield/ha (kg)**	Plant height (cm)**	Nodule[a] count**	Pods/ plant**	Maturity** (day)
June '70	674	81.3	14.7	12.0	68.0
Aug. '70	273	48.8	7.0	16.5	65.0
Sept.'70	147	47.1	7.9	4.5	59.0
Oct. '70	159	55.2	4.7	4.7	61.3
Feb. '71	1,586	47.3	14.6	14.6	71.0
Mar. '71	609	54.6	14.4	12.7	65.0
LSD (0.01)	180	6.2	7.7	3.76	3.0
April '71	701	54.4*		9.8	64.3
May '71	411	50.6*		5.3	64.3
Aug. '71	839	55.5*		12.5	63.0
Sept. '71	591	53.7*		5.9	60.0
Nov. '71	484	49.7*		5.0	59.0
LSD (.05)	73.0	3.48*		2.60	-
(.01)	100.0			3.94	3.4

[a]Only nodules found in the primary roots were counted. ** Significant at 1% level; * Significant at 5%.

distilled water. The spray solution was diluted to a spray volume of 100 ℓ/ha and sprayed evenly over the foliar using a high-pressure hand sprayer.

RESULTS AND DISCUSSIONS

Table 1 summarizes Experiment 1. Due to a seed shortage in one of the cultivars used after the sixth month, a change was made during subsequent months. Thus, we deemed it more meaningful to treat the first 6-month data separately.

Except for seed weight, the other agronomic variables measure were significantly affected by months-of-planting. The data indicate that the best month to seed mungbean at UPLB or areas with similar climatic characteristics is February.

Table 2. Mean values of mungbean yields as affected by row spacing across months-of-planting and 3 mungbean cultivars; UPLB, 1971-77.

Row spacing (cm)	Yield/ha (kg)**
50	588
75	508
100	414
LSD (.01)	69

** - Significant at 1% level.

February, March, and April are dry months in most parts of the Philippines; therefore, moisture becomes the limiting factor for mungbean when seeded during these periods. To take advantage of the abundant insolation and favorable photoperiod, the February planting must be supplemented with irrigation. Row spacing resulted in significant bean yield differences (Table 2). Plants from the 50 cm spacing yielded significantly higher than the others. No significant differences were detected with the other measured agronomic parameters.

Table 3 shows the results of Experiment 2. In the wet season, the 300 thousand plants/ha density gave the highest bean yields. In the dry season, however, the highest yield of 1.04 t/ha was obtained from the 400 thousand plant/ha level. The other agronomic variables were not substantially affected by plant density differential. The data strongly suggest that the optimum plant density for mungbean during the wet season planting is in the range of 300-400 thousand plants/ha, while during the dry season, the range is in the vicinity of 400-500 thousand plants/ha.

Table 4 summarizes the results of the third experiment. TIBA foliarly applied at different concentrations during 3 different growth stages of mungbean did not affect bean yield and the other characteristics measured. Plant height, however, was reduced markedly at the higher concentration. The time of TIBA application shortened height when applied at the mid-bloom stage. Similar data were derived from the wet season planting of CY 1975-76. However, TIBA concentration affected plant height and seeds/pod, although no clear-cut trend was established. Similarly, the growth stage did not affect yield and other parameters, except plant height.

Table 3. Mean values of agronomic variables of mungbear/ as affected by population density across 3 mungbean cultivars, wet season; 1973-74.

Plant density/ha	Yield(kg/ha)*	Pods/plant^{ns}
---- 1000 ----		
200	666	10
300	798	9
400	731	9
500	677	8
600	575	8
700	592	7
HSD (.05)	209	
200	846	9
300	888	8
400	1044	8
500	1026	8
600	920	6
700	836	7
HSD (.05)	774	

* - Significant at 5% level.

Table 4. Significant effects of 2, 3, 5-TIBA sprayed at different growth stages of mungbean, dry and wet seasons; UPLB-CA, 1974-76.

	TIBA (g/ha)	Yield (kg/ha)	Weight 100 seeds (g)	Seeds/pod	Pods/plant	Plant height (cm)
	DRY SEASON					
A	0	1,009	7.71	7.9	10	34.2
	25	1,115	7.71	7.7	10	35.4
	50	1,160	7.75	8.1	10	35.9
	75	995	7.62	7.3	10	31.8
	100	1,020	7.83	7.1	9	30.8
	Application time					
B	2 TF	1,052	7.71	7.5	10	34.5
	4 TF	1,098	7.64	7.8	10	35.0
	Mid-flowering	1,029	7.84	7.6	9	31.4
	F-test (HSD 5%)					
	A	ns	ns	0.980	ns	05.53
	B	ns	0.153	ns	2.6	ns
	A x B	ns	ns	ns	ns	ns
	WET SEASON					
	TIBA (g/ha)					
A	0	817	6.73	10.3	9	82.3
	15	784	6.77	10.3	10	78.7
	30	811	6.83	10.3	9	78.5
	45	786	6.78	10.2	8	73.8
	60	749	6.64	9.9	8	78.8
	75	839	6.64	10.3	8	78.0
	90	787	6.73	10.5	8	77.7
	105	808	6.67	10.1	10	75.3
	Application time					
B	2 TF	839	6.79	10.4	9	81.6
	4 TF	829	6.66	10.2	8	70.4
	Mid-flowering	734	6.73	10.1	9	81.5
	F-test (HSD 1%)					
	A	ns	ns	ns	ns	ns
	B	ns	ns	ns	ns	0.7757
	A x B	ns	ns	ns	ns	ns

Applying TIBA at the fourth trifoliate leaf stage considerably shortened plant height. The evidence from the 2-season plantings points out consistently that TIBA has a dwarfing effect on mungbean. This has a significant implication in terms of reducing lodging.

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Effect of Irrigation on Mungbean Yield

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Mungbean needs water to undergo its normal physiological processes since photosynthesis occurs in an aquatic environment. Physiological studies on mungbean at AVRDC have shown that 7 days of water stress at different growth stages reduces the photosynthetic rate by 76-99%, resulting in a per plant grain yield reduction of 28-45%. The soil moisture level affects the nodulation status and nitrogen content of mungbean as well as the crop quality. Verma (9) reported that a 50% moisture level was the optimum for dry weight and number of nodules, and total N content of root and shoot. Ishii (5) found that more than 90% hard seeds were produced when soil moisture was reduced from 50 to 20% during the flowering-ripening process.

It is generally accepted that mungbean is a deep rooted, drought-tolerant crop. In a study conducted in Taiwan (3), it was reported that the water requirement of mungbean averaged 3.2 mm/day. (Rates for corn and soybean, 3.2-3.3 mm/day; sorghum, 2.8 mm/day; sweet potato, 1.8 mm/day). Bose (2) investigated the root system of 40 different mungbean varieties collected across the Indian peninsula. He found maximum penetration depth ranging from 17.5-35 cm with working depth (abundant secondary root zone) ranging from 3-12 cm. These studies of water requirements and root systems suggest that mungbean could easily be susceptible to water stress under conditions of limited soil moisture. The most positive way to provide a better moisture environment is through irrigation measures.

Irrigation studies conducted in India consistently show that mungbean is highly responsive to irrigation. Agarwal (1) reported that 2 irrigations, once at flowering and again at grain development, produced 1,040 kg/ha which was 33% higher than irrigation at grain development, and 15% higher than irrigation at flowering. Jana (6) found that irrigated mungbean yielded 40% higher than non-irrigated mungbean. Singh (8) studied irrigation and row spacings on summer mungbean with 3 available moisture levels during pre-flowering and 3 levels during post-flowering. The treatment with 60% followed by 40% available water produced the maximum yield which was 2.8 times that of the treatment corresponding to the minimum moisture level combination -- the 20% pre- and 20% post-flowering available moisture level. Irrigation studies (4, 7) conducted in Chainat, Thailand, failed to indicate significant differences among the mungbean responses to different irrigation frequencies. The reason given was the late application of irrigation treatments (initiated at flowering).

To increase this preliminary understanding of mungbean response to irrigation, a study was initiated at AVRDC in spring, 1977.

MATERIALS & METHODS

This experiment was conducted at AVRDC during the late dry season (Mar-May). We planted cultivar PHLV #18 (AVRDC 2184), on March 24 in a randomized complete block design with 4 replications. Laid out to facilitate irrigation and drainage of each plot separately, there were 1.5 and 3.0 m separation spaces between plots and replications, respectively. Plot size was 3 x 6 m and contained four 0.75 m spaced beds. Mungbean was planted on each bed in single rows. All plots were given about 70 mm of water one day after planting to stimulate normal emergence. At 10 days after planting, we thinned the stand to a population density of 260,000 plants/ha. The temperature, precipitation, and evaporation data during the experimental period are given in Figure 1. The sandy loam soil on the farm is low in organic matter content and high in pH value (Table 1). The water table was about 1.5 m below the soil surface for the whole growth period.

Fourteen treatments were designed to test irrigation frequency from 0-6 times, and irrigation timing in different combinations. Only 9 treatments were applied (Table 2), since monsoon rains began on May 12 (52 DAE).

Table 1. Characteristics of typical soil profile from AVRDC experimental farm, Taiwan, 1977.

Depth	pH	Texture sand	silt	clay	Organic matter content
(cm)		-------	%	------	
0-15	8.6	22	54	24	1.4
16-29	8.2	24	52	24	1.4
30-64	8.5	24	48	28	0.7

Each irrigation provided 50 mm of water (900 ℓ/plot). A sample of 6 plants from the outer 2 rows of a plot, harvested at 50 DAE and oven-dried, gave data on the total dry matter. The mature pods in the middle 2 rows of each plot were harvested on May 21, 26, and 31. A 10-plant sample determined the number of pods/plant and number of seeds/pod. Hundred seed weight was calculated from the first harvest. Yield and 100 seed weight were adjusted to a 12% moisture level.

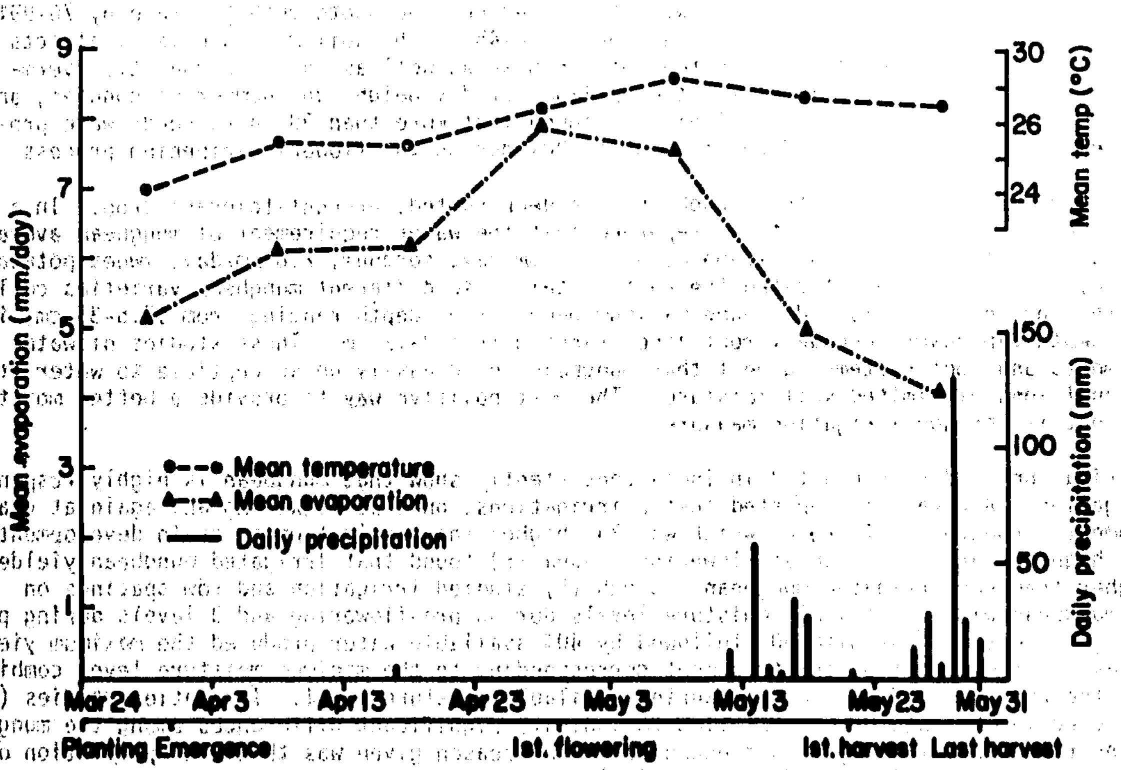

Fig. 1. Daily precipitation, and mean daily evaporation and temperature (10 day period) during the experiment; AVRDC, 1977.

RESULTS AND DISCUSSION

All mungbean plants started flowering about 38 days after planting (30 DAE). Pre-flowering irrigation did not affect flowering date. At flowering, the plants in treatments T_1 (check) and T_4 received no water. Treatments T_2, T_3, T_6, and T_7 received one irrigation; T_5 and T_8 received 2 irrigations; and T_9 received 3 irrigations (Table 2).

The dry matter weight was significantly higher for irrigated treatments than for the non-irrigated check. Treatment T_9 produced 2.2 times as much yield as did T_1. Better vegetative growth of irrigated treatments, as indicated by higher dry matter production, suggest greater capability in accumulating more carbohydrate for bean production.

Irrigation treatments significantly affected the number of pods/plant and number of seeds/pod. Hundred seed weight was unaffected. Comparisons of the weight of dry matter and number of pods/plant between T_2 and T_5 suggest that water stress at flowering results in excessive flower and/or pod abortion. Comparisons of dry matter weight and number of pods/plant between T_3 and T_5 suggest that source limitation was responsible for the low pod number in T_3. Adequate water in both pre-flowering and flowering stage is required for mungbean plants to bear the maximum number of pods. Yield is significantly correlated with the number of pods/plant ($t = 0.99$) and the number of seeds/pod ($r = 0.86$)[a]. The distribution of yield among the 3 harvests was not significantly affected by the irrigation treatments. Irrigated treatments produced more yield than the non-irrigated check. Single irrigation at either 15 DAE (T_2) or at first flowering (T_3) produced greater yields than the non-irrigated check. There were no significant differences between T_2 and T_3. Double irrigations, once at 15 DAE and again at first flowering, produced more yield than any single irrigation treatment. Rain occuring at 12 days after first flowering probably masked any effect of the irrigation at 10 days after first flowering. This explains the yield similarity among T_2, T_3, T_6, and T_7, and the yield similarity between T_5 and T_8. There was a highly significant linear increase in yield with the amount of irrigation water applied before or at flowering (Fig. 2). These results show the importance of avoiding water stress to mungbeans particularly before and during the flowering stage. To develop general irrigation guidelines for optimizing yield, more studies are definitely needed.

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[a]Statistically significant at the 5% level.

Table 2. Yield and yield components of mungbean influences by irrigation, frequency, and timing; AVRDC, 1977.

T	Irrigation frequency	Irrigation timing	Dry matter wt. 50 DAE	No. of pod/plant	No. of seed/pod	100 seed weight	Bean yield
			-- g/plant --			-- g --	-- kg/ha --
1	0	DAE	5.9 d[a]	4.3 cd	6.7 cd	7.0a	442 d
2	1	30 DAE	8.1 bc	5.3 bc	7.3 bc	6.9a	637 c
3	1	30 DAE (first flowering)	6.9 cd	5.3 c	6.8 bcd	7.1a	569 c
4	1	40 DAE[b]	6.2 d	3.4 d	6.3 d	6.9a	309 e
5	2	15 + 30 DAE	8.3 bc	7.5 b	7.7ab	6.4a	891 b
6	2	15 + 40 DAE	7.4 bcd	5.6 c	7.1 bcd	7.1a	602 c
7	2	30 + 40 DAE	7.5 bcd	5.2 c	6.8 cd	7.3a	613 c
8	3	15 + 30 + 40 DAE	9.1 b	7.7 b	7.0 bcd	7.1a	926 b
9	4	10, 20, 30 and 40 DAE	13.1a	9.0a	8.1a	6.5a	1098a

[a]Means with same letter within each column are not significantly different at 5% level. [b]Rain occuring 42 DAE probably masked effect of irrigation applied 40 DAE.

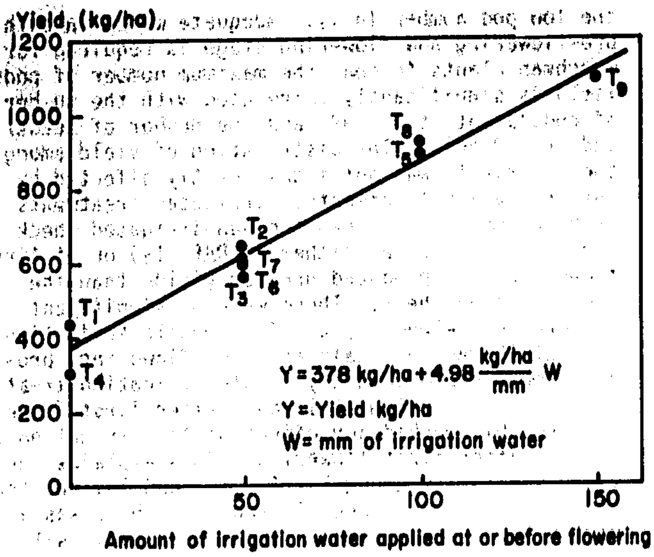

Fig. 2. Yield response of mungbean to irrigation given at or prior to flowering; AVRDC, 1977.

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What We Have Learned From The International Mungbean Nurseries

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I would like to share some experiences gained through the cooperation and efforts of the many dedicated research workers who grew the first 4 International Mungbean Nurseries (IMN's). I will also refer to some of our research on problems identified through the IMN's.

The objectives for the IMN's were ambitious: to study (a) the range of adaptation of the mungbean species, (b) the adaptation of specific mungbean cultivars, and (c) those characteristics of the mungbean plant influencing adaptation. The first 4 IMN's grew a total of 56 strains at 74 test sites located from 2^{o}S to 49^{o}N latitude on 4 continents. Problems such as photoperiod response of the mungbean and its inheritance, the identification of a local virus, and the inheritance of resistance to the local virus have been investigated further at Columbia, Missouri, as graduate thesis research. Data from the 4 IMN's have been published in University of Missouri, Agricultural Experiment Station Special Reports (3-6).

PHOTOPERIOD AND TEMPERATURE RESPONSE IN MUNGBEAN

The IMN's demonstrated that mungbean strains differ in their photoperiod response when grown at different latitudes. When I visited the First IMN in Kalasin, Thailand, in 1972, all strains were flowering within 34-36 days after planting. At Los Baños, flowering ranged from 31-37 days. Yet, at Columbia the spread in flowering was from 43-78 days, and at Morden Manitoba, the spread was from 61-85 days. Similar observations were made in the Second, Third, and Fourth IMN's. In the short days of the lower latitudes, flowering is hastened and the spread in flowering among strains is compressed into a period of a few days in constrast to the wide spread in "days-to-flower" among strains in the long photoperiods of the higher latitudes. Bashandi, verifying this response in controlled environment chambers, obtained a delay in flowering as photoperiod was increased (2). The amount of delay differed among strains. One strain failed to flower within 180 days (16 hr photoperiod).

Temperature also affects days-to-flower, but at different locations the effects of temperature and the effects of photoperiod on flowering cannot be separated. To study the possible interactions of photoperiod and temperature, we grew 40 strains from the First and Second IMN's in photoperiod ranging from 12-16 hrs, and mean temperatures of 18^{o}, 23^{o}, and 28^{o}C (1). The 40 strains could be classified into 8 groups based on days-to-flower in the various photoperiod/temperature combinations. Groups 1-3 flowered in all photoperiod-temperature combina-

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[a]Scientific paper No. 795 of the Missouri Agricultural Experiment Station. This research was financed in part by the United States Agency for International Development.

tions, the groups differing only in the mean days required for flowering. Within a group, days-to-flower was delayed by reducing temperatures or by increasing the length of the photoperiod, the effects being additive.

Strains in groups 5 and 6 failed to flower in 15 and 16 hr photoperiods. One of the strains in group 5 was the same strain that failed to flower for Bashandi.

Swidell studied the inheritance of photoperiod response and found that the difference in flowering of strains from groups 1 and 3 was inherited in a quantitative manner (8). The failure of a strain from group 5 to flower at long photoperiods was inherited as a single dominant gene, designated Ps. The effect of the Ps gene was not expressed when the mungbeans were grown in short photoperiods or in the field at Columbia. The Ps gene, therefore, would not be identified if the strains in group 5 (all of which originated in India) or their progenies, were to be grown in the short days of the low latitudes. This explains reports that the mungbeans in the IMN's were "short and early" when grown in the lower latitudes.

Some related observations have been made on temperature. Minimum mean temperature for productive growth of mungbean appears to be between 20°-22°C with optimum mean temperatures in the range of 28°-30°C, perhaps a little higher if moisture is adequate. Mungbeans are a short day, warm season crop. Little success was obtained with IMN's grown above 40° latitude, apparently due to the delay in flowering resulting from the long photoperiod or poor growth due to the cooler temperature. With short photoperiods and high mean temperatures, mungbeans flower within 30-40 days, and fit well into multiple cropping systems in the tropics throughout the year. In long photoperiods and low mean temperatures, flowering requires 50-80 days, varying with the strain and its photoperiod response. Under these conditions only a single crop may be grown within the frost-free period.

DISEASES AND INSECTS IN RELATION TO VARIETY ADAPTATION

Diseases and insects are important factors in mungbean production and variety adaptation. The diseases most frequently encountered in the IMN's are shown in Table 1. Anthracnose and a bacterial disease (causal organisms unidentified) were reported from Palmira, Colombia.

Powdery mildew. Powdery mildew, reported in 18 of 74 nurseries, was not specific to any geographic area. At Columbia, it always developed late in the season after the start of flowering and pod set, and the effect on yield was minimal. However, if present early in the development of the plant, as was observed in Taiwan, yields may be drastically reduced or plants even killed. Differences in resistance were observed among strains, but none of the strains were highly resistant.

Cercospora leaf spot. *Cercospora* leaf spot was reported from 18 nurseries, always in Southeast Asia, except for Palmira, Colombia. The reduction in yield from *Cercospora* leaf spot depends upon how early in the life of the plant the infection occurs. A severe infection may result in almost total defoliation. As with powdery mildew, no highly resistant varieties were identified.

Mungbean yellow mosaic virus. MYMV is one of the more damaging diseases. Reported from 16 nurseries in Southeast Asia, Colombia, and Ethiopia, MYMV is most severe in the Pakistan-India area of South Asia. The ML-numbered strains from Ludhiana, India, and Hybrid 45 used as a parent in the development of the ML strains, were the most

Table 1. Number of locations from which diseases were reported in the International Mungbean Nurseries

IMN	Nurseries grown	Nurseries reporting presence of			
		virus (unidentified)	MYMV	*Cercospora* leaf spot	powdery mildew
First	10	6	1	1	2
Second	18	11	4	2	4
Third	24	9	6	8	4
Fourth	22	5	5	7	8
Total	74	31	16	18	18

tolerant and productive at Ludhiana and Pantnagar, India, where the IMN's were exposed to severe MYMV infections (Table 2).

Table 2. Yield of mungbean strains resistant to MYMV at Ludhiana and Pantnagar, India; 4th IMN.

Strain	Ludhiana rank	Ludhiana yield	Pantnagar rank	Pantnagar yield
		kg/ha		kg/ha
ML-5	1	900	(not grown)	
ML-1	2	589	1,2	666
Hybrid 45	3	449	4	233
ML-6	4[a]	409	1,2	666

[a]At Ludhiana the 10 next highest yielding strains averaged only 44 kg/ha. Seventeen strains were either killed or so severely damaged that they were not harvested.

Virus (unidentified). Unidentified viruses were observed more frequently than other diseases, having been reported in 31 of the 74 nurseries. Symptoms commonly reported were mosaic leaf crinkling, dwarfing, or flower abortion. It is not certain that a virus was actually involved at every location, or that the same virus or virus complexes were being observed. And differences in resistance ratings were generally slight.

Cucumber Mosaic Virus. At Columbia, the virus symptoms evident in many strains each have now been identified as a strain of cucumber mosaic virus (CMV-M) (7,9). The cowpea aphid, *Aphis craccivora*, is a vector. CMV-M may be mechanically transmitted producing local lesions on resistant strains and mosaic in susceptible strains. A large number of mungbean strains are highly resistant to CMV-M. The resistance of strain M101 to CMV-M is inherited as a single dominant gene (9).

Insects. Little information was obtained on insect depredations in the IMN's. Attacks by white striped blister beetles were reported twice from Ethiopia but evidence of varietal resistance was slight. The bean shoot fly is extremely damaging in Southeast Asia, and was cited as the cause for failure in some of the nurseries even though no data were reported.

Root Knot Nematode. Damage caused by root knot nematodes was observed at Normal, Alabama. Strains M339 and M408 were severely injured, but injury to others was slight.

YIELD POTENTIAL AND PROBLEMS OF OBTAINING HIGH YIELDS

The yield data (3,4,5,6) in the IMN's indicate that the mungbean has a potential for high yield, but high yields were seldom realized. Yield data were reported from 61 nurseries in which:

mean yields of 1000-1771 kg/ha were reported from 17 IMN's;
mean yields of 500-999 kg/ha were reported from 30 IMN's; and
mean yields of less than 500 kg/ha were reported from 14 IMN's.

The 5 highest mean yields were reported from Melka Werer, Ethiopia (2nd and 4th IMN's); Chiang Mai (3rd IMN); Melkassa, Ethiopia (1st IMN); and AVRDC in Taiwan (4th IMN). Other locations with mean yields above 1,000 kg/ha included Columbia, Missouri (1st IMN); Los Baños (2nd IMN); Stillwater, Oklahoma, (2nd and 4th IMN); Suphanburi, Thailand (3rd IMN); AVRDC (2nd IMN); Karaj, Iran (3rd and 4th IMN's); and Normal, Alabama (2nd IMN).

The diversity of these locations is evidence of wide adaptation but makes it difficult to identify specific climatic characteristics which favor mungbean production. A long period in which to set pods appears to be one condition associated with high yields. In 11 of the 14 locations in which yields exceeded 1000 kg/ha, the period from planting to harvest exceeded 90 days, and at 8 locations it exceeded 100 days. Generally, high yields were not obtained in locations where the crop was of short duration from short photoperiods or high temperatures. In northern latitudes, the growing season may be terminated by frost before a sufficient number of pods have been set to produce high yields on late flowering strains. Freedom from debilitating diseases or insect damage during the growing season is also important for high yields.

The highest yield was recorded in strain M409 from Peru, with a yield at Melka Werer, Ethiopia of 6907 kg/ha in the 4th IMN, and 3032 kg/ha in the 2nd IMN. Strain M1134 from Oklahoma yielded 5800 kg/ha at Melka Werer in the 4t IMN. In Southeast Asia, M409 and M1134 yielded poorly. By contrast, M350 from Korea has consistently yielded well in Southeast Asia, although it seldom ranked first in yield at any particular location. Comparison of M350 and M409 at several locations in the 2nd, 3rd, and 4th IMN's are reported in Table 3. Factors contributing to the high yields in Ethiopia and Iran appear to be adequate irrigation, high light intensity, slightly cooler temperatures due to the higher elevations, and a minimum of disease damage. Under these conditions, M409 and M1135 which grow vigorously and flower late, produced large plants and maintained their flowering and pod set over a long period.

Table 3. Yield rank of M350 and M409 in 2nd, 3rd, and 4th IMN yield trials.

Test location	Number of trials	Yield rank among 12 strains M350	M409
Philippines	3	1	12
Korea	5	1	12
Thailand	7	1	12
Ethiopia	8	9	1
Iran	3	11	2

Observations were made in some nurseries on the components of yield: pods/plant, seeds/pod, and seed weight. While pods/plant appear to be an important component, yield was also affected by plant population. The irregularity in stands made it virtually impossible to form valid conclusions from the data.

It is easier to document reasons for the low yields. Cooperators' comments included infertile soil; inadequate soil moisture; poor stands; lack of nodulation; inadequate population densities; sub-optimum temperatures; disease and insect injury; and damage from rain, windstorms, and typhoons. Low yields reported from so many locations indicated the need for intensive production research, as well as the utilization of better production practices insofar as they are known. Many tests were planted on soils low in fertility and poor in structure and without fertilization or *Rhizobium* inoculation. Yields might have been improved with *Rhizobium* inoculum, but this did not seem practical.

Plant populations were often too low, due to poor stands or to row spacings too wide for the size of plants that developed. Unfortunately, seed supplies were often insufficient to obtain optimum stands under adverse conditions. The 90 cm row-spacing most generally used was satisfactory at locations where plants grew large, but was too wide at locations where they did not. It would appear that higher populations may be needed at the low latitudes where short photoperiods and high temperature induce flowering in 30-40 days, as compared to the higher latitudes which may require 40-50 days. Since early flowering is desirable where mungbeans are to be grown in multiple cropping systems, comparisons of yields on a kg/ha/day basis might be more useful than comparisons on the basis of total yield. The effect MYMV on yields of different strains at Ludhiana, already cited, illustrates the need for disease and insect resistant strains if high yields are to be obtained consistently.

COMMUNICATION AMONG MUNGBEAN RESEARCHERS THROUGH THE IMN

In addition to the information collected on yield and adaptation of mungbeans, the IMN's served to develop communication among mungbean researc workers. Except for cooperation within India through the All-India Coordinated Pulse Project, and in Southeast Asia through SEARCA, there has been little communication or exchange of breeding materials among mungbean research workers in the past. The International Mungbean Nurseries provide a mechanism for exchanging superior germplasm among participants, and communication of information gleaned from a variety of environmental conditions. This Symposium is a culmination of efforts to obtain better communication among mungbean research workers. For it, the organizers are to be commended.

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Responses of Mungbean to Sowing Date in Sarawak

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INTRODUCTION

In Malaysia, soybean and groundnuts are the major grain legumes. Mungbean has never been established as a crop although its bean has traditionally been imported for local consumption, mainly for sprouting and confectionery.

In the Malaysian Borneo state of Sarawak, the Department of Agriculture stated an experimental program in 1975 to examine the potential of mungbean as a new grain legume. A wide range of mungbean cultivars have since been introduced from AVRDC for performance testing. Trials are also being conducted to find out the agronomic requirements of mungbean under our conditions.

This paper reports a preliminary study on the influence of sowing date on the performance of a Philippine mungbean cultivar, CES-55 (AVRDC 1387), one of the best cultivars identified from the four International Mungbean Nurseries we have so far conducted (1).

MATERIALS AND METHODS

The experiment was carried out at the Kebuloh Experimental Station (4°07'N; 113°57'E) on a loamy-clay soil, pH 6-7, derived from calcareous shale. After the usual field preparation, mungbean seed was sown without inoculation at a density of 100,000 plants/ha (50cm between and 20cm within rows). Sowing was carried out at the beginning of March, May, July, August, and September, 1976. Four replicated plots were sown each time in a randomized complete block design.

Each plot, measuring 21 m^2, received an adequate supply of N-P-K fertilizers a day before sowing. Crops were grown under rainfed conditions, except during the first 10 days, when they were watered if necessary to promote rapid establishment.

The crop was grown for 70 days and, during the period, 4-5 destructive 10-plant samplings were taken at intervals varying from 10-15 days to follow changes in plant development. Plant height and the number of green and ripe pods were recorded. Plants were then dug up and separated into green leaves (laminae), dead leaves, stem including petioles and peduncles, green pods, ripe pods, and roots. These were oven-dried for dry matter determination.

Leaf area measurement was based on the area/dry weight relation of leaf disks to calculate the leaf area index (LAI) of the crop. Crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) were calculated (2).

To estimate the total seed yield, plants in the central area of the plots, measuring 8 m^2, were harvested on day 60 and 70. Seeds were sun-dried to a moisture content of 14% and weighed. Number of seeds/pod and 1000 seed weight were also recorded. Seed quality was rated visually.

Control of insect pests (using Dimethoate 40% EC) and hand-weeding were carried out when necessary. There was no chemical control for leaf spot caused by *Cercospora canescens*. Severity of pest and disease damage to the crop was assessed visually but not quantitatively scored.

RESULTS AND DISCUSSION

Table 1 shows the growing seasons of different sowing. Climatic data suggest that in March and July, the initial establishment of the crop would be limited by deficient soil moisture if no supplementary water was given. Indeed, field observations indicated that July seedlings were very much stunted by inadequate water (shortage of field labor).

Irrespective of the month mungbean was sown, its phenology was similar: flowering occurred 33 days after sowing, ripening of bean pods was observed at day 51, and the crop matured by day 70. However, there were considerable differences in plant growth. The March and May sowings had the highest total dry matter production whereas subsequent sowings resulted in rather stunted growth (Table 2). Plant height serves as a good indicator of their differences ($r = 0.985$, $P<0.01$).

Figure 1 shows the pattern of changes with plant age in its accumulation of total and component dry matter. A common feature irrespective of sowing dates was that the total DM accumulation was relatively slow in the first 30 days (especially the first 20 days), then increased very rapidly once flowering and pod-setting had commenced (as indicated by arrows), attaining the maximum yield at day 60.

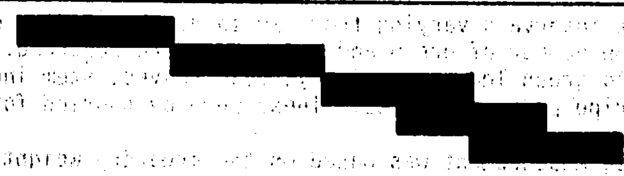
DM decreased after day 60 at a rate significantly different among the various sowing dates. The most rapid decline occurred in May and September, mainly related to a faster rate of leaf senescence. Changes in DM of vegetative plant parts with plant age generally followed the same pattern as the total DM yield.

Phasic changes in DM accumulation were examined by partition among the different plant parts (Table 3). The rapid increase in DM accumulation after flowering was largely attributed to the continued growth of the stem fraction and the fast-growing pods in particular. The proportion of total DM increase due to leaves decreased as the growth period advanced. The decline was particularly rapid after day 45 showing negative value in May, August, and September. The DM contribution by the roots was the smallest, generally decreasing in later growth periods.

An explanation of marked growth differences among the sowings cannot be based entirely on the climatic data. Although low rainfall relative to evaporative demand during July could largely account for the poor establishment and subsequent growth of the July sowing, the same was not true for that of March. That the March sowing was not adversely affected by poor water balance was

Table 1. Growing seasons of different mungbean sowings in relation to climatic conditions at Kebuloh Experimental Station; Sarawak, 1976.

Climatic element	J	F	M	A	M	J	J	A	S	O	N	D
Rainfall (mm)	615	180	40	133	166	102	48	212	85	209	349	295
Open-pan evaporation (mm)	140	121	142	145	172	125	137	122	134	131	113	121
Solar radiation[a] (cal/cm²/day)	319	434	433	444	405	417	419	382	426	407	389	401
Growing seasons												



[a]Measured by "RIMCO" self-integrating pyranometer.

Table 2. Influence of sowing date on plant characters of mungbean; Sarawak, 1976.[a]

Plant characters	March	May	July	Aug	Sept
Final plant height (cm)	55.3a	53.0 a	41.5 b	46.4ab	46.6 ab
Seed yield (kg/ha)	1161 a	585 c	809 b	1091 a	955 ab
Dry matter yield[b] (kg/ha)	3768 a	3567 a	1787 b	2211 b	2438 b
Harvest index[c]	0.3ab	0.17 b	0.49a	0.5a	0.39ab
Ripe pods per plant	29.7a	28.9 a	20.6 b	23.9ab	23.1 ab
Seeds per pod	n.r.	n.r.	10.9 a	11.7a	10.6 a
1000 seed weight (g)	n.r.	39.7 c	65.5 a	62.5ab	52.5 b

[a]Figures along each row not followed by the same letter differ significantly ($P<0.05$); n.r. = not recorded. [b]Maximum yield recorded on day 60. [c]Calculated as seed yield (sun-dried basis) over maximum whole plant dry matter yield.

probably due to the adequate supply of stored soil moisture carried over from the preceeding monsoon months. The favorable water balance during the growing seasons of August and September, however, did not result in vigorous plant growth. Field observations indicated that the intensity of *Cercospora canescens* increased with each successive sowing causing severe loss of leaves. Leaf spots were found even in the early seedling stage of the September sowing. It therefore appears that poorer plant growth in sowings later than May was essentially related to the increased severity of *Cercospora* which reduced LAI. Data in Table 4 show that the maximum LAI attained was indeed lower for sowings ater May. Regression of calculated CGR on LAI showed a significant positive linear correlation ($r=0.966$, $P<0.001$).

The importance of leaf area was further evidenced from the analysis of growth parameters. Figure 2 plots the changes of RGR and its component determinants, NAR and LAR, with plant age

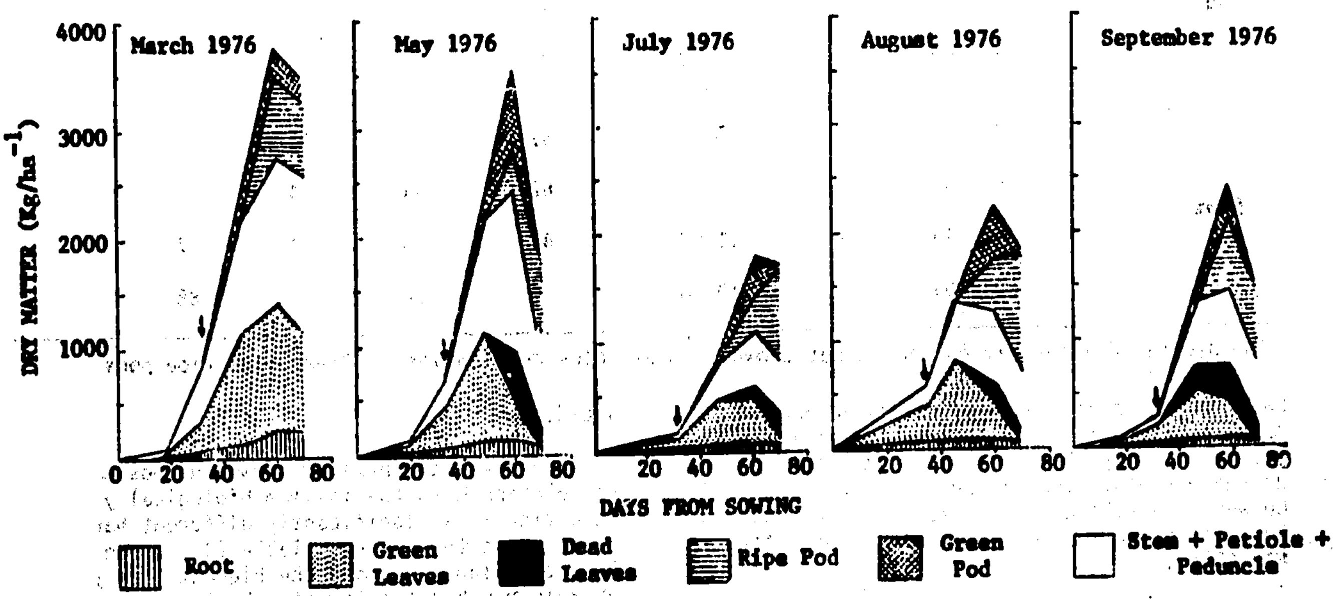


Fig. 1. Changes with time in the pattern of dry matter accumulation of mungbean sown on different dates (arrows indicate the date of flowering)

Table 3. Total dry matter increase/plant and its partitioning among plant fractions at various growth periods of mungbean sown of different dates; Sarawak, 1976.

Sowing date	Growth period (days)	Total DM[a] increase	Total increase due to leaves[b]	stem	root	pods[c]
		--- g ---	--------------	%	--------------	
March	0 - 18	0.52	69	23	8	0
	18 - 32	8.02	57	35	8	0
	32 - 47	15.37	30	50	5	15
	47 - 60	13.77	13	25	8	54
May	0 - 20	1.28	70	23	7	0
	20 - 34	6.00	52	39	9	0
	34 - 48	16.95	34	48	5	13
	48 - 59	11.44	-15	35	2	78
July	0 - 32	1.65	64	24	12	0
	32 - 46	6.51	45	43	8	4
	46 - 61	6.72	8	21	2	68
Aug	0 - 35	5.83	56	34	10	0
	35 - 45	8.16	49	41	3	7
	45 - 60	8.12	-27	16	1	110
Sept	0 - 18	0.81	61	28	11	0
	18 - 32	2.17	62	34	4	0
	32 - 46	11.02	46	43	4	7
	46 - 59	10.38	- 4	14	2	88

[a]DM decreased after day 60, hence not shown. [b]Green plus dead leaves. [c]Green plus ripe pods.

based on the pooled data of different sowing dates as given in Table 4. RGR was found to increase from day 15 to a peak at day 25, then decrease rapidly thereafter. The decrease in RGR between day 25 and day 55, for instance, was due to a faster rate of decline in LAR (56%) than in NAR (36%).

Furthermore, seed yield also showed a strong positive correlation with the maximum LAI ($r=0.925$, $P<0.01$). All this evidence suggests that the source is limiting for maximum biological and seed yield.

Seed yield generally showed no positive correlation with the maximum biological yield resulting in a significantly different harvest index among the sowings (Table 2). March and August sowings recorded the highest seed yield whereas May had the lowest. Sowing later than May had significantly smaller numbers of pods/plant. There were, however, no significant sowing date differences in the number of seeds/pod. Unfortunately, the number of seeds/pod for March

Table 4. Changes with time of growth parameters of mungbean sown on different dates; Sarawak, 1976.

Sowing date	Growth period	LAI[a]	CGR	RGR	NAR	LAR
	--- days ---		(g/m^2/day)	(g/g/day)	(g/dm^2/day)	(dm^2/g)
March	0 - 18	0.08	0.29	0.092	0.078	1.18
	18 - 32	1.03	5.73	0.200	0.157	1.27
	32 - 47	2.01	10.25	0.069	0.070	0.99
	47 - 60	2.39	10.59	0.035	0.048	0.73
	60 - 70	1.92	-2.84	-0.008	-0.013	0.61
May	0 - 20	0.18	0.64	0.128	0.101	1.27
	20 - 34	0.84	0.84	0.124	0.100	1.24
	34 - 48	2.03	12.11	0.086	0.090	0.96
	48 - 59	0.73	10.40	0.035	0.082	0.43
	59 - 69	0.00	-17.76	-0.069	-1.136	0.06
July	0 - 32	0.22	0.51	0.088	0.073	1.20
	32 - 46	0.83	4.65	0.114	0.102	1.12
	46 - 61	0.83	6.48	0.052	0.091	0.57
	61 - 70	0.18	-0.46	-0.003	-0.011	-0.27
August	0 - 35	0.68	1.67	0.116	0.103	1.13
	35 - 45	1.50	8.16	0.088	0.079	1.11
	45 - 60	0.85	5.41	0.031	0.047	0.66
	60 - 70	0.12	-4.03	-0.020	-0.109	0.18
September	0 - 18	0.10	0.45	0.116	0.103	1.13
	18 - 32	0.38	1.55	0.093	0.073	1.27
	32 - 46	1.03	7.87	0.111	0.118	0.94
	46 - 59	0.69	7.98	0.043	0.094	0.46
	59 - 69	0.08	-9.62	-0.050	-0.337	0.15

[a]As at the end of each respective growth period.

and May was not recorded, but observations showed that most of the pods were not properly filled in the May sowing resulting in a smaller number of seeds/pod. This was mainly caused by insect pest damage; the major pests being the sucking bugs (*Riptortus lineari* and *Dysdercus* spp) and pod-borers (*Euchrysops cnejus*, *Maruca testatulis*, and *Lampides* spp.).

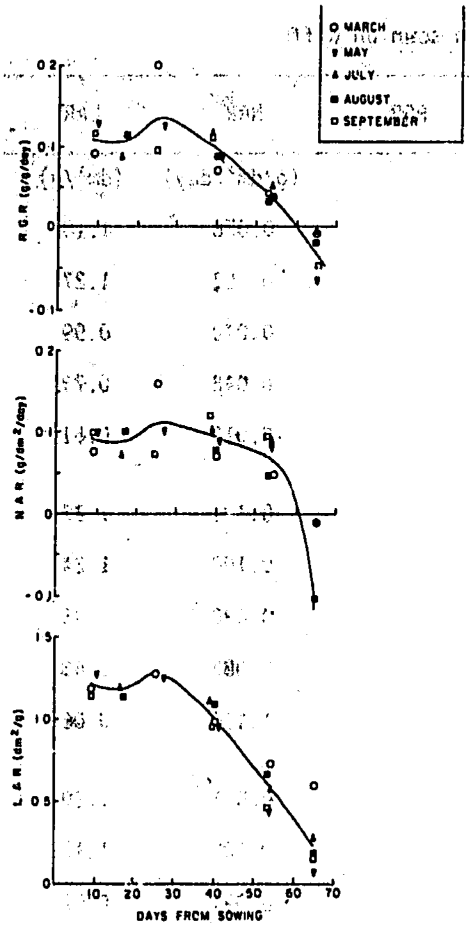


Fig. 2. Changes with time of RGR, NAR, and LAR of mungbean (pooled data from different dowings); Sarawak, 1976.

The 1000 seed weight of the May sowing was also significantly lower than that of later sowings. Both this parameter and poor pod-shelling appeared to provide likely explanations.

The May, and to some extent the March, sowings had the highest proportion of shrivelled, malformed seeds, obviously due to pest damage. The best quality seed was harvested in July and August. Differences in seed quality suggest the possibility of seasonal fluctuations in the insect populations. Quantitative assessment of the pest population dynamics and the actual pod damage done deserve further study.

The major conclusion from this preliminary study is that, under the current experimental conditions, August appears to be the best sowing month. A high yield of good quality seed was harvested. Also, there seems to be a greater efficiency in the partitioning of dry matter for seed production as is suggested by high harvest index. It should, however, be stressed that the definition of best sowing time is only tentative and needs confirmation by replicating field trials over several seasons, in more locations, and with more cultivars.

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Evaluation of Mungbean under Irrigation in Northern Australia

D.F. Beech & I.M. Wood

INTRODUCTION

Mungbeans (black and green gram) are a relatively new crop in Northern Australia and research is its very early stages. Initial studies were carried out under rainfed conditions but recent research has been with irrigation. Dry land studies have been made at Katherine Research Station in Northern Australia (lat. 14.3°S long. 132.3°E), and irrigated studies at Kimberley Research Station, Kununurra, in Western Australia (lat. 15.7°S long. 128.7°E).

The climate of Northern Australia is tropical monsoonal with 2 well defined seasons-- a wet season which extends from mid-November to March and a dry season which extends from April to November. The annual rainfall at Katherine is 900 mm and at Kununurra, 770 mm. Distribution of rainfall at Kununurra and the mean monthly maximum and minimum temperatures are shown in Figure 1.

Eight experiments between 1971-1975 compared a limited range of 10 accessions from Missouri with 2 local green gram cultivars. Recent work has studied the phenology, growth habit, and yield of 183 genotypes from a wide range of countries. Some studies examined the use of defoliation treatments to assist harvesting.

PRELIMINARY EXPERIMENTS

Early studies at Katherine during 1948-54 showed moderate yields under dryland conditions with black gram outyielding green gram. The grain yield for the best black gram cultivar, Regur, was 878 kg/ha over a 4-year period; the best green gram was CPI 11013, which gave a mean yield of 843 kg/ha over 5 seasons.

Under dryland conditions, the potential for mungbean is limited to a planting period of December-January. However, under irrigation the potential growing period is much longer. Studies since the initial work have concentrated on growing mungbeans under irrigation at Kununurra with a range of sowing dates.

The grain yield of range of Missouri accessions and 2 standard cultivars are given in Table 1. The December 13 sowing made the best growth and had the highest potential yield but considerable losses occurred following rain at maturity which caused the seeds to sprout in the pods. The cultivars, Berken, M115, and M68, were the least affected but grain quality was poor. Seed maturation for the February sowing occurred during the early dry season when temperatures were still high. This gave higher grain yields than the March sowing which matured

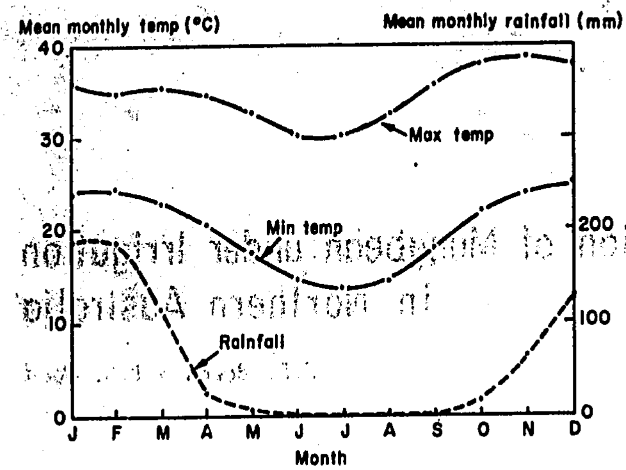

Fig. 1. Climatic data for Kimberley Research Station, Western Australia.

Table 1. Effect of date of sowing on grain yield of 10 mungbean cultivars sown at Kimberley Research Station during the 1971-72 wet season.

Cultivar	Sowing date		
	Dec 13	Feb 1	Mar 21
	kg/ha		
M86	984	1326	648
M115	952	1089	281
Berken[a]	938	1323	622
M758	794	871	605
M75	732	837	326
M15	703	660	364
L.C.C.[a]	601	468	924
M490AE	417	493	196
M49	394	316	597
M740	351	451	463
LSD (P=0.05) Sowing date x CV356			

[a]Local cultivars.

during the coldest period of the year. The cultivars, M49 and L.C.C., were exceptions and their highest yield was obtained from the March sowing.

During the 1972-73 wet and 1973 dry seasons, Berken, M75, M758, and M15, were sown in a date of sowing experiment. Plant characteristics and grain yield were recorded and the data for cultivar M15, which is typical of the results obtained, are given in Table 2.

Plant height, which is an important characteristic for mechanized harvesting, decreased with each successive sowing from the first to the last. This was largely associated with a decrease in the number of nodes on the main stem. There was a slight decrease in the inter-node length with delay in sowing range from 4.4 cm in the last sowing. The number of pods/plant was highest in the first sowing and subsequently declined rapidly. The high pod number/plant in the first sowing is not reflected in the grain yield due to heavy rain just prior to harvest which caused severe losses. Estimated potential yield in this sowing was 1700 kg/ha. The later sowings gave progressively lower yields due to fewer seeds/pod and, to some extent, smaller seed. The increase in seed size in the May 29 sowing was possibly due to the warmer temperatures experienced in August during the grain-filling stage.

EFFECT OF TIME OF SOWING ON PHENOLOGY, YIELD, AND GRAIN WEIGHT OF A WIDE RANGE OF CULTIVARS

In 1975, a collection of 183 genotypes was screened at Kimberly Research Station in a wet (Jan 31) and a dry (Apr 20) season sowing. The collection included 120 genotypes of green gram and 63 of black gram. Plots comprised 2 rows sown in 1½ m raised beds. Data on yield, grain size, plant type, phenology level of dehiscence, and susceptibility were recorded for 168 of the 183 genotypes.

A comparison of the distribution of periods from sowing to first flower is illustrated in Figure 2. Generally, the period from sowing to first flower was shorter for the wet season than for the dry probably as a result of the higher temperatures during the former. The pattern of response was generally similar in the 2 sowings but genotypes showed a differential response which suggests that photoperiod or temperature is involved. Most of the genotypes commenced to flower in less than 45 days in both sowings, and there is only a limited number which are later-flowering.

The relationship between the data for the 2 sowings are shown in Table 3. There is a significant correlation with the exception of days to maturity. When compared with the January sowing, the genotypes in the April sowing generally took more days to flower and reach maturity.

Table 2. Effect of date of sowing on plant growth and grain yield of cv. M15 during 1972-73 wet and 1973 dry seasons; Australia.

	Sowing date				
	Dec 20	Jan 27	March 22	May 5	May 29
Plant height (cm)	72.3	69.8	52.0	47.0	44.8
Number of nodes on main stem	16.4	13.8	9.8	8.9	8.0
Number of pods/plant	32.2	18.1	9.2	11.0	9.6
Yield (kg/ha)	587.0	954.0	475.0	299.0	158.0
100 seed wt (g)	-	6.27	5.98	5.36	5.82

This is possibly due to lower dry season temperatures (Fig. 1). The other plant attributes were lower in the April sowing.

The highest yielding cultivar in the January sowing was CPI 60823 (*V. radiata*/India) with a yield of 3980 kg/ha; in the April sowing CPI 30759 (*V. radiata*/Burma) gave the best yield of 3650 kg/ha. In the January sowing the 100 seed weights ranged from 2.10 g for CPI 60825 (*V. radiata*/India) to 6.45 g for CPI 40704 (*V. radiata*/U.S.A.). In the April sowing, seed size ranged from 2.01 g for CPI 29976 (*V. radiata*/Bangladesh) to 6.73 g for CPI 36088 (*V. radiata*/China). Crude protein content ranged from 24.6% for CPI 29642 (*V. radiata*/Thailand) to 32.6% for CPI 30755 (*V.*

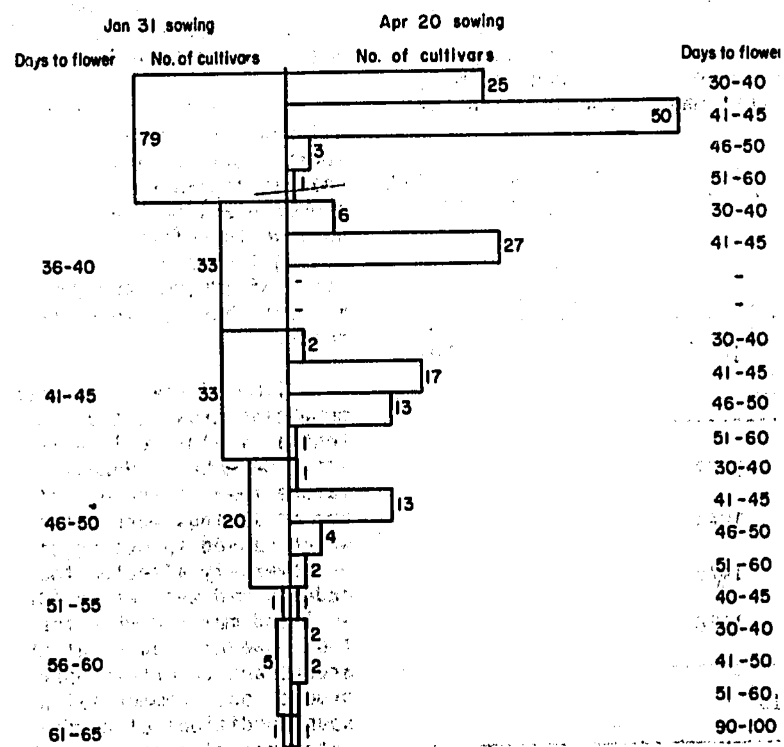

Fig. 2. The effect of Jan 31 sowing compared with an Apr 20 sowing on the distribution of periods from sowing to first flower for 172 genotypes; Australia.

Table 3. Relationships of various attributes for the wet season (S_1) and dry season (S_2) sowings of the mungbean genotype collection; Australia.

Attribution	Regression	Correlation coefficient (r =)
Days to flower	S_2=38.02+0.133S_1	0.270*
Days to maturity	S_2=94.29+0.030S_1	$0.072^{n.s.}$
Plant height (cm)	S_2=19.52+0.295S_1	0.601**
Yield (kg/ha)	S_2=540.7+0.358S_1	0.482**
100 seed wt (g)	S_2=1.145+0.735S_1	0.760**

radiata/Burma) in the January sowing, and from 26.2% for CPI 20144 (*V. mungo*/India) to 33.2% for CPI 27413 (*V. radiata*/Trinidad) in the April sowing.

EFFECT OF DEFOLIATION ON YIELD

One of the problems associated with growing mungbeans on heavy black soils under irrigation is that the crop often fails to shed its leaves at maturity. This leads to problems with mechanical harvesting giving a poorly cleaned sample with a high moisture content which tends to mold. A defoliation experiment was conducted using the dessicant paraquat at 4 rates at 3 stages of maturity (when 50, 75, and 100% of the pods were mature). The experiment was conducted on one crop sown in the wet and another sown in the dry season.

Table 4. Effects of the desiccant Paraquat on the grain yields of mungbean cv. Berken; Australia.

Treatment	Stage of pod maturity[a]			
	Feb 2 sowing		Apr 27 sowing	
	50%	100%	50%	100%
--- ℓ/ha --	-------------- kg/ha			-------------
nil	2090	2167	1652	1833
0.7	1319	1844	1591	1786
1.4	1175	1475	1092	1972
2.8	1103	1628	1355	1859
LSD P=0.05	313		441	

[a]The application of Paraquat at 75% pod maturity gave similar results to the 100% treatment.

Applications made at the 50% mature pod stage significantly reduced grain yields (Table 4). A further decrease occurred as the rates of application were increased. Application at the 75% mature pod stage gave a slight but non-significant decrease in grain yield. Germination percentages were determined on the seed harvested before and after the applications. The various treatments had no effect on the germination level which averaged 94%.

CONCLUSIONS

Under the irrigated conditions of northern Australia, the ideal genotype would be one which, in both wet and dry season sowings, gave yields above 2000 kg/ha, plants taller than 50 cm, and with a 100 seed weight greater than 5 g. Analysis of the data showed that none of the cultivars in our collection meets these criteria. Details for those genotypes which came closest are given in Table 5. Our data show that there are considerable genetic variations among those characters of importance for mechanized production in northern Australia. We propose to extend our collection and, after further testing, to assess genetic variation and heritability to provide information for a breeding program.

In our early experiments, the mungbeans were all sown in single rows on ridges 75 or 100 cm apart. Our observations on plant growth suggest that an increase in yield could be achieved with higher plant populations. In the 1973-74 wet season, we therefore changed our cultural practice, sowing 4 rows on 1½ m wide raised beds. Populations of 300,000-400,000 plants/ha were obtained and this has led to higher yields in later experiments.

Time of sowing studies show that generally mungbeans grow best during the wet season and potential yields decline as sowing date is delayed after December. However, the December sowings mature towards the end of the wet season. A number of sowings were affected by rain at maturity which caused sprouting of the seeds in the pods, or adversely affected the grain color. Sowings made in mid-wet season (Jan or early Feb) grew well and matured when the risk of rainfall was low. However, sowing at this time would be a hazardous and uncertain operation for commercial production. Commercial production under the monsoon conditions of northern Australia needs a later maturing genotype which can be sown during December, flower during early March, and mature during early April. A genotype with a short-day photoperiod response at 12 hrs would greatly assist in meeting these requirements.

Table 5. Characteristics of most promising genotypes from a genotype screening trial conducted at Kimberley Research Station during the 1975 wet season (S_1) and 1975 dry season (S_2); Australia.

Cultivar	Species[a]	Grain yield		100 seed wt		Plant ht		Origin
		S_1	S_2	S_1	S_2	S_1	S_2	
		--- kg/ha --		------ g -----		------ cm -----		
17588	M	3270	2640	4.78	4.58	50	45	Mauritius
21042	R	3480	2350	4.47	4.33	30	45	India
27073	M	2720	2010	4.64	4.00	50	55	India
29219	R	2830	1240	4.68	4.74	100	50	Philippines
29928	R	2800	2570	3.25	3.32	60	50	Pakistan
60814	R	2850	1130	5.80	5.80	40	30	India

[a]R = *V. radiata*. M = *V. mungo*.

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Short Term Storage of Different Quality Mungbean Seeds

H.F. Chin and Othman Yaacob

INTRODUCTION

The tropical environment is generally unsuitable for storing grain legume seeds because of high temperatures, high relative humidity, and excessive rainfall. Mechanization in seed production, processing, and storage facilities are normally lacking in the developing countrie where most mungbean seeds are grown. Consequently, seeds for storage are variable in quality and not properly stored.

The main objectives of seed storage are to maintain seed viability and vigor for planting, and ensure the stored products are suitable for consumption and not damaged by insects and microflora. Many methods and techniques are available for these purposes. Among these, however, the use of insecticides may have deleterious effects. Paradichlorbenzene has been found to greatly reduce germination, though with widely different effect on different genera (3). Fungicides also influence seed life by depressing germination. In seeds for human consumption, insecticides and fungicides are not applicable; natural protectants such as peanut oil have been used. AVRDC (1) reported both peanut and soybean oil suppressed weevil reproduction in stored mungbean when used at rates ranging from 1-3 mℓ/kg of seed, and these treatments do not interfere with germination rates.

In this experiment preventive measures are considered, such as proper drying and storage to maintain seed viability an vigour, at the same time ensuring that the mungbean seeds are still consumable and good for sprouts.

MATERIALS AND METHODS

This storage experiment was carried out using a local glossy variety of mungbean seed. Seeds were sun-dried immediately after harvest. Moisture content was tested according to ISTA rules (4). At intervals, samples were tested and batches of seeds were taken at 7.8, 9.7, and 11.9% moisture levels.

Four replications of .45kg seed samples at each moisture level were placed in 4 glass bottles sealed with rubber caps. A similar number of replications were kept in 0.18 mm polystyrene bags. These 2 types of containers were kept at 2 different storage temperatures; one being at ambient room temperatures (26° ± 3°C) and the other at aircondition temperature (20° ± 1°C). Prior to storage, freshly harvested seeds were tested for their germinability and subsequently seeds were sampled and taken for germination tests according to the ISTA rules at monthly intervals over a period of 3 months. This short period is chosen because it is the normal period for carry-over seeds to enable a farmer practicing crop rotation to keep and use his own seeds.

Germination Test. Four hundred seeds were sampled for each treatment and planted in boxes of sterilized sand in 8 replications at $26^o \pm 3^oC$. Germination counts were taken on the 4th and 7th day after planting. To give the percentage germination, the number of hard seeds were recorded after the final count.

Vigor Tests. The vigor of seeds was determined by 2 methods: - (a) The speed of germination method used by Baskin (2) was carried out simultaneously with the ordinary germination test. A predetermined shoot length of 4 cm was selected as a value for counting seedlings. Seedlings exceeding 4 cm were to be counted 3 days after planting. The number of seedlings counted each day (from 3rd to 7th day) was multiplied by the reciprocal of that day. The higher the value, the more vigorous are the seeds with 100 as maximum. (b) The seedling growth rate test was used to determine the seed vigor as calculated by dry weight of the seedlings after the germination test (7 days). For dry weight calculations, the shoots and roots were separated and dried apart at 150^oC for 24 hrs. The heavier the seedlings, the higher the seedling vigor.

RESULTS AND DISCUSSION

For the short term storage of mungbeans, our results indicate a simple storage method. The method involves drying seeds to moisture contents ranging from 8-12%, and storing them in either sealed glass bottles or polythene bags. At 26^oC, they can remain 3 months without deterioration. There were no significant differences in germination percentage after storage of 1-3 months. Also, the type of sealed containers did not affect germination as shown in Table 1.

The results of the germination test of freshly harvested seeds indicated the presence of a higher percentage of hard seeds, which was reflected in the lower average germination percentage of 86%. After a storage period of 1-3 months, the percentage germination increased due to a reduction in the number of hard seeds, which could be an after-ripening effect. The slight variation in the diurnal temperature of those in storage at $26^o \pm 3^oC$ may play a part in decreasing the number of hard seeds. Daily alternating temperatures cause a fracturing of the impermeable coat at the strophiole allowing moisture penetration (6). The rate at which softening takes place depends on species, stage of maturation of seeds, and the maximum temperature of the daily fluctuation to which seeds are exposed. Those seeds stored at $26^o \pm 3^oC$ generally germinated more readily than those at $20^o \pm 1^oC$; also in the third month of storage the percentage of hard seeds was reduced nearly to zero (Table 2).

The same trend was observed in vigor; there was no significant difference in vigor index between treatments as shown in the speed of germination or by the total dry matter of seedlings in Table 2 and Table 3, respectively.

At both storage temperatures, when seeds are dried to below 12% moisture content, there seems to be no deleterious effect on germination and seedling vigor. However, freshly harvested seeds

Table 1. Percentage germination of mungbean seeds at moisture content (M.C.) 7.8, 9.7, and 11.9%; stored in glass bottles and polythene bags at 20^o and 26^oC; Malaysia.

Storage period (month)	7.8% M.C.		9.7% M.C.		11.9% M.C.	
	bottle	bags	bottle	bags	bottle	bags
Storage at $20^o \pm 1^oC$						
1	96	96	94	97	93	92
2	97	93	99	95	95	94
3	98	97	99	97	96	95
Storage at $26^o \pm 3^oC$						
1	98	96	98	96	96	96
2	97	97	97	96	99	98
3	97	96	97	99	97	98

Table 2. Percentage of hard seeds found in freshly harvested mungbean seeds and those after 1,2, and 3 months storage; Malaysia.

Period after harvest	% hard seeds
0 (freshly harvested)	8-12
1 mo.	2- 8
2 mo.	1- 5
3 mo.	0- 2

did not germinate as readily as those after storage.

On examination at monthly intervals, weevils and fungus were both absent from the seeds. This could be due to proper cleaning and drying prior to storage in sealed containers. In the tropics, insect pest damage is a serious problem, as many insects breed continuously and generations overlap (5). Drying seeds to below 12% is fairly safe preventive measure to control insects.

In conclusion, results from this experiment show that it is practical to store mungbean seeds properly dried to a moisture level below 12% and in sealed polythene bags for at least 3 months 26° + 3°C. Airconditioned rooms or the addition of pesticides are not necessary. Therefore this method is suitable for storing seeds both as planting material and for consumption as sprouts.

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Table 3. The vigor index (speed of germination) of different quality mungbean seeds of 7.8, 9.7, and 11.9% moisture content stored in glass bottles and polythene bags after 1,2, and 3 months storage at 20° ± 1°C and 26° ± 3°C; Malaysia.

Storage period (months)	7.8% M.C.		9.7% M.C.		11.9% M.C.	
	bottle	bags	bottle	bags	bottle	bags
			Storage at 20°C			
1	93	88	93	87	88	86
2	90	87	92	88	91	92
3	93	96	94	90	90	91
			Storage at 26°C			
1	93	90	94	93	92	89
2	96	93	92	93	96	95
3	93	89	96	96	96	95

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The Management of Mungbean in Rice-Based Cropping Systems

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INTRODUCTION

The IRRI Cropping Systems Program works at 3 sites in the Philippines - in Pangasinan, Iloilo, and Batangas provinces - based on their soil characteristics, rainfall patterns, and present cropping intensity. In those sites mungbean is important in the existing cropping systems (Table 1).

Mungbean in the Philippines is either row-planted or broadcast in the non-irrigated areas after rice, and uses residual soil moisture. Yields during the last 10 years averaged about 0.5 t/ha, or 50% of the yields realized in farmer-managed fields at 15 sites in Batangas during a 2-year period where farmers used the best available technology (7). The differences in yield may be due to management, variability of rainfall, pests, or varietal responses to environmental changes. They illustrate the crop's potential, and the need to study crop-environment interactions and crop management methods.

MUNGBEANS IN THE LOWLAND RICE-BASED CROPPING SYSTEMS

The mungbean is an ideal crop to follow rice in the lowland rice-based cropping systems (2). It is relatively drought tolerant, and performs fairly well in soils with poor structure. It requires a low nitrogen input because of its nitrogen-fixing ability. Fertilizer response trials in 12 sites in Batangas showed a lack of mungbean response to applied nitrogen even at the high rate of 100 kg/ha (1,3).

Rice is normally grown during the periods of heavy rain, followed by upland crops to extend the growing period into the dry season. Rice and mungbean have converse environmental requirements and do not compete for the same environmental niche. Figure 1 illustrates a rice-mungbean cropping pattern. The rice is without critical stress from June-November during the monsoon season, and the potential time for mungbean production is from late October to January under conditions of low rainfall but high light intensities.

The period for sowing mungbeans after rice depends on the timing of the rains and the rice harvest. Most plantings are usually from November through January, after an average 40-days turnaround period between rice and mungbean. Minimum tillage can reduce turnaround time by half (4).

Early rice varieties and early rice establishment techniques allow earlier harvest of the rice, hence providing better planting options for the mungbean. Mungbean production thus moves

Table 1. Traditional cropping patterns involving mungbeans (mb) in 3 rice-based provinces of the Philippines, 1976.

Upland rainfed	Lowland rainfed	
Batangas	Pangasinan	Iloilo
Rice-mb	Rice-mb	Rice-mb
Corn-mb	Corn-rice-mb	Rice-mb+cowpea
Rice+corn-mb		Corn-mb
Cowpea-mb		
Eggplant-mb		
Bitter gourd-mb		

into a better soil moisture regime. Improved moisture allows more complete tillage and better crop establishment methods (e.g., seeding in rows rather than broadcasting), and also allows the mungbean to escape insect and powdery mildew build-up, which normally is more serious at the beginning of the dry season.

The shift to earlier mungbean planting, however, adds the risk of high soil moisture injury. Lower light intensities and higher rainfall may depress yields and impair the harvest quality. The attempt to escape powdery mildew exposes the crop to *Cercospora* leaf spot and damping-off.

MUNGBEAN RESPONSES

Response to environment

Mungbean yields vary considerably for different planting dates at the same site (1,7). These effects were considered mainly the result of rainfall during the crop's growth (Fig. 2). However, data indicated that the reducing effect of rainfall becomes a major determinant only when it causes waterlogging. A 60-cm deep soil profile, for instance, would need about 300 mm of rain to become saturated. With evaporation losses of 260 mm for a 65-day mungbean variety, waterlogging may not seriously occur in fields that receive less than 700 mm of rain during the 65 days. Since the results in Figure 3 were from a site in Batangas with well-drained soil, we sought an alternative explanation.

An analysis of monthly planting of rainfed CES 55 mungbean at IRRI showed that yields decreased from July, reached a minimum in October, and slowly increased in November and December. The low yields toward the month of October do not appear due to rainfall (Fig. 3). Rather, solar radiation seems to be the stronger yield determinant (Fig. 4).

Changes in the crop phenology were recorded during monthly plantings of CES 55. Because the plantings were not irrigated, the dates of flower initiation, 100% flowering, and first priming [a]

[a]Data of flower initiation - determined upon dissection by the appearance of a raceme enclosed in a bract-like structure on the youngest leaf.

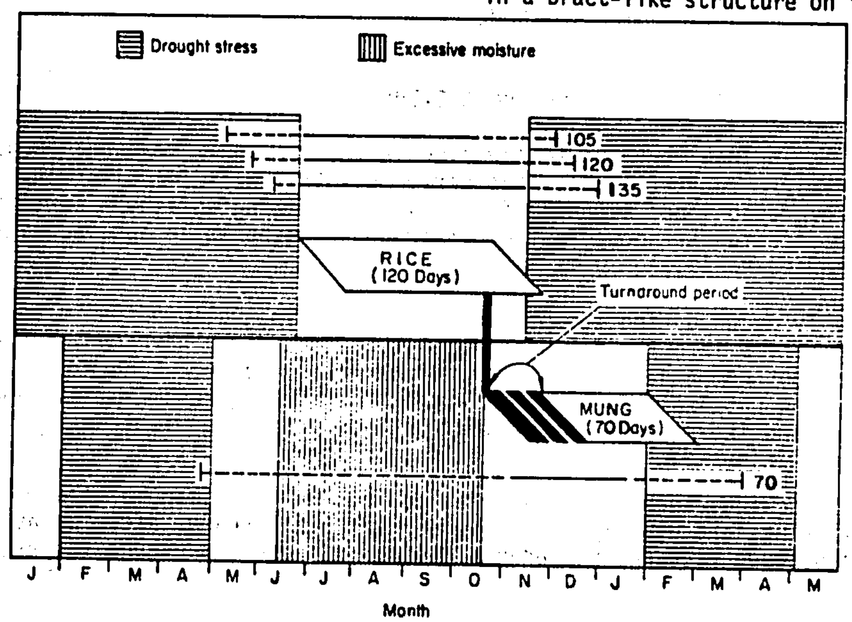
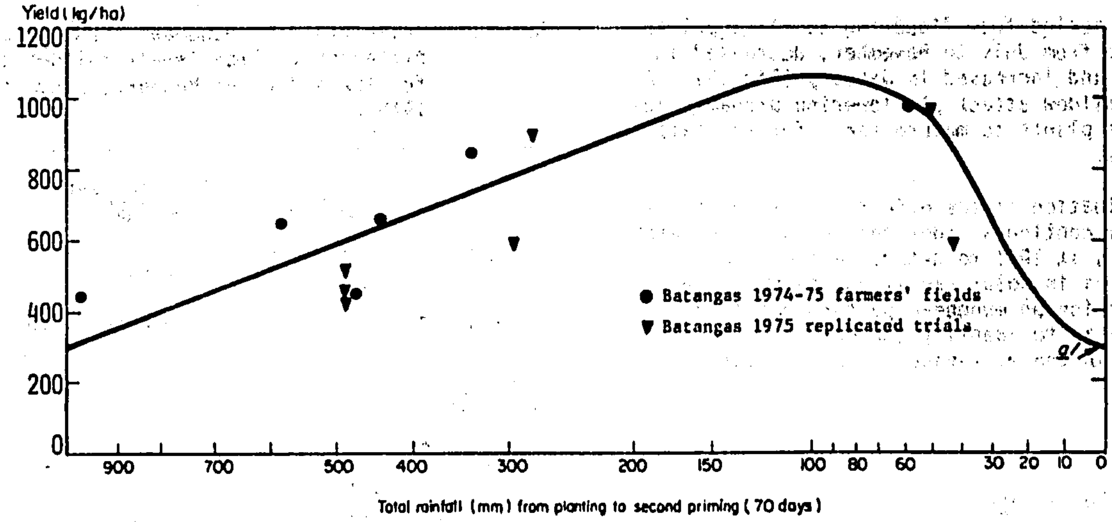


FIG 1. THE PLANTING SCHEDULE AND EVNRIONMENTAL CONDITIONS FOR RICE-MUNGBEAN CROPPING PATTERN IN RAINFED AREAS IN THE PHILIPPINES.



a/ If the soil is saturated at planting

Fig. 2 Approximation of mungbean yield potential for Batangas, Philippines as related to the rainfall between planting and the second priming.

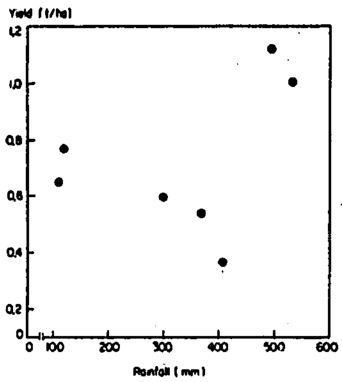


Fig. 3 Relationship of mungbean (CES 55) grain yield to total rainfall received from planting to first priming. IRRI. 1976-77.

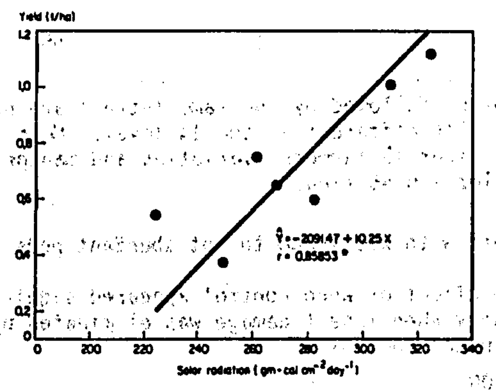


Fig. 4 Relationship of mungbean grain yields (CES 55) to average daily solar radiation from planting to first priming (64 days from seeding). IRRI.

were a result of solar radiation, temperature, and rainfall.

Dates of flower initiation were constant (Fig. 5). The time from flower initiation to 100% flowering decreased from 24 days in July to 18 days in September, then increased again. This 20-day period in January was probably the result of too little rain from the flowering stage onward.

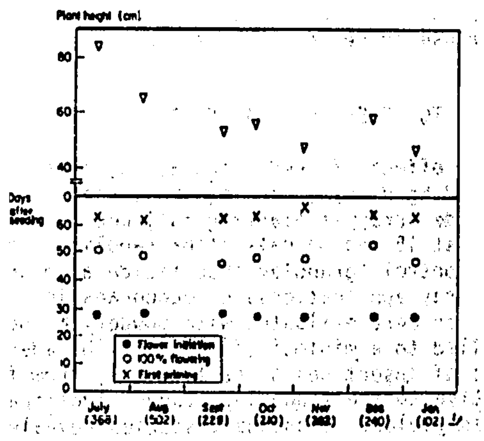


Fig. 5 The effect of planting date on the phenology and plant height at maturity of mungbean (CES 55). IRRI. 1976-77.

1/ Rainfall from seeding to 100% flowering (mm).

The period from flowering to first priming increased from July to November, decreased in December and increased in January (Fig. 5). A powdery mildew attack at flowering probably induced the plants to mature early for the late plantings.

Evaluation of the effect of changes in crop phenology continues under rainfed and irrigated conditions at IRRI to determine the effect of differences in solar radiation, temperature, and precipitation on mungbean performance. The objective is to identify the best time to plant mungbean in the rice-based cropping systems.

Response to tillage

Topographic position, soil type and texture, type of rice culture (puddled or unpuddled), and rainfall all affect the tillage potential of paddy fields. These factors affect turnaround time between crops and, hence, the intensity of cropping, especially when converting puddled fields to unpuddled. The resulting pattern is usually a minimum tillage operation for mungbean.

Tillage studies at Pangasiann demonstrated good potential for zero or minimum tillage for mungbean after puddled rice (Table 2). Complete tillage resulted in excessive soil drying and lower yields. Turnaround period was also a month longer. In Iloilo, where there was more rain after planting, higher yields were obtained with high tillage (6). The implication is that if there is sufficient rain to maintain plant growth toward the dry season, high tillage levels may be desirable. Otherwise, the recourse is minimum tillage for early crop establishment and for maximum use of residual moisture.

Table 2. Grain yield of mungbean (CES 14) at different tillage levels following rain fed lowland rice; Manaoag, Pangasinan. 1975-76.

	Tillage level[a]		
	minimum	medium	high
	t/ha		
Mungbean alone	(6)0.66	(9)0.56	(9)0.49
With corn intercrop	(3)0.73	(1)0.40	(1)0.10

[a]Minimum - no primary tillage; seeds drilled on shallow furrows.
Medium - farmer's method (1 plowing and 1 harrowing).
High - complete land preparation with handtractor.
Figures in parenthesis are number of observations

Table 3. Grain yield of mungbean (CES 55) under various levels of agronomic inputs; Manaoag, Pangasinan, Dec 1975- Apr 1976.

Inputs	Yield[a]	% of best yield
	-- t/ha --	
Control	0.69 c	40
+ inoculation	0.65 c	38
+ weed control (WC)	0.72 c	42
+ nitrogen (N)	0.62 c	36
+ insect control (IC)	1.45 ab	84
+ WC + N	0.64 c	37
+ IC + WC	1.69 a	98
+ IC + N	1.42 b	82
+ IC + N + WC	1.68 ab	97
+ IC + WC + NPK	1.73 a	100
Mean	1.13	65

[a]Any 2 means followed by the same letters are not statistically different at the 1% level. Mean of crop cuts from 15 farmers' varieties and management fields = 0.46 t/ha.

RESPONSE TO OTHER CULTURAL FACTORS

The effect of seed inoculation, fertilizer (30-30-30 kg N, P_2O_5, and K_2O/ha), weed control (herbicide spray at planting followed by hand weeding at 15 and 30 days after seedling), and insect control (granular insecticide at planting and 4 spray applications) on mungbeans in Pangasinan were evaluated with powdery mildew controlled to a minimum (Table 3). The adequate control of insect pests, particularly from the vegetative to the flowering stages significantly improved yields. Subsequent studies revealed the leafhopper *Empoasca bigutula* (Ishida), the flea beetle, *Longitarsus manilensis* (Weise), and the beanfly, *Ophiomyia phaseoli* (Tyron) as the major insect pests responsible for the low yields (5). These pests caused stunting and leaf damage at the early growth stages, thus limiting the ability to compete with weeds and to set abundant pods.

The effect of weed control appeared significant only when insect damage was eliminated by proper insect control.

CONCLUSION

The mungbean plays an important role in the diet of many people and deserves attention as an important component in lowland rice-based cropping systems. Its short maturity period and drought resistance make it a natural fit as a post-monsoon - or pre-monsoon - crop in rice-based cropping systems. Its labor requirement at harvest is high but that falls during slack activity periods after rice. Mungbean can be stored, commands a high market price, and is a versatile food.

A better understanding of the crop's behavior, and its interaction and response to management levels and changes in environment, is a key to the development of technology to bring yields closer to the potential in farmers' fields.

Selection and breeding work on mungbean should further seek to incorporate high and stable yields, good seedling vigor, resistance to insect pests and diseases, determinate growth, uniform maturity, tolerance to early wet conditions and late drought stresses, and better quality protein into elite cultivars.

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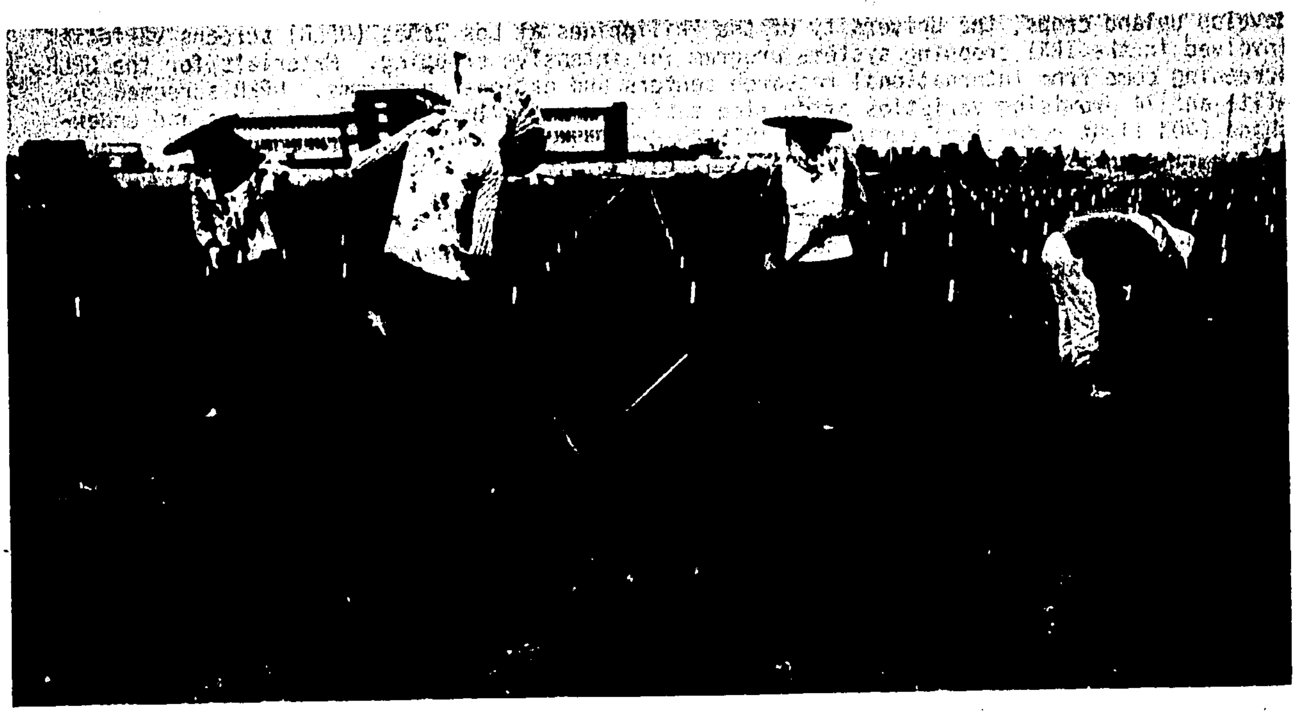

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Performance of Promising Mungbean Varieties Planted After Rice under Different Environments

V.R. Carañgal, A.M. Nadal, and E.C. Godilano

INTRODUCTION

Mungbean is an important pulse crop in Southeast Asia and the Indian sub-continent. It has high protein content, shorter maturity than other upland crops, and fits very well before and after lowland rice in areas where moisture is limiting towards the dry season and cropping intensity is low. Mungbean is generally grown after the main rice crop in the Philippines, Indonesia, Burma, Sri Lanka, and Taiwan. In Thailand, it is grown after the wet season corn crop and, to a limited extent, before the main rice crop.

Besides mungbean, the major food crops used in the IRRI cropping systems research program are: rice, soybeans, corn, sorghum, cowpea, peanut, and cassava. Since IRRI has no mandate to develop upland crops, the University of the Philippines at Los Baños (UPLB) screens varieties involved in the IRRI cropping systems program for intensive cropping. Materials for the UPLB screening come from international research centers and national programs. UPLB screened 20 elite and 74 promising varieties after rice taking advantage of residual moisture and undershade (40% light reduction) during the 1975-76 dry season. They also screened 2,057 accessions before rice in 1976.

The network's variety trials are not uniform as recommended by the Cropping Systems Working Group (leaders from different country programs and 2 IRRI representatives). The UPLB elite materials are evaluated together with varieties from national breeding programs. The only common entries come from IRRI. Trials are conducted after rice towards the dry season and, in some countries, before rice. Cultural management varies from country to country depending on recommeded practices. Data collection and ratings are uniform.

MATERIALS AND METHODS

Mungbean entries

The promising varieties used in the 1975-76 trials were: CES 55, EG Glabrous #3, MG 50-10A (green), CES 87, MG 50-10A (yellow), and CES 14 from the Philippines; Bhacti from Indonesia; Dau Mo from Vietnam; M350 from South Korea; and M101 from India. These varieties did not come from the UPLB screening but were among the most promising collected by UPLB. Two new entries, CES 1D-21 and BPI Glabrous #3 from the Philippines, were evaluated in 1976-77.

Test sites and cooperators

Trails were conducted at the following sites in cooperation with scientists collaborating with IRRI. The same trials were conducted on the IRRI farm.

	Outreach site and station	Cooperator
1.	Oton, Iloilo, Philippines	Rogelio Magbanua and Virgilio Cuaresma
2.	Manaoag, Pangasinan, Philippines	Hermenegildo Gines and Jose Manzano
3.	Tanauan, Batangas, Philippines	Benigno Samson, Armando Barachina and Romeo Villanueva
4.	Bangladesh Rice Research Institute, Bangladesh, Joydebpur, Bangladesh	Zahidul Hoque and Peter Hobbs
5.	Agricultural Research Institute, Yezin, Burma	S.S. Rajan and U Pe Maung Thein
6.	Khon Kaen University, Khon Kaen, Thailand	Terd Charoenwatana and Aron Patanothai
7.	Ubon PiMai and Chainat Rice Experiment Stations, Thailand	Damkheong Chandrapanya, Cherm Sangtian and Chanchai Ongsard
8.	Maros Experiment Station, South Sulawesi, Indonesia	Farid Bahar and Cesar Mamaril
9.	Research Station, Maha Illuppallama, Sri Lanka	N. Vignarajah, Walter Fernando and Mervyn Sikurajapathy

Management

A randomized complete block design with 3-4 replications was used. The spacing between hills was 50 cm with about 23 living plants/m. Plot size for yield determination was 5 m^2. Fertilizer rates were 20-45-45 or 30-60-60 at different sites. In the Philippines, Butachlor was used after planting for pre-emergence weed control at 1.2 kg ai/ha, plus handweeding; Furadan, Malathion, Thiodan, and Azodrin provided insect control; and Benlate was used for *Cercospora* leaf spot and powdery mildew. Other countries used locally recommended insecticides. Some did not use herbicides but weeded the plots.

In Oton and IRRI, the trials were conducted under zero tillage without land preparation. Mungbean seeds were dibbled at the base of rice stalks and rice straw was used as mulch. In the same locations, additional trials were conducted with good land preparation or high tillage. In Oton, the trial under high tillage was conducted in a lowland rice field after the main rice crop, and that at IRRI was under upland conditions. Trials in Tanauan were conducted under upland conditions with good land preparation. At all the other test sites, evaluations were done in lowland rice fields with good land preparation.

RESULTS AND DISCUSSION

Mungbean peformance data from 12 locations were reported and the 2 promising entries in each trial are shown in Tables 1 and 2. The trials in Ubon and PiMai Rice Experiment Stations had very poor growth due to drought and cold weather, and were discarded. The trials in Bangladesh were affected by mosaic, and all the entries were susceptible.

Yield

Tables 3 and 4 summarize mungbean yields from 12 trials conducted at 10 locations in the 1975-76 dry season, and 7 trials in the Philippines during 1976-77. There were only 5 locations that yielded more than 1 t/ha in 1975-76, and 4 locations in 1976-77. The lowest average yield was 0.15 t/ha at Khon Kaen University and the highest was 1.63 t/ha at Maros. Bhacti, a variety from Indonesia, gave the highest overall average yield.

The average yield levels were very low in Oton when evaluated under lowland conditions at zero tillage; in IRRI when evaluated under upland conditions at high tillage; in Khon Kaen University when evaluated under upland conditions at high tillage; and, in Manacag at high water table. The other tests gave reasonable yield levels in spite of problems, particularly water stress. The average yield levels were low at Manaoag because of drought, at Khon Kaen University because of drought and soil problems, and at IRRI because of continuous rainfall at the flowering stage.

At Oton, the trial conducted in lowland rice fields with zero tillage showed lower yields compared to the same entries tested in lowland conditions with high tillage. However, at IRRI zero tillage yielded as good as the high tillage. It seems that traditional lowland rice areas where rice is planted using zero tillage is not advisable for mungbean cropping, especially if moisture is limited.

At the Philippines outreach sites, the outstanding varieties were CES 55, Dau Mo, CES 87, M350, Bhacti, and CES 1D-21 (a new variety included in the 1976-77 dry season trials) (Table 1). These varieties were better than the local checks. We are now using CES 55 and CES 87 in the cropping pattern trials. CES 1D-21 was the highest yielder. It will be used in the cropping pattern trials in the Philippine cropping systems outreach sites as well as on the IRRI farm starting October, 1977.

There were several varieties identified as promising in other countries (Table 2). In Sri Lanka, 7 entries were better than the recommended variety (M1.1) under rainfed and irrigated conditions. The best were CES 87 and MG 50-10A (G) under rainfed conditions, and CES 14 and CES 55 under irrigated conditions. In Indramayu, EG Glabrous and Bhacti gave significantly higher yields. Bhacti was also the highest yielder in Chainat, Maros, and Yezin.

Harvesting for yield determination is usually done 2-3 times. The yield data in all the trials are the total harvest. The data in Yezin had separate yields for the first and second harvest. More than 90% of the seed yield for CES 87, M350, and MG 50-10A was harvested during the first harvest but only 52, 62, and 65%, respectively, for Bhacti, CES 14, and EG Glabrous #3. In other entries, higher percentages were achieved during the second harvest. In rice-based cropping systems, varieties that mature earlier and those providing more than 90% of the yield during the first harvest are desirable.

Days to flower

Days to flower varied from 28-43 days at different locations. Flowering occurred in 29.1 days under zero tillage at Oton, and in 39.9 days at Khon Kaen University. Days to flower was 29.1 days when evaluated under zero tillage at Oton and 30 days at IRRI, compared to 32.8 days at Oton and 34.1 days at IRRI under high tillage.

Days to mature

The test at Indramayu matured in 54.2 days, and at IRRI under zero tillage, 72 days. The zero tillage trials at Oton matured later than those under high tillage. Likewise, zero tillage

Table 1. Yield and agronomic characters of the 2-3 most promising mungbean varieties evaluated at the IRRI and Philippine cropping systems outreach sites; 1975-76 dry season.

Entry	Yield 1975	Yield 1976	Yield Mean	Days to Flower	Days to Maturity	Plant height	Seedling vigor	*Cercospora* leaf spot	Powdery mildew	No. of pods/ plant	No. of seeds/ pod	Wt. of 1000 seeds
	--------t/ha-------					--cm--						-g-
IRRI high tillage upland conditions												
CES 1D-21	-	1.66	1.66	33	77	60	3.7	2.7	-	19	13	47
BPI Glabrous #3	-	1.02	1.02	32	70	56	3.0	5.0	-	9	14	53
Bhacti	0.59	1.33	0.95	35	68	62	2.0	3.0	-	10	12	60
Tanauan, Batangas high tillage upland conditions												
CES 55	1.83	1.04	1.44	39	67	64	3.2	2.8	3.2	16	12	69
M350	1.75	0.99	1.37	38	68	62	3.3	3.4	2.3	17	12	45
IRRI zero tillage with mulch after lowland rice												
CES 1D-21	-	1.43	1.43	30	78	61	2.0	1.5	-	18	12	53
EG Glabrous #3	-	1.35	1.35	30	73	69	1.5	3.0	-	11	13	71
Oton, Iloilo zero tillage after lowland rice												
EG Glabrous #3	0.76	0.20	0.48	29	20	32	2.0	3.0	2.6	5	10	77
CES 87	0.38	0.27	0.33	28	69	32	1.5	3.0	3.1	4	9	73
Oton, Iloilo high tillage after lowland rice												
M350	1.85	1.31	1.58	32	59	61	3.0	3.0	2.5	11	11	48
CES 55	1.63	1.28	1.46	32	62	58	1.5	2.3	3.1	12	10	80
Manaoag, Pangasinan zero tillage low water table												
CES 1D-21	-	1.11	1.11	35	66	54	1.0	1.5	1.5	12	10	54
Local Check	-	0.96	0.96	39	68	62	1.3	2.8	3.3	23	11	44
Manaoag, Pangasinan high water table zero tillage												
CES 87	-	0.31	0.31	49	81	40	3.0	-	2.0	7	10	73
Local Check	-	0.27	0.27	50	81	47	3.0	-	2.0	7	11	36

Table 2. Yield and agronomic characters of the 2 most promising mungbean varieties evaluated in different countries; 1976 wet season.

Entry	Yield	Days to Flower	Days to Maturity	Seedling vigor	*Cercospora* leaf spot	Plant height	Pod length	No. of pods/ plant	No. of seeds/ pod	Wt. of 1000 seeds
	-t/ha-					------cm-------				---g---
Agricultural Research Station, Sri Lanka under rainfed condition										
CES 87	0.92	37	68	2	-	53	-	12	11	68
MG 50-10A (G)	0.88	37	67	3	-	49	-	11	11	77
Agricultural Research Station, Sri Lanka under irrigated condition										
CES 14	1.17	29	64	3	-	46	10	21	11	69
CES 55	1.17	29	64	3	-	44	10	16	12	69
Maros Research Institute for Agriculture, Indonesia										
Bhacti	2.04	32	59	1	2	69	-	18	10	71
MG 50-10A (G)	1.94	32	59	1	4	69	-	18	11	70
Chainat Rice Experiment Station, Thailand										
Bhacti	1.35	40	67	3	1	35	-	13	9	67
Dau Mo	1.22	43	68	3	3	33	-	13	10	62
Agricultural Research Institute, Burma										
Bhacti	2.21	-	-	-	-	-	19.7	19	11	6
CES 14	2.00	-	-	-	-	-	10.7	15	13	6
Indramayu, Indonesia										
EG Glabrous	0.75	-	53	-	-	-	-	-	-	-
Bhacti (IRRI)	0.74	-	56	-	-	-	-	-	-	-
Khon Kaen University, Thailand										
Dau Mo	0.27	43	69	-	-	38	-	-	-	-
CES 87	0.23	39	69	-	-	30	-	-	-	-

Table 3. Summary of yield and other agronomic characters of promising mungbean varieties grown after rice in the Philippines and other countries; 1975-76 dry season.

Entry	Yield	Days to Flower	Days to Maturity	Plant height	Pods/ plant	Seeds/ pod	Weight of 1000 seeds
	-t/ha-			--cm--			-g-
Bhacti	1.03	35	63	48	14	10	67
CES 55	0.87	34	64	48	12	11	70
Dau Mo	0.87	36	65	56	12	11	65
EG Glabrous #3	0.87	35	65	47	12	11	74
MG 50-10A (G)	0.85	34	63	43	12	11	66
M350	0.84	33	63	48	12	11	52
CES 87	0.86	34	64	48	12	11	67
MG 50-10A (Y)	0.82	34	63	42	13	10	72
CES 14	0.90	35	65	53	13	11	68
M 101	0.74	33	63	36	12	10	61
Mean	0.87	34	64	47	12	11	66
Trials	12	9	10	9	10	10	10

Table 4. Summary of yield and other agronomic characters and disease rating of promising mungbean varieties grown after rice in IRRI and the Philippine outreach sites; 1976-77 dry season.

Entry	Yield	Days to Flower	Days to Maturity	Plant height	Pods/ plant	Seeds/ pod	Weight of 1000 seeds	*Cercospora* disease rating
	-t/ha-			--cm--			-g-	
CES 1D-21	1.04	34	69	51	15	12	52	2.0
CES 55	0.89	34	67	58	12	12	71	2.9
Dau Mo	0.88	36	67	62	12	12	65	3.0
CES 87	0.87	35	67	60	11	12	69	3.3
M 350	0.86	34	66	54	10	12	46	3.5
Bhacti	0.85	35	67	56	11	10	70	3.8
CES 14	0.82	36	67	63	11	12	69	3.5
EG Glabrous #3	0.82	37	68	56	11	12	74	3.1
MG 50-10A (Y)	0.77	33	64	51	10	11	73	4.0
MG 50-10A (G)	0.76	34	64	53	11	11	65	4.0
BPI Glabrous #3	0.76	36	67	60	11	12	60	3.3
Mean	0.85	35	67	57	11	12	65	3.3
Trials	7	7	7	7	7	7	7	5

at IRRI matured later than high tillage.

Number of pods/plant and seeds/pod

There were very few pods/plant in trials with very low yields indicating a high correlation between number of pods and yield. The number of pods/plant was highest in Yezin, with an average of 19.1. The zero tillage trial at Oton gave the lowest with only 4.2.

Unlike the number of pods/plant, there were few variations between locations and entries. The number of seeds/pod varied from 9.8 to 12.0.

Seed weight

The seed weight which is an indication of size can be divided into small, medium, and large. M350, CES 1D-21, and M101 were small seeded; MG 50-10A (Y), BPI Glabrous #3, and Dau Mo were medium; and CES 55, CES 87, Bhacti, CES 14, EG Glabrous #3, and MG 50-10A (Y) were large.

Disease rating

The trials were protected by spraying insecticides as often as necessary. Powdery mildew and *Cercospora* leaf spot were the most common diseases recorded in the Philippines. CES 1D-21 was the most tolerant to *Cercospora* leaf spot and powdery mildew with an overall average disease rating of 2.0 and 1.6, respectively.

SUMMARY

Several varieties were identified as promising at the Philippine cropping systems outreach sites. CES 1D-21 was the most outstanding not only because of high yield but also because of its tolerance to powdery mildew and *Cercospora* leaf spot. In Maha Illuppallama, CES 87 and MG 50-10A (G) were promising under rainfed conditions, and CES 14 and CES 55 under irrigated conditions. Bhacti was high yielder in Chainat, Thailand, Maros and Indramayu, Indonesia, and Yezin, Burma. Bhacti also gave the highest overall average yield.

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Multiple Cropping with Mungbean in Chiang Mai, Thailand

Phrek Gympmantasiri, Methi Ekasing, and Suthat Julsrigival

Mungbean is an ideal plant to include in multiple cropping systems in northern Thailand. By virtue of its short growing season, it may preceed the monsoon paddy rice or be planted with equal success in the immediate post-monsoon month of September. Mungbean cultivation has expanded throughout the north and central plains of Thailand due to its steady demand and favorable prices. The Department of Agricultural Technology recently released a new improved variety M-7A (U thong 1), from introduced materials that promises to increase the importance of mungbean in Thailand. The fourth National Economic and Social Development Plan includes mungbean as one of Thailand's main crops, and has set a yield target of 390,000 mt by the end of 1981.

MUNGBEAN CULTIVATION IN THE CHIANG MAI - LAMPOON VALLEY

In the irrigated area of northern Thailand, mungbean is usually grown during summer. Figure 1 shows the common cropping pattern of mungbean with rice and garlic.

Mungbean is planted in hills on seed beds (1.5-2.0 m wide) used during the previous garlic crop. Plant spacings are not always consistent, but 50 x 50 cm is common. Farmers usually place 6-7 seeds/hill. No thinning is practised during seedling establishment. "Golden Pod," a local variety which requires 5 pickings, and the improved M-7 A variety are the most common in the region.

Mungbean, as grown in Thailand's northern provinces, is seldom fertilized or inoculated with *Rhizobium*. Active *Rhizobium* reside in the soil and plants are usually nodulated. Residual fertility from the previously well-fertilized garlic crop is doubtlessly captured by the subsequent mungbean crop.

Weed control consists of 2 hand hoeings for the entire crop season. Insect pests appear to influence yields. However, insecticide applications are not common for the crop. In some areas, pod damage caused by the green stink bug (*Nezara viridula* L.) is very severe. An average mungbean yield is about 1000 kg/ha (Table 1), though ranges between 881-1218 kg/ha have been recorded in recent years, which probably reflect varying climatic conditions.

The Multiple Cropping Project at Chiang Mai University has for 5 years conducted research in intensive cropping systems adapted to the irrigated area of the Chiang Mai - Lampoon valley. The Project is principally concerned with small farmers whose average farm size is 1.5 ha. A major aim is to develop cropping systems that maximize net farm incomes and yet conserve natural resources.

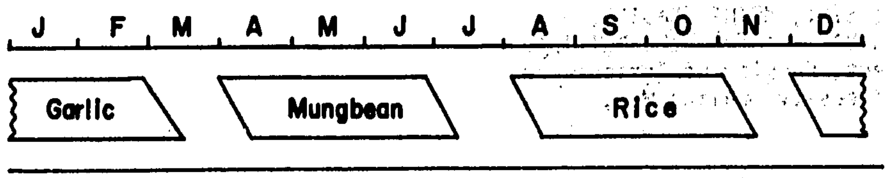

Fig. 1. Common mungbean-rice-garlic cropping system in Thailand.

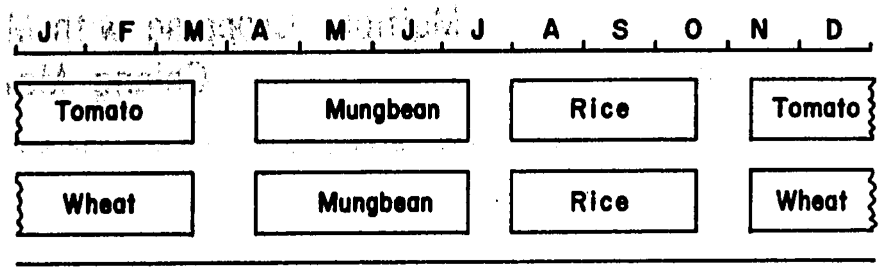

Fig. 2. Two rice-based cropping patterns with mungbeans in Thailand.

Table 1. Average seed yield of mungbean in Chiang Mai, Thailand.

Year	Yield	Total production
	- kg/ha -	--- mt ---
1969	881	239
1970	1032	313
1971	943	356
1972	1000	813
1973	1218	801
1974	1131	234
1975	1100	317

The purpose of this paper is to examine the role and performance of mungbeans in multiple cropping patterns grown between 1974 and 1976.

Figure 2 shows the rice-based cropping patterns, including mungbean that are under study.

Where possible, the rice-based multiple cropping systems include one leguminous crop. The Rice-Tomato-Mungbean system is characterized by transplanting rice early in July, with harvest scheduled during late October or early November. This is possible when non-photosensitive, early maturing R.D. 7 is used. Tomatoes can be planted as early as November so that the crop can utilize the Nov-Dec cool season. This results in good establishment, higher fruit yield, and high prices in the early market. One month lapses during the tomato harvest leaving the field free for summer mungbean, a most desirable legume for the hot season. Mungbean variety CES 55 has been used in the Multiple Cropping Project testing program.

EXPERIMENTS

Individual crops within the sequential cropping system were planted in an 800 m^2 area consisting of completely randomized plots with 3 replications. When one cropping cycle was completed, the second year rice crop was planted to determine the apparent effect of each cropping system on rice yield. Average crop yields are presented in Table 2.

The rice crop during 1974-75 and 1975-76 was fertilized with 80 and 60 kg N/ha, respectively. During 1974-75, mungbeans received 50 kg N/ha but during the second year no nitrogen was added. The average rice yield (6.2 t/ha) obtained in the Tomato-Mungbean system exceeded by 1.2 t/ha the rice harvested from plots similarly managed but containing no legume. For instance, the Rice-Wheat-Field Corn system, and the Rice-Garlic-Sunflower system produced an average rice yield of 5.0 t/ha. The 1975-76 rice yield indicated a similar trend, but the yield difference was not as marked.

Mungbeans were harvested only on June 5, 1975. An unexpected rainstorm in June made the

Table 2. Average crop yields obtained in the Rice-Tomato-Mungbean cropping system; Thailand, 1974-76.

Year	Month	Crop	Avg. yield (t/ha)
1974	July	Rice	5.6
	Nov.	Tomato[a]	-
1975	Apr.	Mungbean	1.9
	July	Rice	6.2
1974-75		Rice	5.0
1975	July	Rice	5.1
	Nov.	Tomato	23.5
1976	Apr.	Mungbean	1.2
	Nov.	Rice	5.1
1975-76		Rice	4.6

[a]The tomato crop was severely damaged by early blight, bacterial wilt, and root rot diseases. Yield could not be assessed.

second harvest impossible due to lodging. Mungbean yield for the first year averaged 1.9 t/ha. which is above average. Beanfly (*Melanagromyza* sp.) was effectively controlled by Furadan. At the pod-setting stage, Lannate was sprayed at 3-week intervals. The green stink bug population was relatively low.

The average yield of 1.2 t/ha for the non-nitrogen fertilized mungbean crop of 1975-76 was about 40% less than the first year crop which received 50 kg N/ha. These results suggest that either the mungbean was not nodulated with an effective *Rhizobium* strain (no inoculant was applied) or accrued residual fertility was minimal.

Mungbean has been reported to have an allelopathic effect on certain subsequent crops. Rice yields obtained in this study do not support this hypothesis. A simple experiment was conducted to test the allelopathic effect of mungbean on a subsequent rice crop. The treatments consisted of:

a. whole mungbean plants removed after harvest;

b. only roots left after harvest

c. whole mungbean plants incorporated during paddy prepration; and,

d. no mungbean as a control.

Rice was transplanted into the various treated plots. Subsequent rice yields, as presented in Table 3, were used as indicators of allelopathy.

Table 3. Rice yields following mungbeans compared with a control; Thailand, 1974-75.

Treatment	Avg. yield (t/ha)
Whole plants removed	5.8
Only roots left	6.2
Whole plants incorporated	8.1
No mungbean: Control	6.1
LSD 5%	2.2

Results confirmed the observations made during the 1974-75 cropping system seasons: mungbeans had a beneficial effect on subsequent rice yields. Indeed, rice grown in plots where whole mungbean plants were incorporated into the soil yielded significantly more grain (8.1 t/ha) than where the mungbean plants had been removed (5.8 t/ha).

MUNGBEAN AS AN INTERCROP

The sequential cropping of Rice-Garlic-Sweet Corn provides an opportunity to intercrop the sweet corn with mungbeans. To maintain even modest yields the Rice-Garlic-Sweet Corn system requires considerable nitrogen fertilizer in most tropical soils. Garlic is fertilized, and possesses a shallow root system. Sweet corn, with a deeper root system, provides a means of capturing residual nutrients when it follows garlic. Nevertheless, additional nitrogen fertilizer is often required for a good sweet corn crop, which makes this a high cost cropping system. An alternative is available to the farmer either by substituting mungbeans for sweet corn or by using it as an intercrop with sweet corn.

An experiment was initiated in summer, 1977, to study the effect of intercropped mungbean in sweet corn with a constant plant population but different row spacings. Yields of both crops were

Table 4. Yields of mungbean and sweet corn under intercropping compared with sole crop yields; Thailand, 1977.

Treatment	Mungbean	Sweet corn
	----------- kg/ha	----------
1. Sole sweet corn		12,250
2. Sole mungbean	1,632	-
3. Intercrop sweet corn (75 x 25) + mungbean (150 x 5)	564	8,958
4. Intercrop sweet corn (100 x 18.75) + mungbean (2 rows 50 x 5)	668	10,416
5. Intercrop sweet corn (120 x 15) + mungbean (2 rows 60 x 5)	805	10,083
LSD 5%	223	1,883
1%	320	2,716

compared with sole crop yields when planted at optimum sole crop plant populations.

The crops were all furrow-irrigated on prepared seedbeds and fertilized with 100 kg N/ha, banded and split-applied where sweet corn was grown. The sole mungbean crop received nitrogen fertilizer at 25 kg/ha. Phosphate and potash were banded in all plots at rates suggested by soil tests. Mungbean and sweet corn yields obtained when grown either under intercropping or as sole crops are presented in Table 4.

A yield loss of 65% could be sustained in mungbean compared with the sole crop when intercropped with sweet corn (Treatment 3). However, when sweet corn (120 x 15) was planted between 2 rows of mungbean (Treatment 5), the total yield per unit area appears quite attractive. Considerable analysis remains to determine the implications of this data including relative Land Equivalent Area values, economic feasibility, and the possible residual effects various treatments may have on subsequent crops. Meanwhile, the technique for such an intercropping system is relatively simple and might be readily adopted by farmers.

These results, though preliminary, suggest the practicality of intercropping mungbeans with sweet corn and thus provide a means to include legumes in a "high cost input" Rice-Garlic-Sweet Corn system.

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Mungbean Varietal Requirements in Relation to Cropping Seasons in India

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Mungbean is grown mainly as a *kharif* or season (July-Nov) crop in almost all the states of India. Its cultivation in *rabi* or winter season (Sept-Jan), however, is restricted to the eastern and southern parts of the country, or 30-35% of its total area (1). It is grown under the following major cropping systems:

1. mixed-cropping with taller millets (sorghum and pearl millet), taller oilseed (sesamum), and other grain legumes (pulse crops) like pigeon peas and urdbeans;

2. inter-cropping with cotton, sesamum; and,

3. sole-cropping during *kharif, rabi,* and summer (Apr-Jun) seasons.

Mungbean contributes only 12-13% of the total pulse production of the country. Grown on only 1.94 million ha out of a total pulse crop area of 22 million ha, it has an annual production of around 600,000 t. Mungbean has, however, the potentiality to make a much large contribution to the pulse economy of India and thereby help overcome the wide-spread protein malnutrition. Its inter-cropping has been found profitable with crops like cotton, sugarcane, tapioca, banana, coconut, and arecanut (4). It also finds a place in several multiple- or relay-cropping sequences because of its short duration and suitability in all 3 cropping seasons. This paper, therefore, discusses mungbean varietal requirements for application to cropping seasons and systems in India.

KHARIF SEASON CROPPING

Mixed- and inter-cropping

Mixed-cropping is still practiced by the traditional farmers in India. In this system seeds of 4-5 different crop species are mixed in varying proportions and broadcast. Generally the major component is millet and minor components are sesamum and pulse crops, like pigeon peas, urdbeand, and mungbeans.

Mungbean and other short duration pulse crops are inter-cropped with cotton, sesamum and other *kharif* season crops on a limited scale. Inter-cropping is now recommended extensively for many other medium to long duration crops because non-legumes grown in association with legumes increase in yield without adversely affecting legume yield (6).

Mungbean cultivars grown in mixed-cropping systems are generally late maturing (120-140 days), tall and twining in growth habit, and shy bearers. If taken as a sole-crop these yield 500-600 kg/ha. Genotypes of almost equal productivity are also being grown in inter- and sole-cropping systems. The first and foremost requirement for any system and season, therefore, is high genotype productivity. Little success has been attained in this direction so far as the presently available mungbean varieties are only marginally superior in yield to the locally grown cultivars. Hence, intensive breeding efforts are necessary by way of making multiple crosses among genetically diverse parents and adopting an effective breeding methodology so that rapid yield gains can be achieved.

Breeding for yield in specific mungbean cropping systems has not been undertaken so far. Present varieties are a product of selection either from naturally occuring variability, or created by limited hybridization and then tested under sole-cropping. Presently, little is known about which characteristics contribute to high yield under mixed- and inter-cropping. In pigeon peas, productivity of the genotype proved to be important irrespective of sole- or inter-cropping (10,12). Spreading genotypes, in general, recorded higher yields than compact or semi-spreading types under both sole- and inter-cropping systems. In soybean, Sehutz and Brim (7) reported differential response of the genotypes for their competitive ability. It should, therefore, be possible to select for genotypes having greater production efficiency under mixed- and inter-cropped systems. Basic information on mungbean genotypic responses for interspecific competition should be gathered before breeding for yield or before initiating a specific cropping system.

Mungbean cultivars are not only low yielding but also asynchronous in maturity and, therefore, 3-4 pickings become essential in order to avoid pod shattering. This makes the crop less remunerative because of extra expenditure. Incorporation of non-shattering or synchrony of maturity in mungbean genotypes should, therefore, prove profitable in all the growing seasons.

Mixed-cropping is generally practiced in areas receiving rainfall above 60-70 cm until the first week of October. Therefore, improved varieties maturing in 110-120 days should only be developed for rainy season cropping since, if sown at the onset of monsoon in July, they come to maturity after the rains stop. But varieties maturing earlier are likely to be caught in the September rains resulting in poor seed quality and sometimes seed-sprouting in the pods.

Acceptable seed quality is another varietal requirement not only for this but for all the cropping seasons. It includes 4-5 g/100 seed weight, and preferably a shining green color with protein content of 20-30%.

<u>Sole cropping</u>

In the *kharif* season, mungbean is sole-cropped mostly in areas receiving rainfall below 70 cm, and also as a preceding crop to *rabi* cereal crops wherever irrigation is available. The specific requirement of this system in this season, therefore, is varietal maturity duration of 80-90 days so that the crop does not suffer from moisture stress in rainfed areas and matures in time for double-cropping in irrigated areas.

The incidence of diseases and pests do not allow full realization of the productivity potential of mungbean genotypes. Therefore, a closer and wider examination of the incidence and extent of losses from different diseases and pests in various seasons and agro-climatic zones will help develop suitable resistant varieties and increase productivity.

The commonly occuring viral diseases in the *kharif* season are yellow mosaic virus (YMV) and leaf crinkle. However, YMV is considerable only in northern and central India. The important fungal diseases are leaf spots caused by *Macrophomina phaseoli* and *Cercospora canescens*, and root rot caused by *Rhizoctonia solani* and *Macrophomina* sp.

The common *kharif* season pests are jassida (*Empoasca kerri*), pod borer (*Adisura atkinsoni*), and galerucid beetle (*Medurasia obscurella*).

Presently we feel that resistance to diseases would be useful under all the cropping systems. However, incorporation of resistance for important diseases should receive priority. For instance, we know that heavy incidences of YMV are causing declines in mungbean and urdbean in the *kharif* seasons in parts of Madhya Pradesh and Uttar Pradesh. Recently urdbean variety Pant U 26 has been found free of YMV infestation under field conditions during the rainy season at Gwalior, where the disease appears under field conditions (3). The resistance of this variety needs confirmation from other YMV prone areas and, if possible, under glasshouse conditions. In mungbeans, such resistant varieties are yet to be identified. However, out of the hundreds of lines tested for 2 years under field conditions, a late maturing variety from Punjab, L 24-2, was found fairly tolerant (2-3.6% plants infected) to YMV as against Jawahar 45 and line 15225 which had shown 30-35% infection (2,3). Until better donors are identified, L 24-2 could be used in breeding YMV resistant mungbean cultivars.

RABI SEASON CROPPING

<u>Cropping systems and varietal requirements</u>

In the *rabi* season, mungbean is either sown after the harvest of early *kharif* paddy September/ October on residual moisture, or broadcast in a standing paddy crop a week before harvest. This latter system is referred to as *utera* cultivation and is prevalent in Bihar, Madhya Pradesh, and Orissa.

Rabi season cropping, feasible only in areas where winter is not severe, is restricted to eastern and southern India. However, with the availability of thermo and/or photo-insensitive varieties, mungbean could be grown in other areas as well as in this season. Presently, however, there is quite a good deal of scope for extension of cropping area for mungbean, urdbean, and cowpea in eastern and peninsular India under both rainfed and irrigated situations. For instance, in the rainfed areas of Orissa, one crop of early rainy season cereal is grown for harvest in September. In irrigated areas, land remains free from 90-100 days after the rainy season harvest until the planting of *dalva* paddy in February. Hence, the September-January period can accomodate early and productive pulse crop varieties because there is no competion with cereals. Under such rainfed conditions, early maturing varieties of mungbean, urdbean, and cowpeas could produce yields of 1400-1600 kg/ha (5). A good crop of mungbean and urdbean could be taken in this season between early maize and wheat under irrigated conditions in Bihar (9).

Besides the common varietal requirements stated earlier and those of thermo- and photo-insensitivity, resistance to powdery mildew (*Erysiphe polygoni*) and YMV are important. These diseases are common in winter and may cause a total crop failure.

SUMMER SEASON CROPPING

Improved irrigation facilities extend summer season cropping to new areas in India. However, there is a very limited choice of crops in this season because only 70-80 days exist between *rabi* and *kharif*. Mungbean, being of shorter duration, fits very well into this growing season.

The mungbean area in the above niche could be increased extensively provided high yielding and early maturing (60-70 days), or photo- and thermo-insensitive cultivars become available. In mungbean, maturity and, possibly, response to photoperiod are reported to be under simple genetic control. Hence, it should be possible to incorporate early maturity with photo- and thermo-insensitivity in locally adapted cultivars by a backcross program. Such day-neutral versions of local types would be very useful not only in summer but also during the *rabi* season.

Disease like YMV, leaf crinkle, and pests like thrips and jassids are common in *rabi* season. Incorporation of resistance to these diseases and pests in mungbean cultivars would be very useful. Until this is done, well known plant protection measures should be observed in order to obtain high yields.

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Weed Control in Mungbean

eith Moody

Mungbean is not very competitive against weeds and, therefore, weed control is an essential and important step in the growth of the crop. The magnitude of yield loss due to weeds is dependent upon environmental conditions and weed growth. For example, in Taiwan, yield losses of 60% occurred in spring, 1975, yet in summer of the same year, only a 27% loss occurred (1). In the Philippines a 95% loss occurred during the wet season. But, in the dry season, when weed growth was less, a 77% loss was recorded (5).

Despite these high losses due to weeds, weeding of mungbean in many parts of Asia is the exception rather than the rule. In the Philippines, farmers may do some interrow cultivation if the crop is sown in rows or, some desultory hand weeding, probably to obtain feed for their animals, if the crop is broadcast-seeded. More often than not the crop is left to fend for itself. Resultant yields are low.

Farmers are probably unwilling to risk their limited resources on weeding considering the low yield potential of the cultivars they currently use and the economic return to weeding. They would have a greater motivation to control weeds if obtainable mungbean yields were 2000 rather than 500 kg/ha.

Weed control in the early growth stages of the crop is essential. Madrid and Vega (5) reported that mungbean need only be kept weeded for the first 5 weeks during the wet season and for only 3 weeks during the dry season to yield as well as fields that were kept weed-free throughout the life cycle (Table 1). Enyi (3), however, reported that weeding as late as 8 weeks after sowing was necessary to obtain optimum yields.

Madrid and Vega (5) reported that weeds had little effect on crop yield if they were allowed to compete with mungbean for 2 weeks during the wet season and for 4 weeks during the dry season (Table 1). After these times, considerable yield reduction occurred as a result of competition. Weeds should be removed before competition begins as crops never recover from an initial setback due to competition, and never yield as well as crops that have not been subjected to competition. Late weeding, however, may be better than nothing. With one late weeding (30 days after seeding), I succeeded in increasing yield in Iloilo, Philippines, by an average of 34% over the yield of the farmer who has not weeded.

Based on Madrid and Vega's findings, it would seem that one timely weeding or, at the most, 2 weedings during the early growth stages should be sufficient such that yields would almost equal those obtained when mungbean is maintained weed-free for its growth duration. At the International Rice Research Institute (IRRI), I observed that when 5 mungbean cultivars were weeded once 2 weeks after emergence, an average yield depression of only 9%, compared

Table 1. Effect of the duration of weed control and weed competition on mungbean yield; Philippines, 1971.[a]

Weed control	Seasonal yield wet (1970)	Seasonal yield dry (1971)	Weed competition	Season yield wet (1970)	Season yield dry (1971)
---- wks ----	------- kg/ha	-------	------ wks -----	---------- kg/ha	-------
1	39	142	1	840	1148
2	354	303	2	978	975
3	402	1092	3	774	964
4	313	1019	4	523	1158
5	1021	1258	5	262	746
6	898	990	6	133	677
7	937	1054	7	39	566
8	948	1283	8	8	266

[a](3).

with the weed-free check, occurred as a result of competition. However, Enyi (3) reported that 3 weedings during the first 8 weeks after sowing were necessary to achieve optimun yields.

METHODS OF WEED CONTROL

Since man first started weeding his crops, a number of weed control methods - biological, chemical, managerial, physical, and preventive - have evolved. To be fully effective, these methods must be applied in combination. However, research on weed control in mungbean is sadly lacking.

LAND PREPARATION

Weed control is a serious problem in mungbean which is sown in land that has been inadequately prepared. There are more weeds present and more time is taken to harvest a crop when less land preparation is done. The chances of success of a post-planting weeding operation, especially if herbicides are used, is lessened when weeds are present at planting. More time will be needed to remove the weeds that are present if manual weeding is practiced.

In order to obtain full benefit from the residual moisture and the end-of-season rains, the possibility of using zero tillage in mungbean needs to be explored. However, problems associated with seed and fertilizer placement, seedling establishment, and weed control must be overcome before such techniques can be used successfully.

CROP COMPETITION

The use of the crop to compete against weeds and suppress them is a weed control technique that is frequently overlooked. Mungbean cultivars vary in their ability to compete with weeds. For 5 cultivars tested at IRRI, the dry weight of weeds at harvest was related to the leaf area index (LAI) of the cultivar in the weeded plots 41 DAE; the lower the weed weight, the higher the LAI except for CES 14 (Table 2).

The reduction in mungbean yield caused by weed competition was not related to weed weight at harvest. The weeds that grew in association with BPI Glabrous #3 had the lowest weight, yet the yield reduction (96%) was greatest for this cultivar. On the other hand, CES 14 had the second highest weight of weeds but the lowest reduction in yield (73%).

The factors which are responsible for the improved competitive ability of certain mungbean cultivars need to be examined further. Emphasis needs to be placed on root development in addition to above-ground plant growth. Frequently scientists tend to overlook root development and, yet, competition between crop and weeds for water and nutrients usually begins before competition for light.

Table 2. Competitive abilities of 5 mungbean cultivars against weeds; IRRI, 1976.

Cultivar	LAI (41 DAE) weeded	LAI (41 DAE) unweeded	Reduction in LAI	Weet wt at harvest	Yield reduction due to weeds
			---- % ---	--- kg/ha ---	----- %
CES 14	1.09	0.84	23	3408	73
CES 55	0.79	0.69	13	2071	83
MG 50-10A (green)	0.53	0.32	40	3974	88
MG 50-10A (yellow)	0.55	0.41	25	3243	89
BPI Glabrous #3	1.21	0.79	35	2027	96

Perhaps plant breeders should select their cultivars in presence of weeds. Thus when a new cultivar is introduced, it will not only be high yielding and have disease and insect resistance, it will also have weed "resistance".

Generally as the plant density is increased, the crop becomes more competitive and yield losses caused by weeds decline. Both soybeans and cowpeas when planted at narrow row spacings are more effective in suppressing weed growth and suffer less yield reduction due to weeds than when they are planted at wide row spacing (Table 3). Surprisingly, row spacing had little effect on the competitive ability of mungbean. Weed growth was approximately the same and weed competition caused about 50% reduction in yield irrespective of the row width. The effect of plant spacing both within and between crop rows on weed growth needs to be researched further for mungbean.

Table 3. Effect of row spacing on weed weight and yield reduction caused by weed competition for 3 legume crops; Philippines.

Crop	Row spacing (cm) 33	50	100
	- weed weight (kg/ha) -		
Soybean (TK 5)	827	997	1813
Cowpeas (EG #2)	213	220	551
Mungbean (CES 55)	3316	2997	3603
	% yield reduction		
Soybeans (TK 5)	14	29	43
Cowpeas (EG #2)	47	73	90
Mungbean (CES 55)	50	57	49

MULCHING

In unweeded plots in trials conducted at IRRI and Pangasinan, Philippines, weed weight declines significantly by 41 and 19% in mulched plots compared with unmulched plots, yet there was no corresponding increase in the mungbean yield. However, Lantican (4) reported an average yield increase of 79% among 20 mungbean cultivars when they were mulched.

The feasibility of using mulch in mungbean needs to be examined further. It appears as though it has considerable potential provided the residues from previous crops are used in situ.

INTERCROPPING

Intercropping of mungbean with sugarcane, cereals, and tree crops is practiced in some areas. The growing of a number of crops in close proximity to one another such that the plant density is greater than in sole cropping should result in greater competition against weeds and thus reduce the need for weeding.

Corn and mungbean are an excellent combination for competing against weeds. In the Philippines, the weight of weeds growing in association with corn-mungbean intercrops has been as low or lower than that of those growing in association with the sole crops (2).

The major methods of controlling weeds in intercropped corn and mungbean are manual or mechanical. Because there are less weeds in the intercrop combination, the time required for weeding is probably less than for the sole crops either because less time is required to do the same number of weedings or fewer weedings are required.

MANUAL AND MECHANICAL WEEDING

Except for India, hand weeding and hoeing are not widely used for weed control in mungbean. Manual weeding operations are extremely time consuming. Row planting of crops instead of broadcasting permits the use of interrow cultivation and considerably reduces the time needed for manual weeding. However, interrow cultivation of mungbean reduces yield compared with plots that were maintained weed-free by hand weeding (6). Root damage due to the cultivation is a possible reason for this yield decline.

CHEMICALS

Herbicide trials in mungbean have been conducted on research stations for a number of years, but to my knowledge, no farmer in Asia uses any herbicide for weed control in this crop.

Mungbean appears to be extremely sensitive to many of the herbicides that are commercially available. Because of the limited market potential, herbicides have not been specifically developed for use in mungbean. Researchers have to rely on compounds that have been developed for, or show promise, in other grain and vegetable legumes.

In Taiwan (1), several commercially available herbicides have given excellent control of the grass and broadleaf weed population, and yields similar to that of the hand weeded check have been obtained (Table 4). These herbicides, however, failed to control *Cyperus rotundus* L. In the Philippines, generally all herbicides that have been tested, including those that performed best in Taiwan, have either been phytotoxic to the crop or failed to control one or more of the dominant weeds. In India, nitrogen and alachlor were very effective in controlling weeds and yields obtained from plots treated with these compounds were similar to the yields obtained from the hand weeded check (7). The crop stand was reduced by both these compounds although alachlor was more toxic.

Unfortunately, many of the trials involving herbicides have been conducted during the wet season or under irrigated conditions. Thus, results obtained are not relevant to the situation where mungbean is planted after the main season crop. Presently available pre-emergency herbicides have limited potential under such conditions because there is insufficient water available to activate them. Suitable selective post-emergence herbicides have yet to be found or developed for use in legume in the tropics.

It is highly unlikely that herbicides will be used on mungbean by the Asian farmer until such time as those that give broad spectrum weed control without crop damage have been identified, and until the yield potential of the crop has been increased substantially.

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Table 4. Effect of different herbicide treatments on mungbean yield and degree of weed control; AVRDC, 1976.

Herbicide treatment	rate	Yield spring	Yield summer	Weed control: annual weeds[a] spring	annual weeds[a] summer	*Cyperus rotundus* summer
	kg/ha	t/ha	t/ha	%	%	%
Butachlor	1.0	1.3	2.2	94	86	8
Pendimethalin	0.5	1.3	1.9	98	69	0
Handweeded	-	1.0	2.2	100	100	100
Butralin	2.0	1.2	1.9	100	73	43
Butralin	1.0	1.1	1.8	99	56	0
Unweeded	-	0.4	1.6	0	0	0

[a]*Eleusin indica, Echinochloa colona, Amaranthus spinosus* (spring only), and *Portulaca oleracea*.

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Discussion

Ballon: I would like to ask Mr. Chiang if he has observed any adverse effects of irrigation when applied before flower formation.

M. Y. Chiang: No adverse effects were observed. However, irrigation stimulated weed growth so that we had to spend more time weeding.

Ballon: What type of irrigation is most effective for Malaysia?

M. Y. Chiang: We normally practice flooded and furrow irrigation. We have not made any comparative study on the effectiveness of each method. However, the type of irrigation used would depend on whether we plant on the rows or on the furrows.

Aspe: Why don't you irrigate the field right after planting? Do you think that irrigating the field right after planting will reduce germination or will it help them germinate?

M. Y. Chiang: We applied 70 mm germination water which we think will balance the initial water requirement. In the dry season planting, as with our experiment, irrigation is essential for germinating mungbean seeds.

H. F. Chin: What are the prospects of pre-emergent herbicides for weed control in mungbean, Dr. Moody?

Moody: If consistently high yields can be obtained, the prospects for use of pre-emergence herbicides when mungbean is grown during the wet season or under irrigation look good provided suitable compounds can be identified. Presently, available pre-emergence herbicides, which require moisture to activate them, should not be used when mungbean is planted after the main season crop and has to survive on residual moisture and end-of-season rainfall.

Islam: In your experiment weeding four times gave the highest yield. Did you consider the cost of weeding with regard to increased yield.

Moody: None of the data presented indicates that the highest yields were obtained with four weedings. Enyi (1973) reported that the highest yields were obtained with three weedings. He did not consider the cost of weeding with regard to the increased yield. However, if the assumption is made that it takes 20 man-days to weed a hectare of mungbean and that the wage rate is ₱ 8.00/day and mungbean sells for ₱ 1.00/kg, then it would be profitable to do three weedings in mungbean based on Enyi's data.

Ballon: What is the prospect of using post-emergence herbicides on mungbean crops?

Moody: None of the presently available selective post-emergence herbicides are suitable for use on mungbeans. Prospects of one being developed do not appear great. Non-selective herbicides could be used provided they are applied as directed applications.

C. Yang: Dr. Wood, what specific mungbean diseases have you observed in Australia's northern territories, particularly during the wet season?

Wood: We have experienced very few problems with diseases in wet season crops. Sporadic outbreaks of "little leaf" especially in the December sowings sometimes occur. This is believed now to be a bacteria *Rickettsia* transmitted by leafhoppers. In dry season crops, powdery mildew is a serious problem. On the whole insects are a more serious problem than diseases. This is possibly a result of strict quarantine procedures adopted for seed brought into the area.

Ballon: Mr. Ng, have you observed differences in varietal response to date of sowing in Malaysia?

Ng: Not at this stage in our program, but we would like to investigate this later.

Ahmad: What is the relationship of seed yield and dry matter yield. Table 2 did not indicate a consistent positive correlation between the two characters.

Ng: There was no consistent positive correlation as can be seen in the significant differences among sowings in the harvest index.

Laing: Have you conducted any experiments on the use of dry lime to dry seeds for storage?

H. F. Chin: No. Once the seed is properly dried, there is no exchange of moisture anymore. The farmer only has to dry the seed and seal the storage container properly.

Ramanujam: How was the moisture content reduced? In most places, the atmospheric humidity at harvest and/or insufficient sunshine may prevent this without artificial heat.

H. F. Chin: The moisture content of mungbean seeds was reduced by sun-drying. In case of wet weather, artificial drying may be necessary.

Lawn: In Indonesia, I have seen farmers include small bags of quicklime in sealed containers for seed.

H. F. Chin: This method of using quicklime in packeted seeds will further enhance the storage life of seeds.

Ballon: What is the most practical and economical way to store mungbean seed?

H. F. Chin: In my opinion the use of polythene bags is more economical and simple. I have not experimented on the effect of various chemicals. As long as seeds are low in moisture and clean, insects do not survive inside the polythene bags.

Park: Is weevil infestation a problem in Malaysia? Do you spray any insecticide before harvesting your material? Have you seen any weevil eggs on the seed?

H. F. Chin: Weevil infestation is a problem in Malaysia. Insecticide, 'Rogor 40,' is sprayed on our crops prior to harvesting. There was no sign of weevil infestation damage or eggs on the seeds.

Engel: We have heard six papers this morning on the production and management of mungbean but none has mentioned the main objective of our research: high protein production. I would be interested in hearing from the speakers about the effects of various management practices on protein content.

Wood: Data are presented in our paper indicating the range of crude protein (%N *6.25) recorded in the wet and dry season sowings of our mungbean collection. These data show that the range of protein content was about 25 to 33% in both sowings. The variation in protein content is much less than the variation in yields and so yield of protein per hectare is more dependent on yield than protein content. Also, we have observed dilution and environmental effects. Extreme temperatures in northern Australia decrease rhizobial activity which, expectedly, affects protein content.

Engel: Is there really a dilution effect?

Wood: It is hard to say. There are other environmental factors involved also. I am a little bit concerned that we are generalizing yields of certain varieties which are tested in different countries under different cropping and environmental conditions.

Carangal: I see your point and I appreciate your concern. The trials are not that uniform. Different cultural patterns are involved. Our main objective in these trials is to see the overall performance of varieties under different environmental conditions so that we can determine which to recommend to countries where the trials are conducted.

Laing: Did you find any variety photoinsensitive in your work in the International Mungbean Nursery?

Poehlman: The term "photoinsensitivity" is often misused. It is not possible to state that a variety is photoinsensitive - not even in wheat - unless it has been tested over the entire range of photoperiod. We examined the mungbean strains only over a range of 12 to 16 hours. Some strains were less sensitive; none were insensitive within the range.

Grewal: Did you come across root rot in mungbean at your station or in any other station where mung nurseries sent by you were grown?

Poehlman: At Columbia, Missouri, we occasionally found a dead plant and suspected root rot but did not identify the organism responsible. In the International Mungbean Nurseries root rot did not appear to be a serious problem at any location.

Protection

-continued-

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Mungbean Diseases and Control

Charles Y. Yang

Mungbean and its close relative, blackgram (*Phaseolus mungo*), are widely grown throughout the tropical countries of Southeast Asia and India, where they are used as a human food in the form of bean sprouts, green beans, boiled dry beans, noodles, and candy confections. The crop also appears suited to production under both dryland and irrigated conditions. Since the mungbean is grown under a wide variety of soil and climatic conditions, it is exposed to numerous diseases, and these are partially responsible for low yields in this region.

Mungbean diseases are caused by parasitic organisms such as fungi, bacteria, nematodes, viruses, and mycoplasma that depend on the host plant for their nutrition. The constant feeding of these organisms weakens the mungbean plants so that they do not grow properly and fail to produce maximum yields. The severity and prevalence of pathogens are determined by environmental conditions, such as temperature and humidity. Therefore, some mungbean diseases are geographically limited, whereas others are widely distributed. Usually, all mungbean diseases do not occur every year in a locality, and it is also not unusual to find fields with several diseases present. A disease may be very destructive in a host cultivar grown in one season but may not appear the next.

A total of 26 diseases are known to attack mungbeans; most of them are found in tropical and subtropical Asia. In this paper the more important diseases, whose presence in mungbean cause losses severe enough to merit control measures, are listed and referenced. Using resistant varieties is the emphasis of control since the cost of using chemicals may be beyond the reach of many mungbean farmers, and is uneconomic for most diseases. A more detailed discussion of mungbean diseases and controls will be published as a monograph by AVRDC in 1978.

FUNGAL DISEASES

A large number of fungi parasitize mungbean and the diseases caused by them vary greatly in importance. As presented in Table 1, there are at least 9 types of mungbean diseases which are known to be caused by fungal pathogens. Of these, damping-off or collar rot, seedling blight, and root rot, are caused by soil-borne plant parasites. The rest are caused by air-borne pathogens.

SOIL-BORNE DISEASES

Mungbean are prone to infection by soil-borne pathogens. Diseases such as pre-emergence and post-emergence damping-off or seedling blight are caused by a group of soil fungi, exerting the disease effect in a concerted fashion; whereas, in other cases, one fungus, such as *Rhizoctonia solani*, can affect many parts of the same plant at different growth stages.

AIR-BORNE DISEASES

Most of air-borne fungal diseases can spread through localized air movement for a short distance or, by wind for a long distance. The diseases and damages which they cause are usual-

Table 1. Mungbean diseases caused by fungal pathogens; AVRDC, 1977.

Disease name	Causal organism	Reference
Damping-off, collar rot	*Pythium aphanidermatum*; *P. ultimum*: *Rhizoctonia solani*	2-4, 16, 22 2-4, 14, 18, 46, 63
Seedling blight	*Phomopsis* sp.	51
Root rot	*Macrophomina phaseolina*; *Rhizoctonia solani*	2-4, 18, 46, 48, 51
Leaf spot	*Cercospora canescens*; *C. cruenta*; *Macrophomina phaseoli*; *Sclerotium rolfsii*; *Alternaria alternata*	1-4, 28, 41, 48, 51, 59, 23 29 11
Powdery mildew	*Erysiphe polygoni* (*Oidium* sp.)	2-4, 41, 48, 55, 59
Rust	*Uromyces appendiculatus*; *U. phaseoli* var. *typica*; *U. radiata*; *Phakopsora pachyrhizi*	48, 51, 59, 62 49, 5 64
Anthracnose	*Colletotrichum lindemuthianum*	48, 51
Leaf blight; *Rhizoctonia* Web-blight	*Tanatephorus cucumeris*; *Curvularia eragostidis*; *Synchytrium phaseoli*; *Rhizoctonia* sp.	61 6 63, 36
Scab	*Elsinoe iwatae*	30

ly dramatic and heavy should epiphytotic conditions prevail in a large cultivated area. Infection of mungbeans by many air-borne fungal pathogens is primarily expressed through external symptoms on the diseased leaves. If severely attacked, premature defoliation will usually result. Complete defoliation at any time can significantly reduce the plant height, number of pods/plant, and grain yield. The greatest reduction occurs when mungbean plants are defoliated at the early-podding stage 8 wks after sowing (4). A 95.3% reduction in mungbean grain yield resulted from a complete defoliation (9).

BACTERIAL DISEASES

Only 2 bacterial diseases - bacterial leaf spot and halo blight - have been found on mungbean (Table 2).

Since the bacterial plant pathogens are extremely minute, their differentiation on the basis of morphology are difficult and inadequate. Therefore, for a successful identification of any disease caused by a bacterial pathogen, all morphological and physiological character, serology, and pathogenicity tests on the host range must be employed.

NEMATODE DISEASES

Whenever grown, mungbeans are attacked and often seriously injured by various plant parasitic nematodes. Nematodes are tiny, round wormlike animals, but the adult female of certain kinds are swollen, being pear- or lemon-shaped. The majority of nematodes are invisible except through a microscope; however, the large forms can be seen with the naked eye. They appear as small white specks on infected roots, particularly when these roots are brown from decay.

A number of plant parasitic nematodes can attack mungbean plants and cause injury or yield losses (Table 3). However, only a few detailed studies regarding each of the nematodes and their particular parasitic relationships with the mungbean hosts are currently available.

Table 2. Mungbean diseases caused by bacterial pathogens; AVRDC, 1977.

Disease name	Causal organism	Reference
Leaf spot; bacterial blight	*Xanthomonas phaseoli*	20, 37, 47, 51, 55
Halo blight	*Pseudomonas phaseolicola*	38, 50, 51

Table 3. Mungbean diseases caused by nematodes; AVRDC, 1977.

Incitant[a]	Scientific name	Reference
Root-knot nematodes	*Meloidogyne incognita* *M. incognita acrita* *M. javanica* *M. arenaria*	7, 8, 15
Soybean cyst nematode	*Heterodera glycines*	10
Reniform nematode	*Rotylenchulus reniformis*	39

[a]Nematodes belonging to *Aphelenchoides, Aphelenchus, Heliotylenchus, Pratylenchus, Tylenchorhynchus* and *Tylenchus* were also found on mungbean plants.

Table 4. Virus diseases reported on mungbean and blackgram; AVRDC, 1977.

Causal agent	Also known as	Reference
Yellow mosaic virus	Yellow mosaic of mung; yellow mosaic	27, 31, 34, 35, 49, 51, 57, 59, 60, 62,
Mungbean yellow mottle virus	Mungbean yellow mottle; MYMV	3, 4
Mungbean mosaic virus	M-BCMV; MMV	18, 19, 41
Mungbean mottle virus	Mungbean mottle; MMV	3, 4
Greengram mosaic virus	GGM_1, GGM_2, GGM_3, GGM_4	44
Mosaic virus of greengram	M-TMV	43
Mosaic virus of blackgram	Mosaic of urid; mosaic of urd	35, 45, 49, 56, 58
Leaf crinkle virus of urd	Blackgram leaf crinkle virus; leaf crinkle; BLCV	21, 32, 33, 35, 51, 62
Leaf curl virus	Leaf Curl	35, 51
Blackgram sterility mosaic virus	BSMV	32
Satellite tobacco necrosis virus		25

VIRUS DISEASES

Many different types of viruses can infect mungbeans. Unfortunately, confusion often exists in the literature owing to insufficient information or incomplete studies. As presented in Table 4, at least 11 mungbean diseases have been reported to be caused by viruses. However, only the few frequently encountered will be described here.

To use resistant mungbean varieties for a given virus disease is the only effective means of control. Weeding, sanitation measures, and the control of insects, if identified as virus transmitting vectors, can help reduce the incidence and severity of some mungbean viral diseases.

MYCOPLASMAL DISEASES

1. Phyllody is caused by a virus, possibly a mycoplasmal-like organism, and is characterized by the transformation of floral parts into leaf-like structures.

2. Mungbean witches' broom (MWB) is a minor disease of mungbean first observed at AVRDC in a field trial.

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Powdery Mildew and *Cercospora* Leaf Spot of Mungbean in The Philippines

F.C. *Quebral*

The diseases of mungbean in the Philippines that merit attention are powdery mildew and *Cercospora* leaf spot.

POWDERY MILDEW

Powdery mildew has been consistently observed on production plantings both at experiment stations as well as on farmers' fields. The disease is caused by a fungus whose development is favored by high relative humidity, cool nights, and trace amounts of rainfall (4). The disease is, therefore, prevalent during the dry season planting (Jan-Feb), when abundant spores can be caught, and practically absent during the rainy season.

Powdery mildew is chiefly a leaf disease. The first visible symptom of infection is the appearance of small white, powdery spots on the upper leaf surface. This white superficial fungus growth later covers part or all of the leaf surface. From a distance, an infected fields looks as if it was intentionally dusted with flour. Severely infected leaves gradually turn yellow, then brown, and defoliate. Tests conducted at the University of the Philippines at Los Baños College of Agriculture (UPLB) showed that powdery mildew can reduce yield as much as 21% when all the leaves are covered with mildew colonies at flowering time (3).

Field experiments conducted in 1968 showed that powdery mildew can be effectively controlled by timely spraying of benomyl fungicides at the rate of 30g/100 liter at least twice during the growing season at 10-14 day intervals (Table 1).

Since benomyl is also claimed to have systemic activity, we conducted a greenhouse test with benomyl incorporated in the soil for the control of powdery mildew. Results indicated that benomyl, when mixed into the soil at 0.5, 0.25, 0.15, and 0.07 g/400 cc of rooting medium, provided complete protection against powdery mildew for 70 days (1).

Various mungbean accessions obtained from the UPLB-CA-SEARCA germplasm, bank were tested for their reactions against powdery mildew in pots and microplots in 1973. A disease assessment was made at the flowering and pod initiation stages. Table 2 shows the disease reaction.

CERCOSPORA LEAF SPOT

CES 14, 55, and the MG series now widely planted in the Philippines are highly susceptible to *Cercospora* leaf spot. Caused by a fungus, the disease is serious during the wet season

Table 1. Yield of mungbean CES 14 in protected and unprotected plots; UPLB-CA, 1968.

Treatment	Mean yield (kg/ha)
Protected	1,138.5
Unprotected	902,5

Table 2. Comparative reaction of different accessions of mungbean and perennial mungbean (PM) to powdery mildew at various stages of growth; UPLB-CA, 1973

Acc. No.	Flowering		Pod Initiation	
	pot	microplot	pot	microplot
226	S	I-S	S	S
290	R-I	R	I-S	R
291	S	R-I	S	I
292	R-I	R	R-I	R
293	R	R	R	R
294	R	R	R	R
295	R	I	S	I
296	R	R	R	R
279	R	R	R	R
304	R	R	R	R
305	R-I	I	S	I
306	R	R	R	R
450	R-I	R	S	R
PM	R	R	R	R

planting (Jun-Oct) and can reduce mungbean yield by 23% when 75% of the foliage is killed (2).

The first and visible symptom of infection is the appearance of water-soaked spots on the leaves. Later, these spots become tan to reddish-brown necrotic areas with small gray centers. The individual spots may join, causing large dead areas on the leaves. Severely infected leaves may have 50-100 spots. A heavy infection of *Cercospora* causes pre-mature drying and defoliation.

Paired plot experiments conducted at UPLB-CA during the 1969 wet season planting showed that spraying with benomyl twice at 10-day intervals during the growing season at the rate of 30 g/100 liters of water effectively controlled leaf spot (2). (Table 3).

Table 3. Effect of leafspot control on mungbean yield; UPLB-CA, 1969.

Treatment	Mean yield (kg/ha)
Protected	764.33
Unprotected	587.19

Spore trapping at UPLB-CA Experiment Station during the 1975 wet season planting showed that *Cercospora* spores were abundant in September, and present on all days sampled with a daytime peak and gradually decreasing at night. *Cercospora* leaf spots were also present in the fields during September.

The hybridization program at UPLB-CA has produced a variety, CES ID-21 (Pag-asa), which is highly resistant to powdery mildew and moderately resistant to *Cercospora* leaf spot.

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Genetic Polymorphism and Ontogenetic Isozyme Patterns of *Cercospora* Leaf Spot Resistant and Susceptible Varieties of Two *Vigna* Species

Desiree I. Menancio and D.A. Ramirez

Resistance and susceptibility are alternative reactions exhibited by a plant in the course of plant infection. The first is characterized by suppression of the disease and subsequent recovery of the plant; whereas, the latter is the enhancement and development of the disease leading to the plant's untimely death. Isozymic analyses of disease conditions help us understand the underlying concept between resistance and susceptibility. Resistance reaction is attributed to the activation of endogenous enzyme systems accompanying altered metabolic processes.

Plant peroxidases have been particularly useful for these studies because of their presence in all plants. Several species of crop plants are reported to have high peroxidase activity and greater numbers of isozymes in the course of diseases and injuries among the resistant varieties as compared to their susceptible counterparts. These isozymes can be separated by gel electrophoresis. They have been shown to vary with plant genotypes, developmental stage, organ, tissue, and location in the cell.

Catalases, on the other hand, have no defined catalytic function. However, they are often associated with peroxidase inhibition. They show the same ubiquity and heterogeneity in the plant system.

Genetic polymorphism is finding increased use in plant breeding. It is a very convenient supplementary tool in screening procedures since it does not resort to destructive methods. Electrophoretic patterns can be obtained rapidly and with small amounts of tissues. Thus, a large number of single plant selections can be tested without sacrificing the whole plant. It appears to be useful both as a preliminary test and as a determinant of genetic origin.

The mungbean plant provides suitable material for studying enzyme profiles. A wide range of disease responses have been observed during the plant's development. Practions range from near immunity to total susceptibility. On this basis, we conducted an ontogenetic study of the enzyme activities of resistant and susceptible varities of *Vigna radiata* and *Vigna mungo*. A second objective was to determine possible differences in peroxidase and catalase patterns between resistant and susceptible varieties, and to establish the period in the plant development when these differences occur.

MATERIALS AND METHODS

We used one *Vigna mungo* and 10 *V. radiata* varieties in this study. Five mungbean varieties were reported resistant to *Cercospora* leaf spot, and 5, susceptible. *V. mungo* was found almost immune to the disease. All the plants were grown in clay pots. A sample collection was made every 7 days from germination to pod-bearing stage. From each plant, 2 leaves were collected and analyzed for peroxidase and catalase patterns and activities using starch gel electrophoresis. For each variety, 3 replications were provided, each with 20 plants.

RESULTS AND DISCUSSIONS

Peroxidase Analysis

Eleven mungbean varieties were examined for possible isoperoxidase differences. One cathodic and 5 anodic banding patterns were detected (Fig. 1); 3 anodally distinct patterns in the resistant accessions (Group I) and 2 in the susceptible accessions (Group II). The cathodic

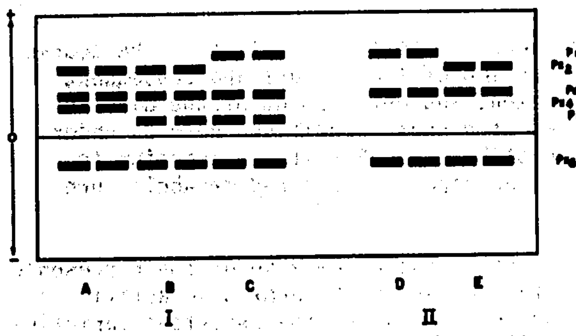

Fig. 1. Composite diagram of banding patterns of peroxidase isozymes detected in crude leaf extrace of 11 varieties of mungbean.

banding pattern observed was common to both groups. The primary difference between Group I and Group II anodic patterns is the absence of Px 4, or Px 5 in the latter. Furthermore, the bands in Group I were generally darker stained than those in Group II, indicating the probability of higher activities of isoperoxidases in the resistant varieties than in the susceptible ones. This relatively small amount of variability in isoperoxidase patterns of *Vigna* species is in marked contrast to the high degree of variability observed in other crops like *Zea mays* (1), barley (4) and *Cucurbita pepo* (2).

Using the number of bands observed at different stages of plant development, we found significant statistical differences between the 2 groups. These findings indicate that isoperoxidase patterns may be used as a selection index for resistance to *Cercospora* leaf spot of mungbean.

A significant deviation from the banding patterns exhibited by the resistant varieties was that of the variety CES 1D-21, a highly resistant variety produced at UPLB-CA. The number of isoperoxidase bands in this variety were not statistically different from any of the susceptible varieties. However, upon closer examination, we observed that this variety differs from susceptible varieties in its isoperoxidase pattern. This indicates that it is not the quantity of isoperoxidases that would be different in a resistant variety but the quality of the isozymes, and confirms that a particular enzyme can be chiefly, if not exclusively, responsible for induced resistance in the plant. Note that all the resistant varieties exhibit Px 4 or Px 5, and that these 2 isoperoxidases were not observed in any of the susceptible varieties (Fig. 2 and 3).

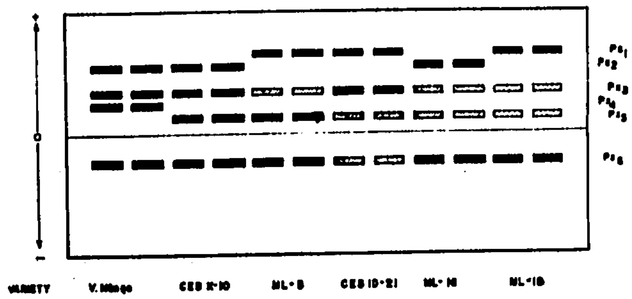

Fig. 2. Perioxidase isozymes of 6 mungbean varieties resistant to *Cercospora* leaf spot.

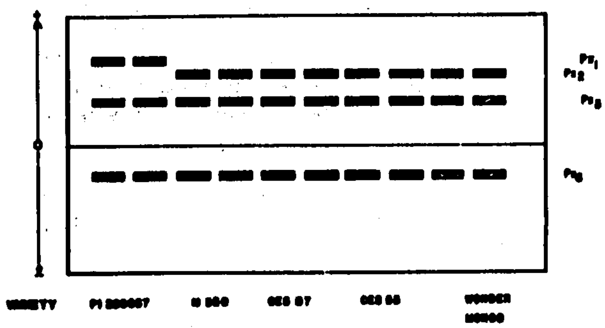

Fig. 3. Perioxidase isozymes of 5 mungbean varieties susceptible to *Cercospora* leaf spot.

Within each group, we observed further subgroup differences. These were classified into the 5 distinct anodic class A banding patterns obtained only from *V. mungo*. It has the characteristic band No. 4 (Px 4) which is not present in any of the other classes. Classes B and C, on the other hand were observed on all the resistant mungbean varieties. They appear to be quite similar because their main difference lies in Px 1 and Px 2. Class B possesses Px 2, while Class C has Px 1. In the susceptible group, class D and E also differed from each other in the same manner as classes B and C. Class D isoperoxidase pattern was exclusive to PI 226657, while the rest of the susceptible varieties showed a typical class E banding pattern. The very distinct banding pattern of *V. mungo* may be a species characteristic since it was only in this accession where Px 4 was observed. This isozyme may also be responsible for the almost immune reaction of *V. mungo* to *Cercospora* leaf spot. Among the mungbean varieties, 2 patterns were distinctly those of the resistant varieties, and 2 were of the susceptible varieties. The resistant varieties have Px 5, which was not observed in the susceptible varieties. Both the resistant and the susceptible varieties have Px 1, Px 2, and Px 3, and the differences were only in terms of the intensity of the band stains. Based on these observations, it may, therefore, be concluded that Px 5 is the resistance factor in mungbean.

Diagrammatic representation of the zymograms of individual accessions are presented in Figures 2 and 3. Qualitative variability between individual isoperoxidases were observed in both resistant and susceptible groups. The fastest anodally migrating bands of each accession did not show any variability in intensity. Variability was more prominent in Px 3, Px 5, and Px 6. The differences in relative activity may be due to intrinsic differences in enzyme concentration in the leaves.

Table 1 shows the results of the ontogenetic studies of the different varieties which established that, during the early seedlings stage, peroxidase activity was absent or at least minimal in both the resistant and the susceptible varieties. An exception is a *V. mungo* accession (CES x-10) which showed a single peroxidase band at one week after germination. Beginning the second week, a general trend of increasing intensity was observed (Fig. 4). While there was an increasing intensity of bands accompanying maturity, a fluctuation in the number of isoperoxidases was detected. Isoperoxidase 3 seemed to be the most affected by the development shift.

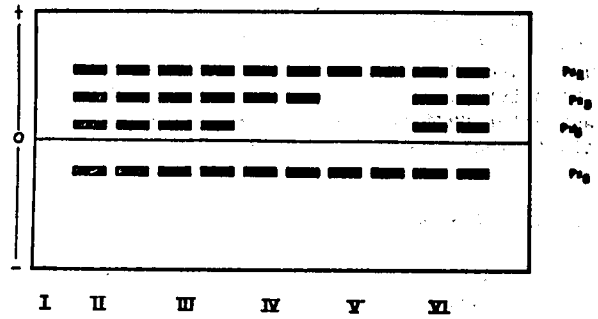

Fig. 4. Isoperoxidase patterns of CES X-10 at different stages of development: I-seedling; II & V- flowering; VI-pod-bearing.

Table 1. Isoperoxidase bands present at different stages of development of several *Vigna* varieties; Philippines.[a]

Species/Variety	Stage of development					
	I	II	III	IV	V	VI
ML-5	-	1,3,6	1,5,6	1,5,6	1,5,6	1,3,5,6
ML-16	-	1,3,5,6	1,5,6	1,5,6	1,3,5,6	1,3,5,6
ML-18	-	2,3,5,6	2,3,6	2,3,6	2,3,5,6	2,3,5,6
CES X-10	-	2,5,3,6	2,3,5,6	2,5,6	2,6	2,3,5,6
CES 1D-21	-	1,3,6	1,6	1,3,5,6	1,6	1,3,5,6
V. mungo	4	2,3,4,6	2,3,4,6	2,3,6	2,3,4,6	2,3,4,6
CES 55	-	2,3,6	2,3,6	2,6	2,3,6	2,3,6
CES 87	-	2,3,6	2,3,6	2,3,6	2,6	2,3,6
M 350	-	2,3,6	2,3,6	2,6	2,3,6	2,3,6
Wonder Mungo	-	2,3,6	2,3,6	2,6	2,3,6	2,3,6
PI 226657	-	1,3,6	1,3,6	1,3,6	1,3,6	1,3,6

[a]1-6 represents the isoperoxidase band number (Px).

The ontogenetic appearance of isoperoxidases suggests that different peroxidase genes are being activated at different periods. Perhaps each isozyme is particularly attuned to a particular cellular change during growth or senescence. The disappearance and reappearance of isoperoxidase 3 could be attributed to the repression of this isozyme by high auxin levels characteristic of the vegetative-flowering stage, and its induction by ethylene near maturity (3). Further verification of the presence of these 2 hormones must be undertaken to establish the isozyme shift observed at different developmental stages.

In addition to using isoperoxidase patterns as a selection index to *Cercospora* leaf spot resistance in mungbeans, screening should be undertaken during the vegetative stage (2 and 3 wks after germination), and at pod-bearing (6 wks after germination). It was during these stages that the Px 5 is detectable.

Catalase Analysis

A small variability in the number of isozyme patterns was detected for catalase. In all 11 accessions, there were only 2 anodally distinct patterns observed with 3 anodal bands and no cathodal bands (Fig. 3). The first pattern, which was observed only in the *V. mungo* accession, is composed of a single band. The second pattern, which was exhibited by all the other varieties, has 2 distinct anodal bands. This uniqueness in the catalase pattern of *V. mungo* corroborated the findings in this variety's peroxidase pattern. Statistical analysis for the catalase isozyme did not show significant differences between resistant and susceptible varieties which have similar catalase isozyme patterns (Table 2). Individual isozyme analysis did not show any qualitative variation among the different varieties. This further indicates that catalase isozymes cannot be used as a selection index for resistance to *Cercospora* leaf spot.

Developmental studies of catalase isozymes showed more pronounced qualitative changes (Fig. 5). There was an increase of one band from the

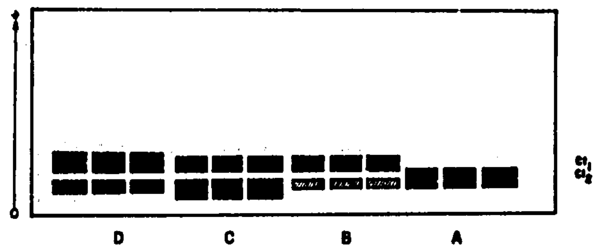

Fig. 5. Catalase isozyme patterns of CES X-10 at different stages of development: A- seedling; B- vegetative; C- flowering; and, D- pod-bearing.

Table 2. Isocatalase bands present at different stages of development of several *Vigna* varieties; Philippines.[a]

Species/Variety	Weeks after germination					
	I	II	III	IV	V	VI
V. mungo	3	3	3	3	3	3
ML-18	2	1	1,2	1,2	1,2	1,2
ML-16	2	1	1,2	1,2	1,2	1,2
ML-5	2	2	2	1,2	2	1,2
CES X-10	2	2	1,2	1,2	1,2	1,2
CES 1D-21	2	x	2	2	1,2	1,2
CES 87	2	1	1,2	1,2	1,2	1,2
PI 226657	2	1	2	1,2	1,2	1,2
M 350	2	1,2	1,2	1,2	1,2	1,2
Wonder mungo	2	1,2	1,2	1,2	1,2	1,2

[a]1-3 represents the isocatalase band number (Ct).

seedling stage to the vegetative stage. Both catalases and perpxidases showed increased activities from the seedling stage to maturity. Quantitative measurements of the relative activities of both enzymes will give more accurate information about the relationship between catalases and peroxidases.

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Fungal Diseases of Mungbean in The Philippines

Lina L. Ilag

INTRODUCTION

Several fungal diseases attack mungbean. Some of these diseases attack the plant at specific growth stages; others may cause infection at any stage.

ANTHRACNOSE[a]

Serious outbreaks of this disease occur in Mindanao, in the southern Philippines (2). It is specially severe during the rainy months.

Symptoms

In seedlings, brown sunken lesions are formed on the cotyledons and the young stems. In wet weather the lesions increase rapidly in size and number, and the young plant is killed. In pods, depressed black cankers appear, sometimes with flesh-colored centers. The seeds may also be infected. When such seeds are planted, the seedlings may die before emergence.

Cause

Anthracnose of mungbean is caused by *Colletotrichum lindemuthianum* (Sacc. & Mgn.) Bri. & Cav. (3). The fungus forms saucer-shaped erumpent acervuli. Filiform setae are present, 2-to 4-septate, 3.5-12 um. Conidia are cylindrical or ellipsoidal, hyaline, non-septate. Conidia measure 3-6 um x 10-20 um. When present in mass they form pink or orange slimy drops.

CERCOSPORA LEAF SPOT

Cercospora leaf spot has long been a serious mungbean disease throughout the Philippines. It is especially severe during the rainy season but also occurs during dry months. The Philippines' "Pag-asa" variety has moderate resistance.

Symptoms

The leaf spots are somewhat circular to irregularly-shaped with tan or gray centers, and reddish brown or brown to dark brown margins. Lesions vary in size depending on the isolate

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[a]Color pictures of the disease symptoms mentioned are shown on page 157

of the fungus and host variety. Individual lesions vary in size depending on the isolate of the fungus and host variety. Individual lesions increase in size and coalesce until the greater part of the leaf, or the entire leaf, turns brown and dries up. Defoliation may then occur. Plants of all ages are subject to infection.

Causal organisms

Two species of *Cercospora* were isolated from infected mungbean leaves and both were found to be pathogenic.

In culture and in the host tissues, the conidia of *C. canescens* Ell. & Mart. were acicular with a truncate base and narrow tip, hyaline, straight or curved, multi-septate, measuring 53-224 x 3.4-6.4 um with an average of 142.0 x 4.9 um. Conidiophores are multiseptate, usually straight or slightly curved, light brown, measuring 144-234 x 5.25-6.97 um with an average of 183.0 x 6.06 um.

C. cruenta Sacc. has multiseptate conidia, pale olivaceous, straight or slightly curved, obconic base, sub-acute tip, measuring from 54-181 x 3.6-5.0 um with an average of 112.0 x 4.2 um. Conidiophores are light brown, sometimes branched, septate or non-septate. Fruiting by both fungi on the leaf surface is amphigenous.

The morphology of the 2 fungi agree with Chupp's description (1) except for slight variations in spore measurements.

Wells (5) attributed the cause of this disease in the Philippines to *C. cruenta*.

POD ROT OF MUNGBEAN

The disease was first observed in the summer of 1976 in various parts of Laguna. No previous report of the occurrence of pod rot is known. Serious damage can occur as entire pods blacken and rot before maturity.

Symptoms

The first symptom appeared 2 days after inoculation as a soft rot on unfilled young pods. Infection spread rapidly and, within 5 days after inoculation, the entire pod had rotted and turned dark brown to black. Darkening usually starts from the stem end and progresses to the tip of the pod. The infected pod, at first soft and soggy during the early stages of infection, eventually becomes dry and hard. If infection occurs after the pod-filling stage, but before the seeds are fully developed, the seeds become dark and shrivelled.

Cause

Initial studies reveal that the associated organism forms pycnidia on the infected pod. After isolation, pathogenicity tests were performed.

The pathogen is *Diplodia* sp. Pycnidia are globose or subglobular, black, occur singly, immersed in host tissue, erumpent. Conidia are one-celled and subhyaline, becoming dark brown, 2-celled and striated with age, ovoid or ellipsoid, non-constricted, are borne on simple conidiophores. Pycnidia measure 285.6-938.4 um in diameter. Conidia are 16-38 x 11-17 um, and 28 x 14 um on the average.

The fungus also causes soft rots in pricked and unpricked pods of the common bean (*Phaseolus vulgaris*), cowpea (*Vigna sinensis*), and "sitao" (*V. sesquipedalis V. sinensis*). Six to 8 days after inoculation, specks of black pycnidia can be seen on the surface of infected pods. Under moist conditions a white to grayish velvety mat of mycelium may cover the pods. When the weather is dry, diseased pods dry up and become hard.

POWDERY MILDEW OF MUNGBEAN

The disease is most serious during the dry season and is practically nonexistent during the rainy season. The disease is favored by temperatures from 22-26^{o}C, and relative humidities 80-88% (4).

Symptoms

Infection usually starts on the lower leaves. The earliest visible symptom is the appearance of small white powdery areas on the upper leaf surface. These powdery spots, which consist of the causal organism's structures, increase and may cover the entire leaf surface. In some instances the powdery mass may also be observed on the lower surface. In severe infections, the leaves turn yellow, wilt, and defoliate.

Causal organism

The cause is *Erysiphe polygoni* D.C. (4). In the Philippines only the asexual stage has been observed. Mycelium and spores are formed on the host surface with haustoria below the epidermis. Conidia are hyaline, one-celled, cylindrical, measure 25.1-33.7 x 16.4-21.4 um with an average of 28.0 x 18.4 um, produced in chains; conidiophores are simple, upright, bear chained conidia.

ROOT AND STEM ROTS

The mungbean seedling is susceptible to rotting of the stem near the soil. This makes the infected portion too weak to support the plant and the young seedling dies. Older plants are also subject to root and stem rots which are caused by various fungi.

Symptoms and Causes

Lesions, caused by *Rhizoctonia solani* Kuhn, appear on the stem near the soil surface and are oblong to elongate, sunken and reddish brown to dark brown with clearly defined margins. The lesion may appear only on one side or may girdle the stem. Roughly circular to irregularly flattened (1-4 mm dia), brown sclerotial bodies soon appear embedded in the infected portion. Roots may disintegrate. Leaves soon wilt, and the plant dies. The host range of this fungus includes soybean, cowpea, tobacco, peanut, common garden bean, corn, eggplant, and pepper (5).

Root and stem rot caused by *Sclerotium rolfsii* Sacc. first appears as dark-brown lesion adjacent to or just below the soil surface. The lesion may later girdle the stem. Under moist conditions a white mycelial mat covers the lesion. Tiny, spherical sclerotia, the size of mustard seed, appear on the affected portion. Sclerotial bodies are whitish or cream at first and turn brown later. In severe cases, the leaves turn dark brown, wilt, and the plant dies.

Other fungi associated with mungbean root and stem rot are the various species of *Fusarium* and *Pythium*. These fungi also cause damping-off in very young seedlings.

RUST

Mungbean rust has been present in the Philippines for sometime as a minor disease. Recently, however, we've observed that many commerical varieties of mungbean are susceptible to rust, and the occurrence of the disease appears to increase in frequency and in extent.

Symptoms

The earliest symptom appears as tiny light-colored flecks or spots on the lower and upper leaf surfaces. In a few days these become dark reddish-brown circular pustules about the size of a pinhead. The rusty or cinnamon-brown color is due to the uredinia containing powdery masses of spores which occur on both leaf surfaces. The pustules may be surrounded by a yellow halo. After some time the leaf turns yellow, then brown as it dries up, shrivels, and defoliation occurs.

Causal organism

The disease is caused by *Uromyces vignae* Barcl Uredinia are sub-epidermal in origin, erumpent, amphigenous, cinnamon-brown on petioles. Uredospore one-celled with 2 usually supra-equatorial pores, obovoid or broadly ellipsoid; wall, echinulate throughout, light golden, 1.2-1.73 um thick. Uredospores measure 25.4-32.0 x 18.8-25.0 um. No other spore stage aside from the uredinial stage was observed.

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Mungbean Scab in Indonesia

Mukelar Amir

OCCURRENCE

A fungus "scab" disease of mungbean occurred at Cikeumeuh and Muara Substation of CRIA, in 1973-1974 (2). The disease seriously attacked almost all mungbean varieties, including Indonesia-improved and promising varieties Siwalik, Arta hijau, and CRIA No. 129.

Further investigations in 1973-1975 at CRIA, Bogor, and the National Institute of Agricultural Sciences, Tokyo, identified the fungus of mungbean scab as *Elsinoe iwatae* Kajiwara et Mukelar sp. n. (3).

SYMPTOMS

The disease appears on leaves, leaf stalks, stems, and pods. When plants are severely infected young leaves curl and plants are stunted.

Leaves. The leaf lesions are at first small, circular, about 1-2 mm in diameter and brown to reddish brown in color. Frequently the leaf tissue around the lesion shows yellowing. The lesion enlarges gradually up to 3-5 mm, and sometimes appears slightly angular. In old lesions, the center turns gray or grayish white and drops out, giving the leaf a "shot-hole" appearance. Leaf lesions are usually produced on or along the veins and midrib. They look like buff-colored scabs, and are more conspicuous on the lower than the upper side of leaves. Leaves show distortion and curling when they are infected at a young stage.

Stems. Lesions on the stem are round to elliptical, 3-5 mm in diameter, gray to grayish white in the center, and surrounded by reddish brown borders. They are sometimes confluent and reach 1 cm or more in length, being parallel to the axis of the stem. Such lesions are somewhat raised and show typical scab symptoms.

Pod. Pod lesions constitute the most conspicuous symptoms of the disease. Individual lesions on immature green pods are somewhat sunken, elliptical, semicircular, or sometimes irregular. They range in size from mere flecks to 5-8 mm in diameter, are dark brown to reddish brown in color, and their centers are frequently gray. As the pods mature, the lesions are raised gradually and the color becomes lighter.

Generally these symptoms resemble those of anthracnose caused by *Colletotrichum lindemuthianum*. The symptoms of scab disease, however, are different with respect to the conspicuous distortion of the organs and the absense of pinkish spore masses on the lesions.

DISTRIBUTION AND HOST RANGE

In a short report from Kenya *E. phaseoli* was designated as the causal fungus of mungbean scab but details were not described (6). In Southeast Asia, we found no report on either *Elsinoe* or *Sphaceloma* attacking mungbean.

Observations conducted in 1975 and 1976 found infected areas in Lampung, Central and East Java. No survey has been conducted on the occurence of mungbean scab in other provinces of Indonesia.

The host range of *E. iwatae* is apparently not wide. At the National Institute of Agricultural Sciences, Tokyo, we studied host plants in 1975. The results are presented in Table 1.

Table 1. Pathogenicity of mungbean scab fungus to leguminous plants; Indonesia, 1975.[a]

Plant name	Variety	1st trial	2nd trial
Mungbean[b]	Siwalik	++++	++++
	CRIA No.129	++++	++++
Azuki bean	Oodate No. 1	+	+
Kidney bean	Kairyo-otabe	-	-
Lima bean	Henderson bush	-	-
Hyacinth-bean	Nakate-shirobana	+	+
Soybean	Norin No. 4	-	-
Asparagus-bean	Kurodane-sanjaku	-	-
Swordbean[b]	CE 52	-	-
	CE 53	-	-
	CE 58		-
Pea	Hakuryu-endo	+	-
Broadbean	Nagasaya-wase-sorrmame	-	-

[a](4). [b]CRIA is the source of these varieties; Japan is the source of all others.

[b]The fungus isolated from mungbean severely infected both Simalik and CRIA No. 129. The symptoms appeared 5 days after inoculation, and typical symptoms could be seen 7-9 days after inoculation (5). This fungus also showed slight pathogenicity to hyacinth-bean (*Dolichos lablab*) and azuki bean (*Phaseolus angularis*). On hyacinth-bean, Chlorosis appeared on hyacinth-bean leaves 4 days after inoculation, and small convex brown spots were produced on leaves and stem 2-4 days later, but they did not enlarge. On adzuki bean, small brown spots were produced on leaf veins and stems. The fungus did not show pathogenicity to other legumes, including sword bean (*Canavalia gladiata*) or lima bean (*Phaseolus lunatus*).

ECONOMIC IMPORTANCE AND YIELD LOSSES

The results from an experiment performed at Cikeumeuh Substation in the 1974-1975 wet season clearly indicates that mungbean scab can cause serious yield losses (4).

The disease significantly decreased with the application of Topsin M, Bavistin, or Benlate, and the yield of treated plots reached about 2.5-2.6 times that of the control.

Further experiments are needed to confirm whether chemical control is economically feasible.

CHEMICAL CONTROL

Further experiments on chemical control were continued in the 1975-1976 wet season. The results indicate (Table 3) that 3 selected fungicides: Thiophanate, Bavistin and Benlate were still effective in controlling mungbean scab.

VARIETAL RESISTANCE

The prevalence and severity of mungbean scab at both the CRIA experimental Station Cikeumeuh and Muara is a hindrance to the breeding program and to seed production at CRIA. Our previous experiment indicated that the disease caused yield losses of about 60%. A control method should be established as soon as possible. Since 1974, joint research between CRIA plant pathologists and breeders have screened hundreds of varieties and lines against this disease using natural infection (Table 4).

PATHOGEN MORPHOLOGY AND TAXONOMY

Kahiwara and Mukelar (3) described the morphological and cultural characteristics of the causal fungus of mungbean scab as follows:

Conidial stage:

Acervuli develop in the central region of recently formed lesions and in the marginal-zone of younger lesions. They are disc- or cushion-shaped. Condidiophores arising from a stroma-like base are very short, closely compacted, and not easily distinguishable.

Conidia are produced abundantly on the conidiophores under favorable conditions and piled up on the acervuli. However, they are scarcely formed on the old lesions. Conidia are hyaline, 1-celled, oblong or elliptical and 5-6.5 x 2-3 µm in size.

Perfect stage:

The fungus produces asci in stroma formed under the host epidermis. Perithecia are absent. The asci develop singly or in groups, sometimes with their wall in contact. Asci are hyaline, ovoid, globose to ellipsoid, 25-27.5 x 17.5-22.5 µm in size. In water, they become oblavate and the outer gelatinous wall ruptures, discharging 8 ascospores from an ascus. Ascospores are obovate or elliptical, hyaline, 2-3 septate, and 11-14 x 5-7.5 µm in size.

Colonies from single ascospores grow slowly on PDA media, reaching 1 cm in diameter after 2 months at room temperature (22°-26°C). Colonies rise conspicuously and have a very wrinkled surface. They are yellowish at first and then turn reddish purple or redish brown in the center. Usually conidia are not present in the colony on PDA.

From these morphological and cultural characteristics, the fungus belongs to *Elsinoe* and *Sphaceloma* are described for the legumes (Table 2).

The mungbean scab appears similar to *E. canavaliae*, *E. dolichi*, and *E. calopognii* in morphology, and is somewhat different from *E. phaseoli*, *E. sebaniae* and *E. wisconsinensis* in the size of asci and conidia. However, the differences among them are not too distinct.

Results of inoculation tests indicate that the fungus of mungbean scab appears to be a different species from *E. canavaliae* and *E. phaseoli*, as it did not show the pathogenicity to sword bean and lima bean.

From the taxonomical concept, when a fungus is the same in the morphology but different in the pathogenicity with a certain species, the fungus is usually designated as a *forma specialis* of that particular species. In view of such a concept, we concluded that *Elsinoe* on legumes might be unified under one species and each should be named as an individual *forma specialis* of *E. canavaliae* as Jenkins (1) already pointed out. It is, however, necessary that further investigations on the pathogenicity of each *Elsinoe* and *Sphaceloma* from the leguminous plants be clearly designated before unification.

Table 2. Comparison of the morphology of the causal fungus of mungbean scab and species of *Elsinoe* and *Shpaceloma* on legumes; Indonesia, 1975.[a]

Species	Asci	Ascospores	Conidia
Fungus of mungbean scab	Ovoid, globose-ellipsoid 25-27.5 x 17.5-22.5 µm	Obovate, elliptical hyaline, 2-3 septate 11-14 x 5-7.5 µm	Oblong, elliptical hyaline 5-6.5 x 2-3 µm
E. canavaliae (Raciborski 1900)	Ovoid, elliptical 20-22 x 16-19 µm	Oblong, hyaline, 2-3 septate 9-12 x 2.8-3.5 µm	
E. calopogonii	Globose, ovate-globose 26-32 x 20-24 µm	Oblong hyaline, 3 septate 14-17 x 4.5-6 µm	
E. dolichi (Jenkins et al.1941)	Subglobose, pyriform ellipsoid 20-32 x 15-22 µm	Immature 1-septate probably becoming 3-septate upon maturity, 7-13 x 3-5.2 µm	On host: 3.5 µm in culture: sperical-elliptical 3-76 x 1.5-3 µm
E. phaseoli (Bruner and Jenkins, 1933)	Ovoid, subellipsoid 40 x 30 µm	Oblong-elliptical, 3 septate 13-15 x 5-6 µm	Spherical, ovoid, oblong-elliptical hyaline, 10 x 4 µm
E. sesbaniae (Limber and Jenkins, 1946)	Globose, ovoid 11.5-16 x 11.5-15 µm	Subclavate-oblong hyaline, 1-3 septate 10-12 x 3.5-4.5 µm	Oblong-ellipsoid 3.6-6 x 1.5-3.5 µm
E. wisconsinensis (Greene 1957)	Loculate, subglobose broadly ellipsoid or ovoid, 15-25 µm	Cylindric hyaline, 3 septate 10-12 x 4-4.5 µm	Ellipsoid, ovoid hyaline 2-7 x 2.5-3.5 µm
S. arachidis (Bitancourt and Jenkins 1940)			Macroconidia: elongate cylindric 0-1 septate 12-20 x 3-4 µm microconidia: sphirical, hyaline
S. glycines (Kurata and Kuribayashi 1954)			Macroconidia: ovoid, elliptical, pale-colored 4.7-13 x 2.1-5.6 µm Microconidia: spherical hyaline
S. korniae (Bitancourt and Jenkins 1940)			Marcroconidia: none Microconidia: oblong, 1 x 0.5 µm

[a](4).

Table 3. Effect of 3 selected fungicides on mungbean scab. Cikeumeuh Substation, 1975-1976 wet season; Indonesia.

Chemicals	Active ingredient	Disease infection		Grain yield	
		I	II	I	II
	-- kg/ha --	---------- % ----------		-------- kg/ha ----------	
Thiophanate 70% WP	0.19	67.92**	53.33**	275.00**	319.71**
Bavistin 50% WP	0.19	56.67**	37.08**	265.17**	271.66**
Benlate 50% WP	0.19	60.00**	52.08**	344.46**	383.21**
Control	-	93.33	95.83	102.33	162.38
LSD at level 5%		3.82		82.15	
1%		5.12		110.24	

I : 1 application at 20 d.a.s. (days after seeding).

II: 2 applications at 20 and 40 d.a.s.

For these reasons, the fungus of mungbean scab is identified as a new species, and proposed here to be named *Elsinoe iwatae* Kajiwara et Mukelar sp. n. until further extensive cross inoculation tests are done with the *Elsinoe* on the legumes. The name of *E. iwatae* is given in memory of D. Y. Iwata who has contributed distinguished service as the leader of the Japan-Indonesia Joint Food Crops Research Program since 1970.

Table 4. Varieties resistant to mungbean scab (*Elsinoe iwatae*); Indonesia.[a]

CRIA Acc.no.	Common names
127	Black matse
9/2	Kacang hijau
100	Black grain var. gwalier 2.
133	Kacang hitam
70	*Phaseolus mungo* No. CPI 12106
74	*Phaseolus mungo* No. CPI 3335
1/2	Boc E. Kojae
14	Kassa
89	Minoe 505
5/2 (R check)	Kacang Hijau I
129 (S check)	BPT mungo No. 50-10A

[a]Replicated 4 times.

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Diseases of Mungbean in India[a]

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Pulses provide essential protein to the vegetarian population of India. Ranking fourth among pulses in area and production, mungbean is grown on 1.94 million ha, and production reached 0.6 million t.

Diseases such as yellow mosaic, and *Cercospora* and bacterial leaf spots cause heavy production losses in mungbean. Prevalent in all states, these diseases are relatively more destructive in the northern and central states of Punjab, Haryana, Rajasthan, Uttar Pradesh, Bihar, Madhya Pradesh, and Orissa. Powdery mildew, another important disease, is prevalent in the southern states of Maharashtra, Andhra Pradesh, Tamil Nadu, and Rajasthan.

In the All-India Co-ordinated Project for Improvement of Pulses, our major emphasis is on the development of high yielding, disease and pest resistant varieties. In order to achieve this, study of the pathogens and identification of sources of resistance are essential.

YELLOW MOSAIC[a]

The first symptoms appear on young leaves as yellow specks or spots. The leaf emerging from the apex shows bright yellow patches interspersed with green areas. In several cases there is complete yellowing of the leaves, and infected plants are stunted in growth. Diseased plants usually mature late and bear very few flowers and pods.

The disease is transmitted by a white fly (*Bemisia tabaci*) to *Vigna radiata*, *V. mungo*, *V. acutifolia*, *V. lathyroides*, *Glycine max*, and *Dolichos biflorus*. The disease is not transmitted through sap, soil, or seed; however, there are reports that transmission can occur by grafting (4,5). In grafting and white fly transmission, disease symptoms appear within 12-16 days. Detailed investigations of the virus/vector relationship revealed that even a single viruliferous white fly can transmit the disease, and 100% transmission was obtained with 10 white flies (11). The vector acquires the virus within 15 minutes of acquisition feeding. The minimum inoculation period was found to be 10 min, and 30-60 min was enough to cause 100% infection. A latent period of 5-6 hrs after acquisition feeding was necessary for successful transmission. Pre- and post-acquisition fasting for different periods did not increase the transmission efficiency of the vector.

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[a]Color pictures of the disease symptoms mentioned are shown on page 158.

Table 1. Incidence and intensity of yellow mosaic in promising mungbean varieties; India, 1976.

Variety	1975 plants infected	1975 disease intensity[a]	1976 plant infected	1976 disease intensity
	%			
L 24-2-1	0	Free	0	Free
15227	0	Free	0	Free
15225	3.0	Traces	0	Free
15229	3.0	Traces	0.5	Traces
15176	6.0	Light	2.0	Traces
15127	10.0	Light	2.0	Traces
LM-168	10.0	Light	10.0	Light
LM-170	5.0	Mod	22.0	Mod
LM-87	15.0	Mod	5.0	Mod
189-4-1	30.0	Heavy	35.7	Heavy
294-1	50.0	Heavy	66.6	Heavy
305	100.0	Heavy	100.0	Heavy

[a]Free (nil); traces (0-5%); light (5-25%); mod (26-50%); and, heavy (above 50%).

We screened 681 mungbean genotypes for resistance to yellow mosaic. The disease reactions of 11 promising lines tested over 2 years under epiphytotic conditions are given in Table 1.

LEAF CRINKLE

The chief symptoms of leaf crinkle are conspicuous crinkling on the upper surface of young leaves. The inflorescence of the affected plant bears large numbers of small flower buds with thick dark-green sepals giving a bushy appearance. The virus is sap, seed, and aphid transmissible (*Aphis craccivora* Koch. and *A. gossypii* Glov.) (1). *Aphis craccivora* is a highly efficient vector giving 100% transmission. Its host range is restricted to mungbean, urdbean, mothbean, and cowpea.

CERCOSPORA LEAF SPOT

The leaf spots caused by *Cercospora canescens* Ellis & Martin are brown with greyish white centers and reddish brown margins. Prevalent in all mungbean growing areas, the pathogen is seed-borne to some extent. The initial symptoms are observed 30-35 days after sowing, depending on temperature and humidity. Sporulation is heavy at 27°C and 96% relative humidity (9). Leaf spots increase in number and size during flowering, but the increase is most rapid in September when the pods are filling. In susceptible varieties infection increases rapidly, resulting in premature defoliation. The size of pods and seed is reduced, thus causing a yield reduction.

The mungbean germplasm collection and promising lines were screened for resistance to *Cercospora* at Ludhiana and Kanpur. LM 162 was graded as resistant to Ludhiana. Lines 6008-1, 364-68-1, 546-68-1, 554-1, and 155-1, showing 0.1-10% leaf infection, were graded as tolerant Kanpur. These lines are being tested at other stations before introduction into the disease resistance breeding program.

Bavistin (2-methoxy carbamoyl benzimidazole), Benlate [2-methyl-1-(butyl carbamoyl)-2-benimidazole carbamate], Captan (N-trichlor methylmercapto-4-cyclohexene, 1-2-dicarboximide), and zineb (Zinc ethylene bisdithiocarbamate) were sprayed on variety S-8, 35 and 50 days after sowing to compare their efficacy for the control of *Cercospora* leaf spot at New Delhi (Table 2).

Table 2. Effect of *Cercospora* leaf spot on the yield of mungbean variety S-8 with different fungicide treatments; India, 1976.[a]

Fungicides	Dosage	1975 disease incidence	1975 yield	1976 disease intensity	1976 yield
	- kg/ha -	------ % ------	- kg/ha -	----- % -----	- kg/ha -
Bavistin	0.5	10.5 (18.91)[b]	750	11.2 (19.52)	700
Benomyl	0.5	24.0 (29.33)	600	25.0 (29.94)	520
Zineb	2.5	25.0 (30.00)	580	25.0 (29.94)	520
Captan	2.5	32.5 (34.57)	540	24.5 (29.08)	510
Control		45.1 (42.19)	500	48.7 (44.27)	470
C.D. at 5% level		(3.94)	0.15	(4.68)	0.94

[a]4 replications in 5 x 3 m plots. [b]Angular transformed values.

POWDERY MILDEW (*Erysiphe polygoni*)

The fungus attacks all parts of the plant except the roots, and initial symptoms are marked by faint, slightly dark areas on the leaf. These areas develop into small, white powdery spots. They enlarge and coalesce to form a complete coating of white powder on leaves, stems, and pods. The powdery mass, consisting of mycelium and conidia, eventually turns dirty white. In cases of severe infection, defoliation takes place. Pods are not formed, and, if already formed, they remain stunted and bear subnormal seeds.

Mungbean germplasm lines and selections were screened for powdery mildew resistance in major mungbean growing states of India. Line 29-13-2 remained free from disease even under epiphytotic conditions at Banapur (Maharashtra). Varieties found resistant in one state were often susceptible in another, and the possible existance of physiologic races has not been ruled out. Powdery mildew can be effectively controlled by 3-4 sprays of wettable suplhur (3 kg/ha) at 10- day intervals starting on the appearance of the disease. Control increases the yield by 35-100% depending on the incidence and intensity of the disease.

ROOT ROT (*RHIZOCTONIA BATATICOLA* AND *RHIZOCTONIA SOLANI*)

Root rot is prevalent in all mungbean growing states, but is particularly important in Tamil Nadu. Mungbean is attacked by *Rhizoctonia bataticola* and *R. solani* in India. The former causes more damage than the later.

R. bataticola attacks the stem at ground level, forming localized dark brown patches which coalesce and encircle the stem. Soon after, a number of tiny black dot-like sclerotia are formed on the surface and below the epidermis on the outer tissue of the stem and root. Mature sclerotia are smooth and measure 100-150 μ. Spots formed on the leaves and stem coalesce to bring about a blight effect. Dark brown to black pycnidia of *Macrophomina phaseoli* are formed on the spots. The pycnospores coming out of pycnidia can infect the host, and help in the aerial spread of the disease. Lines LM-220 and MS 9385 have been found resistant to this disease at Coimbatore.

Rhizoctonia solani attacks mungbean seedlings. It infects the stem at ground level forming reddish brown patches. In older plants the infected leaves and stem wither. Sclerotia on diseased plant parts are bigger than those of *R. bataticola*. Sclerotia are white at first and later change to brown. There is a second type of microscopic growth on leaves: 2-3 sterigmata are borne on club shaped basidia under the white layer of fungus. Each sterigmata carries a single spore. The spores are hyaline, oval, unicellular, 10-12 x 6-8 μ in diameter. The basidial form is known as *Thanatephorus cucumeris* (fr.) Donk. This is produced in nature under well-shaded, damp conditions. *T. cucumeris* infects more than 20 hosts (10).

BACTERIAL LEAF SPOT

Bacterial leaf spot caused by *Xanthomonas phaseoli* (Smith) Dowson was first observed in India on urdbean (8), and in China on mungbean (3). Bacterial leaf spot has been reported from all states and is characterized by raised dry spots. The first appear as superficial eruptions and gradually invade the tissue through the leaf thickness, becoming corky or rough. In some cases, when the corky cells wither away, spots appear sunken or coalesce to form big necrotic areas. The lesions on petioles are brown, raised, occur singly or in long streaks. *Xanthomonas phaseoli* can infect *Phaseolus vulgaris*, *V. lunatus*, *Dolichos lablab*, and *Lens esculentum*, but the reaction is not as severe as on mungbean (6).

Patel et al. screened 2160 mungbean germplasm lines for resistance to *Xanthomonas phaseoli*; 29 proved resistant (7). Lines P 476, P 530, PLM-501, and one variety, Jalgaon 781, were better than others.

HALO BLIGHT

Another seed-borne bacterial disease of mungbean, halo blight, is caused by *Pseudomonas phaseolicola*. Recorded for the first time at New Delhi, halo blight produces water soaked spots surrounded by a characteristic halo, as well as other symptoms similar to bean halo blight (6). The distribution has not been worked out yet.

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Virus Diseases of Mungbean in Indonesia

Mitsuro Iwaki & Hamid Auzay

Mungbean is an important secondary crop in Southeast Asia. In Indonesia, mungbean is cultivated in many localities and an a large area. But, many kinds of diseases causing great yield damage, have been observed during field surveys. The following virus diseases were observed on some mungbean fields: mungbean yellow mosaic virus (4), mungbean mosaic virus (1), urdbean leaf crinkle virus (7), alfalfa mosaic virus (2), cucumber mosaic (2), bean common mosaic virus (3), southern bean mosaic virus (6), and tobacco ringspot virus (5).

In this experiment, the diseased plants were collected, causal viruses were isolated, and the properties of these viruses were investigated. Two viruses isolated were identified as mungbean mosaic virus (MMV) and bean yellow mosaic virus (BYMV).

MUNGBEAN MOSAIC VIRUS (MMV)

Host range and symptom

Thirty-seven plant species belonging to 11 families were inoculated mechanically with the juice of a diseased cowpea leaf by the usual method using carborundum (600 mesh) to test their susceptibility to the virus. The tests were replicated 3 times. The presence of the virus in the inoculated leaves without symptoms one week after the inoculation, and also in the non-inoculated leaves without symptoms 3 weeks after the inoculation, were investigated by back inoculation to *Chenopodium amaranticolor*.

As shown in Table 1, the virus infected 13 plant species belonging to 4 families (Chenopodiaceae, Amaranthaceae, Leguminosae and Pedaliaceae), showing the narrow host range of the virus. Especially, systemic infection was limited on a few plant species.

Transmission test

1. Aphid transmission: aphid transmissibility of the virus was tested by using non-viruliferous aphids (*Aphis craccivora* and *A. glycines*). Cowpea was used as both the source and test plants. Allowed to fast in a glass beaker for about one hour, colonies of these aphids were transferred to the diseased cowpea to feed for 15 min. After acquisition feeding, each 10 insects were transferred to each test plant. The following day, they were killed by insecticide. For the control, 10 non-viruliferous aphids were transferred to each of the test plants to feed. They, too, were killed with insecticide the following day. *A. craccivora* transmitted the virus to 7 of 10 plants in 2 trials; and *A. glycines* transmitted to 15 of 18 plants in 3 trials. However, in control, 6 and 3 plant were not infected by *A. craccivora* and *A. glycines*, respectivel

Table 1. Host range of mungbean mosaic virus (MMV).

Family	Species (variety)	Symptom[a] Inoculated leaf	Symptom[a] non-inoculated leaf
Polygonaceae	*Fagopyrum esculentum*	-	-
Chenopodiaceae	*Chenopodium amaranticolor*	L	-
	Spinacia oleracea	-	-
	Beta vulgaris	(+)	-
Amaranthaceae	*Gomphrena globosa*	(+)	-
Cruciferae	*Brassica rapa*	-	-
	Raphanus sativus	-	-
Leguminosae	*Arachis hypogaea* (Bantong)	-	-
	Astragalus sinicus	-	-
	Centrosema pubescens	-	-
	Crotalaria juncea	-	-
	Glycine max (Okuhara wase)	(+)	-
	Glycine max (Kishiyama edamame)	(+)	-
	Lathyrus odoratus	(+)	-
	Phaseolus angularis	(+)	M
	P. radiatus	(+)	M,Mal
	P. vulgaris (Honkintoki)	L	Mal,M
	P. vulgaris (Top crop)	-	-
	P. vulgaris (Tamashiro kurosando)	(+)	-
	Pisum sativum (Greenpeas)	(+)	-
	Pisum sativum (Sanjunichi kinusaya)	(+)	-
	Trifolium incarnatum	-	-
	T. pratense	-	-
	T. repens	-	-
	T. repens f. giganteum	-	-
	Vicia faba (Wase sorameme)	L	-
	Vigna sesquipedalis (Kurodane sanjaku)	(+)	m
	Vigna sinensis (Black eye)	L	M
Malvaceae	*Hibiscus esculentus*	-	-
Apocynaceae	*Vinca rosea*	-	-
Solanaceae	*Capsicum annuum*	-	-
	Capsicum annuum (Peaman)	-	-
	Datura stramonium	-	-
	Lycopersicon esculentum (Ponderosa)	-	-
	Nicotiana tabacum (Bright yellow)	-	-
	N. glutinosa	-	-
	Petunia hybrida	-	-
Pedaliaceae	*Sesamum indicum*	L	VC,M,Mal
Cucurbitaceae	*Cucumis sativus*	-	-
	Cucurbita pepo	-	-
Compositae	*Arctium lappa*	-	-
	Lactuca sativa (Great Lakes)	-	-
	Lactuca sativa (Maya Head)	-	-
	Zinnia elegans	-	-

[a] L=local lesion, M=mosaic, Mal=malformation, VC=vein-clearing, m=mild mosaic, (+)=no symptom but positive in back inoculation to *C. amaranticolor*, -=no symptom and negative in back inoculation to *C. amaranticolor*.

2. Seed transmission: seed transmissibility of the virus was investigated by using cowpea, mungbean, and adzuki-bean. The plants showing mosaic by mechanical inoculation were grown until maturity in the greenhouse. Seeds harvested from these plants, were planted in pots. The presence of the virus in the seedlings was investigated by back inoculation to *C. amaranticolor*. We tested 826 mungbean seeds (Siwalik, No. 9/2, and No. 26/1), 27 adzuki bean seeds, and 101 cowpea seeds. Among these, 5 of 295 mungbean seedlings (No. 9/2), and 1 of 27 adzuki bean seedlings showed mosaic. The presence of the virus was proven by inoculation tests to *C. amaranticolor*.

Stability in vitro

Thermal inactivation point, dilution end point, and longevity of the virus was investigated from the crude juice of diseased cowpea leaves. Three grams of diseased cowpea leaves were macerated together with 30 ml of 0.05 mol phosphate buffer (PB) (pH 7.2), and squeezed through double cheesecloth. This juice was centrifuged at 3000 rpm for 20 min, and the supernatant was used as a crude juice. Infectivity of the virus was assessed by the number of local lesions on 4-6 leaves of *C. amaranticolor* inoculated. Thermal inactivation point of the virus was 55°-65°C for 10 min, dilution end point was 1,000-100,000 times, and longevity in vitro was 3-7 days.

Virus particles

Two kinds of samples were prepared from diseased cowpea leaves by the dip and direct negative staining methods. These samples were sent to Japan by air mail and observed by Dr. Tochihara at the Institute for Plant Virus Research, using EM Hitachi HU 11B in Chiba, Japan. Elongated flexuous particles, 700-750 nm in length, were observed in both samples.

Serological test

One gram of diseased leaf was macerated together with 5 ml of 0.05 mol PB (pH 7.2), and squeezed through double cheesecloth. Then, this juice was centrifuged at 10,000 rpm for 5 min. The clarified juice was used as an antigen. One drop each of antigen and antiserum against BYMV, which was provided by Dr. Tochihara, were dropped in the hole of a slideglass, and mixed. This solution was covered by liquid paraffin. The reaction was observed 2 hrs after mixing and results showed no reaction in every trial.

BEAN YELLOW MOSAIC VIRUS (BYMV)

Host range and symptoms

Thirty-six plant species of 11 families were inoculated mechanically with the juice of diseased cowpea leaves to test their susceptibility to the virus. As shown in Table 2, 21 plant species of 6 families (Chenopodiaceae, Amaranthaceae, Leguminosae, Solanaceae, Pedaliaceae and Compositae) were proved susceptible to the virus, indicating that the virus has a wider host range than MMV.

Transmission test

1. Aphid transmission: aphid transmissibility of the virus was investigated using non-viruliferous aphids (*A. craccivora* and *A. glycines*). Soybean and mungbean plants were used as virus source plants. Healthy soybean and cowpea were used for test plants. *A. craccivora* transmitted the virus to 3 of 6 plants, and *A. glycines* transmitted it to 9 of 10 plants in 2 trials.

2. Seed transmission: seed transmissibility of the virus was investigated by using mungbean, soybean, and cowpea. These plants, inoculated with the virus and producing mosaic, were grown in the greenhouse until maturity. The seeds were harvested and sown in pots in the greenhouse. The presence of the virus in the seedlings was investigated by the inoculation to *C. amaranticolor*. There were 270 mungbean seedlings (Siwalik and Bhakti), 137 soybean, and 22 cowpea. Only 2 mungbean seedlings (Siwalik) showed mosaic, and the presence of the virus was proven by inoculation tests, but the other seedlings had no virus.

Table 2. Host range of bean yellow mosaic virus (BYMV).

Genus	Species (variety)	Symptom[a] inoculated leaf	Symptom[a] non-inoculated leaf
Polygonaceae	*Fagopyrum esculentum*	-	-
Chenopodiaceae	*Chenopodium amaranticolor*	L	-
	Beta vulgaris	(+)	-
Amaranthaceae	*Gomphrena globosa*	(+)	-
Cruciferae	*Brassica rapa*	-	-
	Raphanus sativus	-	-
Leguminosae	*Arachis hypogaea* (Banteng)	(+)	-
	Astragalus sinicus	L	VC,M
	Centrosema pubescens	(+)	M
	Crotalaria juncea	(+)	VC,M
	Glycine max (Okuhara wase)	L	CS,M
	Glycine max (Kishiyama edamame)	L	CS,M
	Lathyrus odoratus	L	-
	Phaseolus angularis	-	-
	P. radiatus	(+)	M
	P. vulgaris (Honkintoki)	L	CS,M
	P. vulgaris (Top crop)	-	-
	P. vulgaris (Yamashiro kurosando)	(+)	-
	Pisum sativum (Greenpeas)	(+)	CS
	Pisum sativum (Sanjunichi kinusaya)	(+)	CS
	Trifolium incarnatum	(+)	M
	T. pratense	-	-
	T. repens	(+)	-
	T. repens f. giganteum	-	-
	Vicia faba (Wase nagasaya)	(+)	CS,M
	Vigna sesquipedalis (Kurodane sanjaku)	(+)	-
	V. sinensis (Black eye)	L	M
Malvaceae	*Hibiscus esculentus*	-	-
Apocynaceae	*Vinca rosea*	-	-
Solanaceae	*Capsicum annuum*	-	-
	Capsicum annuum (Peeman)	-	-
	Datura stramonium	-	-
	Lycopersicon esculentum (Ponderosa)	-	-
	Nicotiana tabacum (Bright yellow)	(+)	-
	N. glutinosa	-	-
	Petunia hybrida	(+)	-
Pedaliaceae	*Sesamum indicum*	L	VC,M
Cucurbitaceae	*Cucumis sativus*	-	-
	Cucurbita pepo	-	-
Compositae	*Arctium lappa*	-	-
	Lactuca sativa (Great Lakes)	-	-
	Lactuca sativa (Maya head)	-	-
	Zinnia elegans	(+)	-

[a]L=local lesion, M=mosaic, VC=vein clearing, mM=mild mosaic, CS=chlorotic spot, (+)=no symptom but positive in back inoculation to *C. amaranticolor*, -=no symptom and negative in back inoculation to *C. amaranticolor*.

Stability in vitro

Thermal inactivation point, dilution end point, and longevity of the virus were tested using the crude juice of diseased soybean leaves. The crude juice was prepared the as same as with MMV.

The thermal inactivation point of the virus was 55°-60°C for 10 min dilution end point was 10,000-1,000,000 times, longevity in vitro was 3-7 days at room temperature (24-30°C).

Virus particles

Samples were prepared from diseased soybean leaves as previously described. The present virus consisted of elongated flexuous particle, 700-750 nm in length.

Serological test

Test methods were the same as MMV. The reaction of antiserum to antigen from the diseased soybean leaves was found positive, but negative to that from healthy leaves, indication that the virus has a serological relationship with BYMV.

EFFECT OF INFECTION OF 2 VIRUSES ON MUNGBEAN YIELD

The effects of the 2 viruses on mungbean yield was investigated by using mungbean (Bhakti) grown in pots (1/5000 a). Each virus was inoculated on 6 plants, and 6 healthy plants were used as the control. These pots, put in the greenhouse at random, were grown for about 2 months. The number and weight of seeds from diseased plants, measured after harvest, decreased about 64-78% compared to those from healthy plants. The rate of decrease was larger for MMV than BYMV. But it was not clear whether this difference was due to the virus or to the susceptibility of the variety of mungbean to each virus.

REACTION OF VARIETIES/LINES OF MUNGBEAN TO 2 VIRUSES

Eight mungbean varieties/lines (Siwalik, Arta Ijo, Bhakti, No. 5/2, No. 9/2, No. 108, No. 129, and No. 160), from the Agronomy Division of CRIA, were tested for resistance to MMV and BYMV by mechanical inoculation. The reaction of each variety/line was very different. Siwalik, Arta Ijo, and No. 160 seemed to be resistant to MMV, showing a low percentage of infected plants. However, there were no varieties/lines that seemed resistant to BYMV

DISCUSSION

The occurrence of MMV and BYMV on mungbean in Indonesia was proven in this test. MMV is a seed-borne virus, and the percentage (0-25%) of seed transmission is very different depending on variety (1). Although the percentage of seed transmission was low on varieties/lines used in this test, it should be investigated on others. However, a few varieties/lines seemed resistant to MMV. Further field tests are desirable.

BYMV was shown to have a wide host range in leguminous plants. BYMV is usually not seed-borne, but it was reported that the virus could be tranmitted through the seed of such plants as: pea, broadbean, white sweet clover, and yellow and white lupin. In this test, the virus was transmitted through mungbean seed (Siwalik), although the percentage was low (about 1%). Varieties of mungbean resistant to BYMV were not found in this test.

These viruses in mungbean do not occur widely in Indonesia. But, the fact that these viruses are transmitted through seeds is very important, because they might be introduced by seed to new localities. Therefore, precautions should be taken to collect seeds from healthy plants. Efforts should be made to find resistant varieties.

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Virus Diseases of Mungbean in The Philippines

Dante R.A. Benigno & Angelita C. Dolores

INTRODUCTION

Only 11 mungbean diseases have so far been reported in the Philippines (2). Six of these are caused by fungi, 3 by nematodes, and 2 by viruses (Table 1).

Investigations on mungbean virus diseases in this country started only recently. This paper describes 4 virus diseases and their viruses.

YELLOW MOSAIC

The virus causing the yellow mosaic disease is isometric, measuring about 25-30 nm. It is a seed-borne virus and readily sap transmitted, but not apparently transmitted by aphids,[a] by leafhoppers (*Nisia atrovenosa* Leth. & *Sogatella furcifera* Howarth), or by whitefly (*Bemisia tabaci* Genn.). It is highly stable *in vitro* being still infectious at 100°C after 10 min exposure, and at $1{:}10^8$ dilution. The virus in crude extracts, kept at room temperature (25°-32°C), lost infectivity after 3 weeks but remained infectious for more than 3 months when kept at freezing temperatures. It causes necrotic local lesions and systemic yellow mosaic in mungbean, necrotic local lesions on cotyledon leaves of *Vigna unguiculata*, and vein necrosis on *Phaseolus vulgaris*. *Chenopodium amaranticolor, Datura Stramonium, Gomphrena globosa, Nicotiana glutinosa*, and *N. tabacum* were not hosts of the virus (6).

GREEN MOSAIC

The virus causing green mosaic is rod-shaped, measuring on the average about 333 nm, and aphid-borne. It does not induce necrotic local lesions in mungbean and *V. unguiculata*, but produces numerous small faint chlorotic local lesions on *C. amaranticolor*. In mungbean, inoculated cotyledon leaves usually exhibit vein necrosis. The uninoculated first trifoliate leaves show vein yellowing with several tiny yellow dots, followed eventually by systemic green mosaic. It is also seed-borne and readily transmitted mechanically by sap. It is very stable *in vitro* with a thermal inactivation point between 90°-100°C and a dilution end-point between $1{:}10^4$-10^5.

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[a]According to Soria, *Aphis craccivora* Kock, is the vector of this virus (10).

Table 1. Diseases of mungbean in the Philippines.

Causal organism	Disease	Reference
Cercospora cruenta Sacc.	Leaf spot	12
Colletotrichum lindemuthianum (Sacc.&Magn.) Briosi & Cav.	Anthracnose	7
Erysiphe polygoni DC.	Powdery mildew	9
Meloidogyne javanica (Tr.) Chit	Root-knot	11
Meloidogyne spp.	Root-knot	5
Pratylenchus spp.	Root lesion or root rot	5
Rhizoctonia solani Kuedin	Blight, stem end-rot	8
Rotylenchulus sp.	Root rot or decay	3
Uromyces appendiculatus (Pers.) Link	Rust	9
Virus	Mosaic	4
Virus	Yellow mosaic	6

LEAF CURL BROWNING

Leaf curl browning virus is aphid-borne, seed-borne, and transmitted mechanically by sap. It induces narrowing and inward curling of top leaves, enlargement of veins, followed by a purplish-brown discoloration on the nether surface of curled leaves. It induces very few large chlorotic local lesions in *C. amaranticolor* with pin-head sized straw-colored centers. No reactions were observed on *D. stramonium, G. globosa, N. glutinosa,* and *N. tabacum*. No virus particles were seen in the electron microscope when crude and semi-purified extracts were examined. This difficulty in locating the virus particles could be due to a low virus concentration as evidenced by the few lesions produced on *C. amaranticolor* when inoculated mechanically.

LITTLE LEAF

The morphology of the virus causing littleleaf is not yet established. However, it is also seed- and aphid-borne, but apparently not mechanically transmitted by sap. No other properties of the virus are known. It is suspected that this virus is similar to, if not the same as, the cowpea littleleaf virus previously reported (1).

Aphis craccivora Kock, an aphid which colonizes on mungbean, transmitted all the last 3 named viruses in a nonpersistant manner.

REMARKS

All 4 virus diseases can occur in a mungbean plant or in one field at the same time. However, all 4 can also be isolated into pure cultures by using differential hosts (Table 2). Mungbean and cowpea are good diagnostic hosts for mungbean yellow mosaic virus for they react by local lesions when inoculated mechanically. Mungbean and *C. amaranticolor* are good diagnostic hosts for mungbean green mosaic virus for mungbean reacts by *vein necrosis* (cotyledon leaves only) while *C. amaranticolor* by numerous faint *small chlorotic local lesions*. For the leaf curl-browning, *C. amaranticolor* is a good diagnostic host for it reacts by large chlorotic local lesions with distinct pin-head sized straw-colored center. Littleleaf virus can be isolated through aphid-transmission to mungbean using *Aphis craccivora* as the vector. Trifoliate leaves become diminutive in size.

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Table 2. Differentiating the 4 mungbean viruses through the use of differential hosts.

Virus		Remarks
Mungbean yellow misaic	*Phaseolus radiatus*	Necrotic local lesion and systemic mosaic
	Vigna unguiculata	Necrotic local lesion
	Phaseolus vulgaris	Vein necrosis
Mungbean green mosaic	*Phaseolus radiatus*	Vein necrosis and systemic mosaic
	Chenopodium amaranticolor	Numerous small, faint chlorotic local lesion
Mungbean leafcurl-browning	*Chenopodium amaranticolor*	Very few large chlorotic local lesion with pinhead size straw-colored center
	Phaseolus radiatus	Inward curling of top leaves, enlargement of veins, browning of nether surface of leaves
Mungbean little leaf	*Phaseolus radiatus*	Diminutive trifoliate leaves

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Breeding for Yellow Mosaic Virus Resistance in Mungbean

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Mungbean has been cultivated in India since ancient times. Numerous varieties are found in different parts of the country, but this plant is not known in the wild state. The closest related species is *Vigna radiata* var. *sublobata* (Roxb.) which grows wild in India and Indonesia, and may be the proginator of both mungbean and urdbean (*V. mungo*).

Disease reduces the average yields of both mungbean and urdbean in India. The major diseases in order of severity are mungbean yellow mosaic virus (MYMV), bacterial blight (C.O.:*Xanthomonas phaseoli*), leaf spot (C.O.:*Cercospora cruenta*), and leaf crinkly and leaf curl viruses. Powdery mildew, among others, is of minor importance in northern India.

MYMV is the major disease limiting the exploitation of mungbean yield potential, and breeding for MYMV resistance is of prime importance to production. Disease surveys show that MYMV is prevalent on mungbean, urdbean, and soybean throughout India, and is most severe in the north (1).

TRANSMISSION AND HOST RANGE

MYMV is transmitted by whitefly (*Bemesia tabaci*) Genn. (3). Nene examined the host-virus-vector relationship and reported that this virus is not transmitted through soil, seeds, sap, or by any other insect (5,6). MYMV infects many host plants such as: *Brachiara ramosa* (Gramineae); *Cajanus cajan, Dolichos biflorus, Vigna aconitifolia, Phaseolus acutifolius, V. radiata* var. *radiata, P. lathyroides, V. mungo*(Leguminosae); *Eclipta alba* and *Xanthium strumarium* (Compositae)(3,7). Two additional hosts, *Cosmos bipinnatus* cav. and *P. vulgaris* L. var. Manitou, were reported by Rathi and Nene (8).

SYMPTOMS

MYMV symptoms on mungbean appear as yellow mottling on susceptible varieties with mild scattered yellow specks or spots appearing on young leaves. The next trifoliate leaf emerging from the growing apex shows alternating irregular yellow and green patches. The size of the yellow areas increases in the new growth, and utlimately some of the apical leaves turn completely yellow. The diseased plants usually mature late and bear very few flowers and pods. The pod size is reduced and the proportion of immature and small seeds increases with the severity of the disease. On some varieties mottling of seeds with a yellow tint may occur. Another type of symptom, called necrotic mottling occurs, on some urdbean cultivars (4). The necrotic mottle is visible first as small spots well delimited by finer veins. The spots increase in number but not much in size. Very soon a necrotic center develops in most of these yellow specks; however, the leaves rarely turn completely yellow. These symptoms are systemic and both the necrotic and yellow mottle are host reactions to the same virus. The varieties showing necrotic mottle yield better and are less severely affected than those showing yellow mottle. Apparently, the necrotic mottle is a type of resistant reaction to MYMV (2). Under field conditions the spread of yellow mosaic in the yellow mottle type of varieties is faster than in the necrotic mottle type. The differences in acquisition feedings of these 2 groups of varieties may be responsible for the differences in rate of spread; or these differences may be due to differential nutritional compatibility of the host plant and the virus.

BREEDING FOR RESISTANCE

The wide host range of MYMV and the presence of host plants throughout the year leave no other alternative except to breed varieties with inherent resistance to minimize yield loss. The generally high mutation rate in viruses makes vertical resistance less dependable, so horizontal resistance is favored in such situations.

In the Punjab, mungbean improvement was initiated in the 1930's by making pure line selections from local mixtures. As a result of selection, 2 improved mungbean varieties, No. 54 and No. 305, were released for cultivation under irrigated and rainfed conditions, respectively. Moong No. 54 was fairly tolerant to MYMV, and other bacterial and fungal diseases. The yield potential of these varieties was not more than 700 kg/ha. Shinning Moong No. 1, a selection from China, was released in 1962 for spring cultivation on the plains, and for general cultivation in the hills. Though this variety could give a good spring crop (March-June), the yield potential did not improve much.

IMPROVED MYMV RESISTANT VARIETIES

The research on mungbean was intensified at the Punjab Agricultural University in 1967. Objectives included yield improvement and its stabilization by incorporating resistance to MYMV and other diseases. Screening available germplasm for disease resistance, and the hybridization of elite strains were initiated simultaneously. This breeding program led to the development of new improved lines which were more resistant to MYMV and other diseases. A significant improvement in grain yield was also achieved in a limited number of lines. Out of these lines, ML 1 was released for general cultivation in the Punjab in 1973, but it had hard seeds. Another strain, ML 5, which was free from hard seeds had a marginally higher yield than ML 1 and was released for cultivation in the Punjab in 1977. This variety was approved for general cultivation in the north plain (west and east zones) of India. The yield potential of both these varieties is about 2500 kg/ha, but on the average they yield 1000-1200 kg/ha. They possess a fair degree of field resistance to MYMV.

The performance of some newly developed promising strains at Ludh.ana during *kharif*, 1976, is given in Table 1.

ML 109, 131, and 161, which possess a high degree of resistance to MYMV, will be further assessed in disease and insect pest nurseries at Ludhiana and Gurdaspur, as well as in multilocation yield trials.

The derived lines from different crosses possess a higher degree of resistance than either of the parents as a result of selection pressure applied during segregating generation for MYMV resistance under heavy natural disease incidence at Ludhiana. This resistance appears to be of the horizontal type in many strains. No work on MYMV inheritance has so far been reported in India; however, investigations have been initiated at Ludhiana.

RESISTANT GENETIC STOCKS

Some ML lines having a high degree of resistance to MYMV, as indicated by the initial observations during *kharif*, 1976, are: 37, 74, 94, 101, 102, 104, 105, 113, 116, 124, 125, 126, 127, 128, 129, 130, 132, 133, 134, 154, 157, 158, 162, 163, 164, 165, 166, 167, 168, and 171. These lines will be further critically evaluated in disease nurseries at 2 locations, and utilized in a crossing program.

The following ML lines, evaluated in 1973 at Missouri Agricultural Experiment Station, Columbia, against an unidentified complex of viruses, were given a virus score of around 20 on a scale of 0-100: 1, 3, 4, 18, 24, 29, 37 (12). The viruses were suspected of transmission by an insect. ML 1 and 3 were observed to be fairly resistant, and ML 37 was highly resistant to MYMV at Ludhiana under field conditions.

The preliminary screening in 1972 of the 713 LM germplasm lines available at Ludhiana under heavy natural incidence of MYMV indicated that only 13 lines possess some degree of resistance: 134 from Madagascar; 168 from Pakistan; 238, 392, 404, 496, 509, 687, and 692 from India; 113 from Afganistan; 170 and 171 from Iran; and 87 from Turkey (10). Further evaluation of these lines and other lines under field and glasshouse conditions during 1973 and 1974 found LM 94, 168, 354, 392, 404, 671, and 692 tolerant to MYMV

Table 1. Performance of promising strains at Ludhiana during *kharif*, India, 1976.

Variety	Pedigree	Avg. yield	Days to maturity	100-seed wt	Disease score[a] MYMV	BB	LS
		-- kg/ha --		- g -			
Trial 1							
ML 53	EC 27515 x Hyb. 45	1643	88	2.6	2.75	3.25	2.50
ML 5 (check)		1290	87	2.5	3.00	3.50	4.50
C.D. 5%		172					
Trial 2							
ML 109	ML 1 x ML 13	1390	82	2.5	0.00	2.00	4.75
ML 111	G 65 x ML 4	1310	78	2.4	1.00	3.25	5.00
ML 5 (check)		1189	86	2.5	2.50	3.25	4.75
C.D. 5%		216					
Trial 3							
ML 131	ML 4 x ML 23	1154	82	2.9	1.00	2.00	4.00
ML 135	ML 1 x ML 23	1154	87	2.7	1.75	2.00	3.75
ML 5 (check)		822	87	2.7	2.50	2.50	4.00
C.D. 5%		236					
Trial 4							
ML 161	ML 7 x ML 23	1203	87	2.6	0.00	3.66	3.00
ML 5 (check)		979	85	2.4	3.00	3.66	3.66
C.D. 5%		326					

[a] MYMV - mungbean yellow mosaic virus; BB - bacterial blight, LS - leaf spot; disease scale: 0-free, 1-traces, 2-light, 3-medium, 4-high, 5-very high.

(11). LM 214 was resistant under both glasshouse and field conditions, and appeared to be better among all the lines tested. Lines LM 113, 168, 170, 171, and 404 were resistant to MYMV under field conditions at Ludhiana, and also possessed a high degree of resistance (or tolerance) to bacterial blight and *Cercospora* leaf spot.

FUTURE PROGRAM

The diverse genetic material generated from crosses discussed in the previous section will be selected for better plant type, optimum maturity period, and resistance to MYMV and other diseases. With this, we hope to push up the yields further by breeding for better plant types responsive to increased plant population and for disease and pest resistance. We propose to screen the entire world mungbean germplasm in collaboration with AVRDC, Taiwan, against MYMV under field condition at Ludhiana. We hope to identify diverse sources of resistance in order to further enlarge the genetic base in breeding for higher yield potential. The resistance of MYMV is also achievable by breeding for vector resistance. Screening for resistance to whitefly is under way. Mutation breeding for inducing vector and virus resistance needs to be explored.

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Major Mungbean Insect Pest Management Alternatives

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Insect pests attack mungbean[a] throughout its growth and storage. Beanflies, (*Ophiomyia phaseoli* (Tryon), *O. centrocematis* (de Meijere), and *Melanagromyza sojae* (Zehntner), attack especially in the seedling stage and, at times, severely weaken or totally destroy the crop stand. Cowpea aphids (*Aphis craccivora* Koch) attack throughout the growing period; however, their occurrence is usually confined to the cooler months. Although cowpea weevil (*Callosobruchus chinensis* (Linn.)) infestation starts in the field during pod development, the main damage occurs during storage periods when the grain is riddled with holes and covered with egg masses. At the Asian Vegetable Research and Development Center (AVRDC) we launched an integrated mungbean pest management program which included screening for varietal resistance, application of chemicals, and pest and parasite population monitoring.

VARIETAL RESISTANCE

In the beanfly resistance field screening we planted 50 seeds of each accession. Two 10-plant dissection counts were made for each variety 4 and 6 weeks after planting. The number of beanfly larvae and pupae/plant, and percentage of plants with damaged stems, were recorded. The greenhouse screening test was similar to the field tests except that fewer plants and fewer varieties were used under caged conditions with introduced beanflies.

As of June 1976, 2640 AVRDC mungbean accessions had been screened for beanflies 2 or more times in different seasons. AVRDC accession numbers 1667, 1741, 2517, 2520, and 2774 were selected as moderately resistant. One hundred cultivars selected by AVRDC plant breeders for superior agronomic traits and designated as parental lines were screened in Taiwan, Thailand, and Indonesia (Table 1). A standard deviation (SD) classification technique was applied to the data counts to rank the mungbean varieties into 5 categories. Those accessions ranking more than 2 SD below the overall mean were catagorized as highly resistant, those more than one SD below were considered to be moderately resistant. Twelve accessions were thus selected as moderately resistant in 2 locations and one accession, 2500 (LM 196), was moderately resistant at all 3 test sites.

We developed a systematic mass-screening technique in 1976. High beanfly populations were maintained by sequentially planting known susceptible varieties of soybean, mungbean, and snapbean as source rows at 2-week intervals. A series of screenings were regularly conducted by

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[a]Pictures of the insect pests discussed may be seen on page 160

Table 1. Mungbean varieties with moderate beanfly resistance at 2 or more Asian test locations; AVRDC, 1975.[a]

AVRDC acc no.	Cultivar	Location[b]		
		Taiwan	Thailand	Indonesia
1180	LM 115	X		X
1533	LM 001		X	X
1548	NP-16-3		X	X
1667	M 0236	X		X
1741	LM 210	X		X
2106	M 1879	X	X	
2127	M 1897	X		X
2275	ML-8	X	X	
2366	CO-1		X	X
2500	LM 196	X	X	X
2542	NALUR	X		X
2547	LM 210	X		X
2774	ML-4	X		X

[a]100 entries planted at each location. [b]Shanhua, Taiwan - planting date: Nov 3, sampled: Dec 4-12; Chiang Mai, Thailand- planting date: Mar 2, sampled: Apr 4; Bogor, Indonesia- planting date: Sept 29, sampled: Nov 4-5.

planting 100-140 accessions once biweekly. Data counts and varietal resistance ranking methods used the SD classification technique. As of March 1977, we have screened 1180 AVRDC mungbean accessions using this system and 24 accessions were ranked as moderately resistant.

We also evaluated mungbean varieties for resistance to cowpea aphids twice during spring, 1976. In the first greenhouse screening, 100 mungbean varieties were planted in pots and aphids were released at 14, 18, and 21 days after planting. Aphid infestation levels were evaluated on each variety 2 weeks after the initial release. Varieties which had the lowest number of aphids in the first screening were selected and screened again for confirmation. In the second screening with 3 replications, 18 cultivars identified in the first screening as either highly resistant or resistant were compared to a variety previously classified as highly susceptible. The results of the first and second screenings were consistent. We selected 14 varieties as free from cowpea aphid attack (Table 2).

Table 2. Secondary screening of cowpea aphid resistant mungbean cultivars; AVRDC, 1976.[a]

AVRDC acc. no.	Cultivar	Screening[b]	
		1	2
1180	LM 115	HR	S
1250	M 0101	HR	HR
1377	EG-MG-12	HR	HR
1381	MG 50-10A	HR	HR
1387	CES-55	HR	HR
1952	R.S. 4	HS	HS
1394	EG-MG-4	HR	HR
1397	PHLV. #18	HR	HR
1476	Stb. #129	HR	HR
1854	OB 76-1/4	HR	HR
1944	MG 50-10A yellow	HR	HR
1952	R.S. 4	HS	HS
1945	BPI Glabrous # 3	HR	HR
1946	Yellow Mungo	HR	HR
1947	CES-44	HR	HR
2179	PHLV. #13	HR	HR
1954	S-8	HS	S
1952	R.S. 4	HS	S
2837	V 1067-1-1	HR	HR
1177	M 0236	R	S
1410	MD 15-2	R	HR
2216	PHLV. # 177	R	HR
1952	R.S. 4	HS	HS

[a]Planting date: 30/4/76; aphid release dates: 13/5/76, 17/5/76, 20/5/76; sample date: 5/25/76. [b]Resistance rating: no aphids, highly resistant (HR); 10-100 aphids/plant, resistant (R); 10-1000 aphids/plant, susceptible (S); more than 1000 aphids/plant, highly susceptible (HS).

CHEMICAL CONTROL AGENTS

In late 1975 and 1976, we conducted 3 insecticide evaluation experiments at AVRDC. Each experiment, involving 9 insecticides and a control (10 m^2 plot size), was replicated 4 times in a randomized complete block experimental design. Granular insecticides were topdressed by hand, and emulsifiable and wettable powder formulations were applied with air pressure sprayers. Evaluation was based on the dissection and count of the actural number of larvae and pupae, and the percentage of damaged plants in 30 plant samples. Oxamyl 24 ℓ (0.25 kg, a.i./ha) was most effective for the control of beanflies in a winter test. In an early spring test, phorate 10 g (1 kg, a.i./ha). DDT 25 EC (0.5 kg, a.i./ha), and carbofuran 40 F (2 kg, a.i./ha) foliar sprays provided the most effective control. In a later spring trial, phorate and disulfoton 5 g (2 kg, a.i./ha) granular treatments provided the best control.

In an experiment evaluating phostoxin (aluminum phosphide) to control southern cowpea weevil, we found that all life stages were killed by a dosage of 1.6 g/1000 ℓ. In addition to the phostoxin treatment, peanut oil mixed with mungbean seeds at the rate of 2.0 ml/kg of seeds provides protection from the cowpea weevil for up to 4 months, and the treatment has no adverse effects on seed viability.

LOCAL INFESTATION PREDICTION THROUGH THE MONITORING OF POPULATION DYNAMICS

During 1976, a pest population dynamics study monitored beanflies and their parasites. Beanfly larval and pupal populations increased in February and declined in May. Numbers remained comparatively low until November, when there was an abrupt population increase which was the maximum observed for the year (Fig. 1). The percentage of damaged plants reached 100% in February and May, then fluctuated between about 20-80% until November when 100% was again reached. We observed a positive correlation between the beanfly

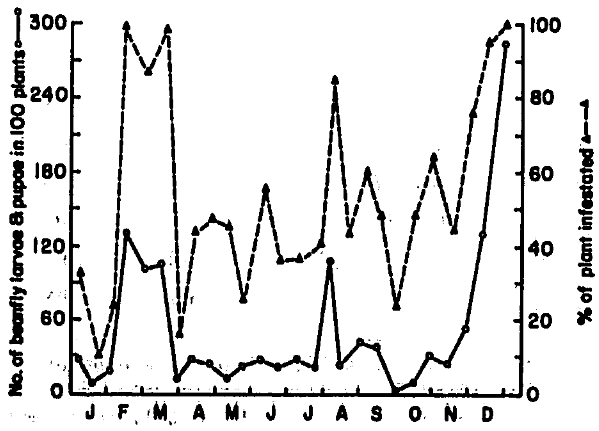

Fig. 1. Variation in beanfly population and mungbean plant infestation, 4 weeks after planting at AVRDC during 1976.

population and the percentage of plants with damage similar to a 1975 survey of AVRDC (1). The percentage of parasitized beanfly pupae fluctuated considerably during the year but surpassed 60% during July and declined to nearly 0% in December and January (Fig. 2). As expected, a negative correlation existed between the populations of beanfly and the parasite and, thus, the parasite appears to suppress the beanfly population.

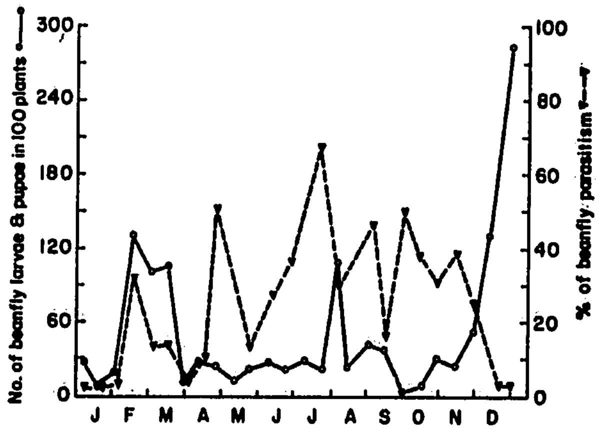

Fig. 2. Variation in beanfly population and parasitization, weeks after mungbean planting at AVRDC during 1976.

CONCLUSIONS

The purpose of integrated pest management is to utilize at least 2 control methods to reduce pest populations and maintain them at levels below economic significance while minimizing cost, labor, and pesticide hazards. Use of the pest management practices discussed in this paper would be simple, feasible, and compatible for practical application on the farmer's fields.

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Introducing Pest Control Technology to a Low Management Crop: The Mungbean Example in The Philippines

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INTRODUCTION

Pest control technology is a component of the multidisciplinary approach in the design and testing of new cropping patterns at the International Rice Research Institute and the Philippine Bureau of Plant Industry. Sites in the Philippines currently receiving the attention of the Cropping Systems research team are: Tanauan, Batangas (upland rice); Oton and Tigbauan, Iloilo; and Manaoag, Pangasinan (rainfed or partially irrigated lowland rice) (3,5).

The site-specific focus of the program calls for pest control technology designed to fit the local conditions of farmer resources, managerial capabilities, crop production practices, pesticide availability, traditional cropping systems, and pest complexes. Most of our research effort focuses on adapting recommended pest control practices rather than formulating new ones.

MUNGBEAN - A LOW MANAGEMENT CROP

Mungbeans in the Philippines are most commonly grown by rice farmers cultivating small land units in lowland rainfed or upland areas where little or no irrigation is available (6). Over the years these farmers have evolved methods of cultivation fitted to local physical and biological conditions. Although farmers purchase seed and insecticides, cash inputs are low since fertilizers, herbicides, or fungicides are seldom included.

Our research over the past 2 years on farmers' fields has demonstrated that yields of over 1,500 kg/ha are attainable if higher insecticide inputs are used (4). With such a demonstrable potential, why is it that farmers do not employ higher management levels to mungbeans as they do to rice?

In this paper we address the issues behind the yield gap between farmer- and research-managed fields, and point out the implications to future research and extension efforts.

THE PEST PROBLEMS

Two years' research has revealed that mungbeans are attacked by 26 insects, 6 diseases, and 2 nematodes from the seedling stage through post harvest (Table 1).

Table 1. Check list of mungbean insect, disease, and nematode pests with reference to type of plant damage, pest status and peak infestation levels recorded in each of the three Philippine provinces, 1975-76.

Pest species	Damage/pest status[a]	Mean peak infestation levels recorded by province: Sampling unit	Batangas 1975	Iloilo 1975	Pangasinan 1975	Pangasinan 1976
INSECT						
Beanfly *Ophiomyia phaseoli* (Tryon) (Agromyzidae)	Plant stunting, seedling loss (BPI)	Larvae + pupae/ 15 plants	5	7	8	11
Flea beetle *Longitarsus manilensis* Weise (Chrysomelidae)	Seedling loss, defoliation (P)	10 net sweeps at night	2	8	83	21
Leaffolder *Lamprosema indicata* L. (Pyralidae)	Defoliation	No. tunnels/ 15 plants	< 1	4	< 14	< 1
Coffee leaf roller *Homona coffearia* Nietner (Tortricidae)	Defoliation	"	< 1	5	3	2
Leaf roller *Sylepta sabinusalis* Walker (Pyralidae)	Defoliation	"	< 1	3	0	0
Leafhopper *Empoasca biguttula* Shiraki (Cicidallidae)	Plant stunting (BP)	No. nymphs/ 15 plants	7	< 1	25	2
Black bean aphid *Aphis craccivora* Koch (Aphidae)	Plant stunting (BI)	Rating scale	Small colony/ plant	Small colony/ plant	None	Small colony/ plant
Semi-looper *Chrysodeixis chalcites* (Esper) (Noctuidae)	Defoliation	No. larvae/ 15 plants	2	< 1	< 1	1
Cutworm *Spodoptera litura* (Fabricius) (Noctuidae)	Defoliation	"	< 1	1	< 1	12
Armyworm *Mythimna separata* (Walker) (Noctuidae)	Defoliation	"	< 1	< 1	< 1	< 1
Hornworm *Agrius convolvuli* (Linnaeus) (Sphingidae)	Defoliation		< 1	< 1	< 1	2
Grasshopper *Atractomorpha psittacina* (Haan) (Acrididae)	Defoliation	"	< 1	7	0	< 1
Locusta migratoria manilensis (Meyer) (Acrididae)	Defoliation	No./10 net sweeps	< 1	< 1	< 1	< 1
Katydid *Phaneroptera furcifera* Stal (Tettigoniidae)	Defoliation	"	2	30	2	< 1
Epilachna philippinensis Dreke (Coccinellidae)	Defoliation	"	< 1	0	0	0
Leafminer *Stomopteryx subsecivella* (Zeller) (Gelechiidae)	Defoliation	No. tunnels/15 plants	6	14	3	13
Bean bug *Riptortus linearis* (Fabricius) (Coreidae)	Seed loss	No./10 net sweeps	< 1	1	< 1	< 1
Green stink bug *Nezara viridula* Linnaeus (Pentatomidae)	Seed loss	"	4	7	2	1
Bean thrips *Taeniothrips longistylus* Karny (Thripidae)	Bud loss	No./10 buds	-	-	-	16
Corn earworm *Heliothis armigera* (Hubner) (Noctuidae)	Flower, pod, and seed loss defoliation (P)	No. larvae/15 plants	-	0	1	0
Bean lycaenid *Catochrysops cnejus* Fabricius (Lycaenidae)	Flower, pod, and seed loss defoliation	No. larvae/15 15 plants	< 1	0	4	2
Bean pod borer *Maruca testulalis* (Geyer) (Pyralidae)	Flower, pod, and seed loss	"	2	1	1	< 1
Lima bean pod borer *Etiella zinckenella* Tretsche (Pyticidae)	Seed loss (I)	"	0	15	0	0

[a]Key pests by province - B - Batangas, I - Iloilo; P - Pangasinan in parentheses.

(Cont'd)

Table 1 (Cont'd)

Pest species	Damage/pest status[a]	Mean peak infestation levels recorded by province: sampling unit	Batangas 1975	Iloilo 1975	Pangasinan 1975	Pangasinan 1976
Squash beetle *Aulocophora similis* Oliver (Chrysomelidae)	Pod and seed loss	No./10 net sweeps	2	0	0	0
Bruchid seed weevil *Callosobruchus* spp. (Bruchidae)	Seed loss in storage (BIP)	No.adults/100 seeds	< 1	< 1	< 1	< 1
Toy beetle white grub *Leucopholis irrorata* (Chev.) (Scarabaeidae)	Root loss	No./1 sq. m soil	< 1	0	0	0
DISEASE[b]						
Powdery mildew *Erysiphe polygoni* DC	Loss of photosynthetic area (BIP)	% leaf area infested	10	10	40	51
Cercospora leaf spot *Cercospora* spp.	Loss of photosynthetic area	"	5	5	0	17
Rust *Uromyces vignae* Barcl.	Loss of photosynthetic area	"	< 5	< 1	< 1	< 1
Damping-off *Rhizoctonia solani* Kuhn, *Sclerotium rolfsii* Sacc.	Seedling loss	% seedling loss	0	< 1	0	0
Bacterial wilt *Pseudomonas solanacearum* E.F. Smith	Plant loss	% plant loss	< 5	0	0	0
NEMATODES						
Root knot *Meloidogyne* spp.	Plant stunting	No./250 cc soil and 1 gm roots	126	8	-	7
Reniform *Rotylenchulus* spp.	Plant stunting	"	91	6	-	1

[a]Key pests by province - B - Batangas; I - Iloilo, P - Pangasinan in parentheses. [b]Batangas - peak/month of planting, average of 4 fields; Iloilo - average of 4 fields; and Pangasinan, 1975 - average of 5 fields, 1976 - average of 6 fields.

APPLICATION OF CURRENT PEST CONTROL TECHNOLOGY

Relying solely on pesticides for insect and disease control, we brought about dramatic yield increases over current farmer levels, particularly in Pangasinan (4). Proper timing and dosages with pesticides, plus identification of the pest problems, were the keys to high yields.

Trials conducted on farmers' fields in Pangasinan over 2 years indicate that the key insect pests differed each year. In 1975, the main pests were pre-flowering-flea beetle, beanfly, and *Empoasca* leafhopper.

Lower yields were achieved in 1976 because of the sudden appearance of *Heliothis* in addition to the flea beetle and beanfly. The best treatment, 4 applications of monocrotophos, yielded 0.9 t/ha (Table 2). Insecticide costs were greater ($120/ha) because higher dosages (0.75 kg ai/ha) were needed for *Heliothis* control giving a benefit to cost ratio of 3.6:1. Even with this high input, we did not achieve an acceptable level of control. Applications with higher dosages should have been started at flowering.

FARMERS' CURRENT PEST CONTROL PRACTICES

Understanding the extent of pest control practices currently employed by farmers forms a basis from which to make changes leading to better pest management. Small increments of change are preferred over quantum leaps if we expect early adoption by farmers. A goal of the Cropping Systems Program is to maximize farmers' resources (5).

We monitored farmers' practices through the daily record keeping of farm operations in the 3 provinces. The survey included 48 farmers who grew mungbean in Pangasinan, 31 in Iloilo, and 15 in Batangas. In addition, we interviewed 36 other farmers in each of the 3 locations.

Use of Pest Resistant Varieties

No mungbean varieties with any pest resistance were mentioned in the interviews. Our observation of traditional varieties in farmers' fields bears this out, since we recorded the same pest intensity as on the introduced CES varieties.

Table 2. Insect control, costs and returns, and mungbean response to pre-flowering and post-flowering insecticide treatments. Variety CES 55 planted in December after lowland rainfed rice, Manaoag, Pangasinan, 1976-77.[a]

Defoliation[b] (%)		Flea beetle[c] (no./10 sweeps) 40 DAE	Per 10 plants				Damaged pods (%)	Plant stand (1000/ha)	Pods/ plant (no.)	Pods (millions/ ha)	Yield (kg/ha)	Insecticide cost ($/ha)	Benefit/ cost[d]
			beanfly (20 DAE)		*Empoasca* (no.) 40 DAE	*Heliothis* (no.) 40 DAE							
20 DAE	35 DAE		(no. larvae + pupae)	infested plants (%)									
Four applications - monocrotophos sprays at 5, 21, 35, and 45 DAE.													
11 a	6 b	7 a	2 a	33	1	3 a	16	139 a	14 a	2.0	903 a	120	3.6
Four applications - monocrotophos sprays at 5, 15, 25, and 35 DAE.													
12 a	5 a	3 a	1 a	28	0	4 a	29	133 a	11 a	1.5	639 a	80	3.4
Three applications - carbofuran basal, monocrotophos sprays at 21 and 35 DAE.													
14 b	8 c	2 a	3 a	33	0	4 a	31	132 a	11 a	1.4	396 b	55	2.3
No insecticide.													
24 c	45 d	21 a	7 a	75	1.3	2 b	24	112 a	6 b	0.7	193 c	-	-

[a]Average of 6 fields. Two applications of benomyl to all plots. Days after emergence (DAE). Carbofuran (Furadan 3 G) 0.5 kg a.i./ha, monocrotophos (Azodrin 16.8 EC) 0.22 kg a.i./ha (5-35 DAE), 0.75 kg a.i./ha (45 DAE). Means in columns followed by a common letter are not significantly different at the 5% level (DMRT). [b]Visual per-plot estimate. [c]Night. [d]Mungbeans priced at US$0.60/kg. Change in value of product/insecticide cost.

Use of Cultural Control Practices

Farmers employ a wide variety of cultural practices which reduce pest pressure or allow a greater tolerance to pest damage. They have developed these methods through experience by measuring yield responses; for the most part, farmers are unaware that they are influencing pests.

Seeding rate. Lowland farmers use high seeding rates, frequently attaining stands of over 300,000 plants/ha. We found this particularly common in Pangasinan where the flea beetle often reduces up to 30% of the stand (4). By using seeding rates above 30 kg/ha, farmers are spending money to compensate for seedling loss due to insect damage. If they properly understood the causative agent, they might opt to apply insecticide as it is less costly. In our interviews, 58% of the farmers stated that they increased seeding rates to control pests.

Time of Planting. Farmers are quite aware of the seasonal occurrence of pests, and, if offered a choice, they will adjust the date of planting to avoid pest problems. In Pangasinan, 31% of the farmers avoid planting mungbeans in October and November because they notice that seedling loss is greater during these months. But by delaying mungbean establishment until December, farmers run the risk of drought unless they have supplemental irrigation available.

Synchronous planting. Farmers are also aware that late plantings, out of phase with neighboring fields, will result in heavy pest pressure. Due to sociological reasons and local environmental conditions, this is generally not true for large areas covering several villages, but occurs in contiguous units at or below the village level.

Crop rotation. Upland farmers practice crop rotation of grain legumes and vegetables with rice and corn. Experience shows they will achieve higher yields by doing so. Yet, they are unaware that the damaging effects of pests, such as plant parasitic nematodes and soil-borne pathogens, are reduced by crop rotation.

Flooding. Lowland farmers do not need to practice crop rotation to control soil pests because plant parasitic nematodes and soil borne pathogens are suppressed by the flooding that occurs during paddy rice culture (2).

Use of Mechanical Control

In our survey 84% of the farmers interviewed practice hand picking large insects from the crops or removing rogue disease-infested plants.

Biological Control

We have no evidence that farmers manipulate or conserve natural enemies of insect pests. Very few farmers know that there are beneficial arthropods in their fields and tend to think all arthropods except spiders and dragonflies are pests. For instance, lady beetle predators of aphids are considered to be defoliators because farmers associate holes in the leves with their presence. Surprisingly, we have found no numerous natural enemies of insect pests in mungbean fields (4). This may mean that the major pests have been introduced into the Philippines without their natural enemies.

Use of Pesticides

All farmers interviewed in the survey used pesticides, and 98% believed they achieved increased yields through pesticide use. However, only 41% of the farmers used insecticides and less than 2% used fungicides on mungbean. In Iloilo, only 10% used insecticides.

In the Philippines, pesticides are readily available, and only 9% of the farmers reported that they were not able to purchase a pesticide when it was needed. All farmers reported having access to knapsack sprayers (8-19 ℓ capacity): ownership (60%), borrowing from neighbor (33%); or, cooperative (11%). Most farmers (94%) do the spraying themselves; however, 31% hire helpers from time to time.

Most tenant farmers (97%) make the decisions regarding pesticide usage without the influence of the landlord. All farmers chose sprayable insecticide formulations (Table 3).

We asked farmers how they chose the insecticide they currently use. The extension worker was the principal source (32%) followed by the farmer himself (24%).

To determine the amount of pesticide to add to sprayers, most farmers (77%) said they followed the written directions on the containers. They use either the bottle cap (69%), tablespoon (25%), or graduated cup (10%) to measure the pesticide. Dosages per application are very low, especially in Pangasinan - monocrotophos averaged 0.079 kg a.i./ha (Table 3). This is <u>3-10 times less</u> than the recommended dosage. However, farmers (81%) stated that they increased insecticide dosage in response to greater pest pressure.

We asked farmers what volume of knapsack sprayer they had and how many sprayer loads they used per field. From this, we calculated the size of the field and determinded that farmers apply 135 ℓ/ha, which is about <u>3-10 times less</u> than the recommended spray volume. Water for sprayers is generally accessible; however, 31% of farmers said water was difficult to obtain.

The farmers (95%) said they aim the spray nozzle over the plants rather than under the leaf canopy, and 90% emphasized that it was important to spray all the plants in the field. Eighty percent said the pesticides wash off the plants during rains.

Frequency of insecticide application varied from 1-4 times (Table 4). Except for Iloilo, where little insecticide was used, the percentage of fields receiving one, 2, or 3 applications was about the same for Pangasinan and Batangas. We asked farmers what signs they looked for to guide them in timing insecticide applications. The most frequent response (60%) was the occurrence of flowering, followed by the presence of pests (16%).

The timing of applications varied in Pangasinan and Batangas (Table 5). No insecticide applications occurred during the first 2 weeks in Pangasinan, as the majority were directed at mungbeans in the podding stage. It is evident that farmers timed their insecticide sprays to control pod borers rather than the early season pests. Surprisingly, farm record-keeping data revealed that there was no relationship between insecticide usage and mungbean yield (Table 6). Even in Batangas, where higher dosages are evident, farmers who used no insecticide had comparable yields to those who sprayed 1-3 times.

Pangasinan farmers each spent more on insecticides for mungbeans (US$3.80) than those in Batangas (US$0.50). These differences are related to differences in land area/farmer (Table 4). When converted to a per hectare basis, Batangas farmers out-spent (US$10.16) Pangasinan farmers (US$7.76).

Almost all the farmers (94%) purchase pesticides with their own money, and 6% said the landlord provided the cash input. Farmers' source of cash was 63% from personal savings, 62% from bank loans, and 28% borrowed from relatives or neighbors.

REASONS FOR THE YIELD GAP

Choice of Variety

It may be argued that farmers are adequately controlling pests on their local varieties but that the varieties are not responsive. Extensive variety trials using the local varieties as a check, show that the local varieties are responsive to high management and often outyield improved varieties (1).

Cultural Control

We have shown that farmers already employ a wide array of cultural practices which reduce pest pressure. We conclude that the high yields in research-managed plots are not due to differences in cultural control practices.

Biological Control

The higher insecticide input in research-managed fields would be more severe on natural enemies than in farmer-managed fields. It is

Table 3. Insecticide usage and average dosages/application on mungbeans for 33 farmers in 2 Philippine provinces, 1975-76.

Insecticide		Average dosage	Farmer-users
		- kg a.i./ha -	%
PANGASINAN			
Azodrin	monocrotophos	0.079	59
Sevin	carbaryl	0.136	18
Parapest	methyl parathion	0.190	11
Eradex	chlorpyrifos	0.085	11
Rogor	dimethoate	0.066	4
Etrofolan	MIPC	0.020	4
Thiodan	endosulfan	0.055	4
Meptox	methyl parathion	0.371	4
Resistox	methyl parathion + mevinphos	0.033	4
BATANGAS			
Folidol	methyl parathion	0.260	80
Thiodan	endosulfan	0.146	10
Perthane	perthane	0.109	10

unlikely that biocontrol agents are more numerous in high yielding plots.

Chemical Control

As we stated, 64% of the farmers in the 3 research sites did not use any pesticides on mungbeans. Among those who did, 100% used insecticides and 2% used fungicides. Because of the intensive insect pressure, it is not surprising that non-users obtained low yields. However, the harvest of those using insecticides was also low, in fact no different from non-users.

Choice of insecticide. In Pangasinan most farmers used monocrotophos, which is a very effective insecticide. In Batangas the favorite was methyl parathion, which has broad spectrum activity and is recommended for legumes.

Insecticide dosage. Farmers use very low dosages, especially in Pangasinan where the average dosage/application of monocrotophos was only 0.079 kg ai/ha. Farmers tend to follow the pesticide manufacturers' recommended rates when they measure the chemicals into sprayers, but fail to deliver the correct spray volume/hectare. In Batangas the dosages are high enough to control early season insect pests but would have little effect on pod borers.

Frequency of applications. High yields were obtained from 2-4 insecticide applications on research-managed fields, depending on the presence of pod borers. Of the farmers using insecticides, the majority applied them at least twice. Insufficient number of applications does not appear to be a reason for low yields.

Timing of applications. We have shown the importance of early season protection, within the first week after crop emergence. In Pangasinan our data showed that no farmer applied insecticide during the first 2 weeks of crop growth. Insecticides are aimed at pests attacking the pods, and applications are made at the flowering stage.

Table 4. Frequency of insecticide application to mungbeans for 93 farmers in 3 Philippine provinces, 1975-76.[a]

Applications	Fields Pangasinan	Iloilo	Batangas
	%		
0	60	94	62
1	18	6	12
2	8	0	15
3	10	0	12
4	3	0	0
No. farmers	48	31	14
No. fields	93	67	26
Land/farmer (ha.)	0.81	0.55	0.07

[a]A mixture was considered 1 application.

Table 5. Weekly frequency of insecticides applied to mungbeans by 33 farmers in 2 Philippine provinces, 1975-76.

Week after planting	Total applications/field Pangasinan	Batangas
	%	
1	0	10
2	0	10
3	1	15
4	11	15
5	8	5
6	15	5
7	17	25
8	21	10
9	18	5
10	4	0
11	2	0

Table 6. Relationship of mungbean yields to insecticide frequency for 93 farmers in 3 Philippine provinces, 1975-76.

Province	Without insecticide	Insecticide application 1	2	3	4
	kg/ha				
Pangasinan	171(9)[a]	253(3)	179(3)	390(2)	187(1)
Batangas	204(12)	236(2)	255(3)	213(1)	
Iloilo	165(21)	51(1)	-	-	

[a]Number of observations in parentheses.

Pest Recognition

An explanation for the improper insecticide timing and lack of fungicide use could be that farmers are not aware of the major mungbean pests. We approached this problem in 3 ways in our farmer interviews: First, we determinded if farmers have names in their local dialects for each mungbean pest. We reasoned that if farmers do not have names for pests then they cannot consider them important. Second, we asked them to rank the 3 most important pests and compared their list with ours in each of the 3 sites. Finally, we showed farmers color photographs of major pests with the associated damage symptoms and asked them to identify the problem.

Pest names in local dialects. Farmers have names in the 3 dialects - Tagalog, Ilongo, and Ilocano - for most insect pests, particularly the larger more conspicuous ones such as defoliators and pod borers. Most of the terms are very general and translate into English as "worm", "bug", "beetle", "aphid", and "fly". They apparently have no names for leaf miners, thrips, and other small arthropods. Farmers are less precise about plant diseases; many have no name at all. They do have terms for powdery mildew, bacterial wilt, and rust. It is not surprising that they have no name for nematodes.

Pest ranking. A clearer picture emerges when we compare farmers' rankings of pests in the 3 provinces (Table 7). Of the 3 key pests according to our ranking, farmers recognize only aphids and pod borers. Beanfly, flea beetle, and powdery mildew diseases are absent from their list. Farmers have names for these organisms but do not consider them pests.

Table 7. Comparison of farmers' (108) and researchers' ranking of the most important mungbean pests by province, Philippines, 1976.

Rank	Batangas		Iloilo		Pangasinan	
	farmer	researcher	farmer	researcher	farmer	researcher
1	Aphid	Beanfly	Lady beetle	Beanfly	Army worm/ cutworm	Flea beetle
2	Caterpillar/ worm	Powdery mildew	Aphid	Powdery mildew	Aphid	Pod borers
3	Termite	Aphid	Caterpillar/ worm	Aphid	Pod borers	Beanfly

IMPLICATIONS TO EXTENSION PROGRAMS

We conclude that farmers are not achieving higher yields because they do not recognize most of the key pests and, therefore, do not properly time their insecticide applications nor use fungicides against powdery mildew. We further conclude that farmers need to increase pesticide dosages to achieve adequate control.

These gaps can only be bridged by extension campaigns designed to instruct farmers on pest identification, proper pesticide timing, as well as adequate spray volumes/ha. From our experience farmers do not know that yields over one ton/ha are possible with mungbeans. Extensive demonstration plots on farmers' fields would be one way of stimulating farmers to practice better pest control practices.

IMPLICATIONS TO FUTURE PEST MANAGEMENT RESEARCH

We have achieved dramatic yield increases solely from pesticide usage. Such a single-factor stress against pests is bound to cause pest resistance to chemicals in time if extensively adopted (3). There is an urgent need to broaden the base of pest control methods in order to obtain long term sustained yields.

The pesticide input that we used in achieving high yields is 15-fold ($10 vs $150) more than the farmers' current level in terms of capital, when we consider only the value of pesticides and not labor. The returns to pesticide input are high so farmers are likely to increase usage once they see the results of better pest control practices.

There is a need to improve pesticide delivery systems to replace the knapsack sprayer which requires such a high water volume that farmers find difficulty in relizing the desired dosages. The hand-held spinning disc sprayers now being developed may fill this need. There is little need to screen new pesticides as there already exist a wide array of effective chemicals.

There is an urgent need for research programs to concentrate on developing multi-pest resistant varieties, cultural control practices, and the biocontrol component of pest management.

Figure 1 shows the present and projected future contributions for each of the various pest control technologies to mungbean yield. In the farmers' current system, yields and inputs are low. There are contributions from pesticide, biological, and cultural control but nonefrom pest resistance. With the adoption of a greater pesticide input, yields soar, but at the expense of the biocontrol aspect. We do not expect these gains from pesticides to remain high over time because of the imminent danger of pesticide resistance developing. Rather than enter into the all-too-familiar pesticide treadmill syndrome, we can begin to shift the emphasis from pesticides to pest resistant varieties. This will not only lower the capital input requirement but will reduce the pesticide decision-making requirement on the part of the farmer, letting him concentrate his efforts with higher yields as the end result. As these aims are being achieved, more effort can go into developing more effective cultural control mechanisms such as fine adjustments of planting time, plant spacing, and intercropping. The most time-consuming, and last to be integrated, would be the manipulation of natural enemies, either through augmentation or introduction of exotic species. This end result is at least a decade away but would place pest management on a more stable footing.

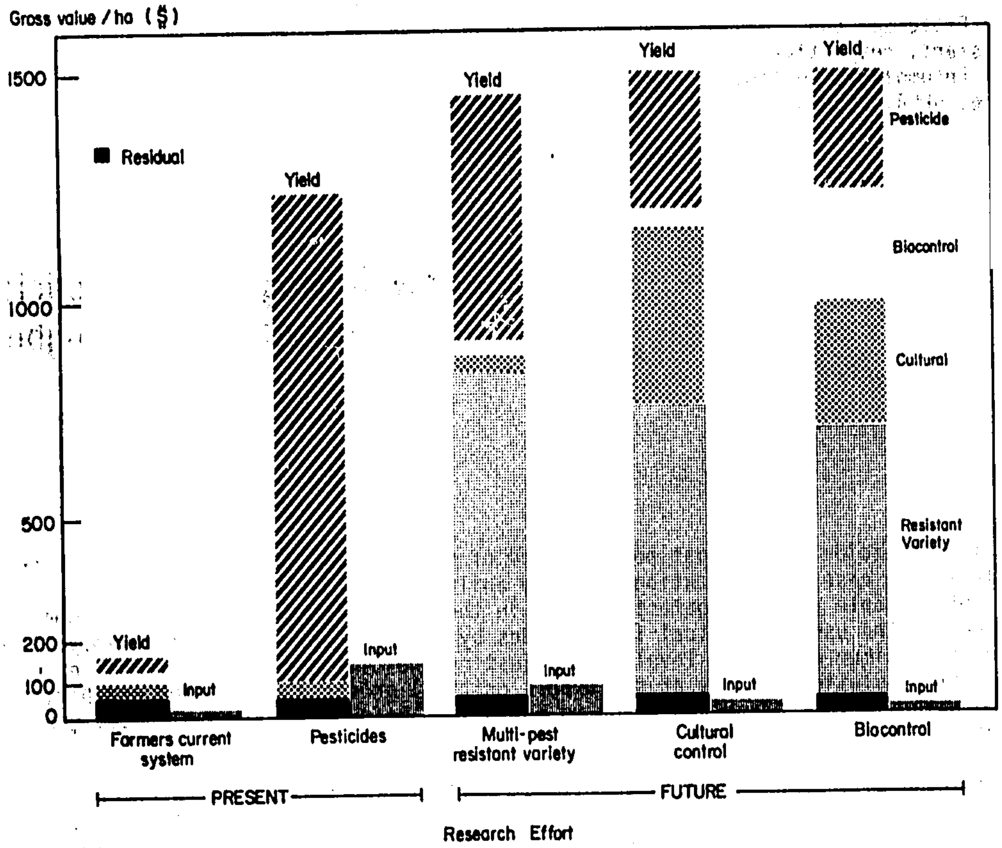

Fig. 1. Present and future contributions of the various insect, disease, and nematode pest control technologies (pesticides, varietal resistance, cultural and biological) to the gross value (US dollars) per hectare of mungbeans with the associated pest control input costs to the farmer.

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Critical Growth Stages for Insecticidal Application in Mungbean

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The use of insecticide is the most popular form of insect pest control in the world because of availability, ease of application, and the ability to decimate pest populations (3). In the absence of workable pest management schemes in the developing countries, it becomes practical to rationalize the use of chemical insecticides by reducing application frequency, lowering dosages to the minimum effective level, and adjusting the timing of applications in relation to the pest's peak population density at the crop's critical growth stages. For example, furrow application with systemic granulars prior to sowing and before flowering elicited good growth and higher yields from mungbean and soybean (2,4).

Mungbean is generally grown in small and isolated areas, and often as a catch crop with few or no protection inputs resulting in low yields (1). Any protection provided is mainly chemcial based on a calendar system of application which is not only expensive but also environmentally disruptive.

This experiment was conducted to define the proper timing of insecticidal treatments in relation to the growth stages, and to develop a simple and practical approach for use by small farmers.

MATERIALS AND METHODS

A $600m^2$ upland area was planted to mungbean at UPLB, Philippines, and divided into plots each measuring $13.3m^2$. The land was prepared and the crop grown according to standard cultural practices during the dry and wet seasons of 1976-77(5).

We laid out 15 treatments with 3 replications in randomized complete blocks. The growth period was divided into the following critical growth stages: emergence (3 DAE), mid-vegetative (17 DAE), flower initiation to full bloom (31-34 DAE), and pod-fill to pod maturity (41-45 DAE) stages. Insecticide was selectively applied at single stages or at a combination of stages (Tables 1 and 2). Azodrin 168 (monocrotophos EC) was applied at .05% using approximately 1.34 kg ai/ha in a single spraying which started at 3 DAE.

Sampling methods included sweeping with a net (50 sweeps/plot/week) followed by actually counting the insects caught. The recognized major mungbean pests on which this investigation is based are: Beanfly (*Ophiomyia phaseoli* Tryon), corn semi-looper (*Chrysodeixix chalcites*), leaf folders/leafrollers (*Lamprosema indicata* and *Homona coffearia*), common cutworm (*Spodoptera litura*), pod borers (*Maruca testulalis* and *Etiella zinckenella*), and corn earworm (*Heliothis armigera*).

Beanfly damage was assessed during the first and second week after emergence by placing a leaflet over a mm grid and directly reading the degree of defoliation (Tables 1 and 2). One hundred pods/plot were examined individually at pod-fill and at maturation, and the percentage of pod infestation determined. The number of damaged seeds and the total number of seeds/100 pods were counted, and the yield/plot determined.

RESULTS AND CONCLUSIONS

Rather than follow the calendar method, insecticide treatment(s) could be properly timed to correspond to the mungbean's pest-sensitive growth stages. Although the beanfly infestation was relatively low during both seasons, the yield was generally higher when 2 or more growth stages were sprayed. One spray at any given stage of growth did not provide adequate protection to mungbean based on yield.

During the dry season, growth stage spraying at 3+17+31+45 DAE produced the highest yield followed by 17+31+45, 3+17+31, 17+31, and 3+17 DAE. Where beanfly is not a problem, 17+31 DAE is the minimum treatment, and 17+31+45 when defoliators are heavy.

During the wet season 2 spraying at 31+45 DAE gave the best yield followed by 3+31, 3+17+31, 3+17+31+45, and 17+31 DAE. These dry and wet season results were identical as far as relative

Table 1. Reduction of insect pest damage by appropriate timing of insecticidal application at indicated growth stages of mungbean (dry season); UPLB, Philippines, 1976-77.

Spray schedule	Beanfly damage[a] week 2	Defoliation[b]	Pod damage[c] pod fill	Pod damage[c] maturity	Yield[d]
(DAE)		--- mm²----	----------- %	--------	kg/ha
3	1.23 b	13.61 ab	28.33 bc	31.66 bc	375.93 e
17	1.81 ab	14.06 ab	28.66 bc	32.00 bc	363.40 f
31	1.23 b	13.99 ab	15.33 h	32.66 abc	338.34 g
45	1.68 ab	19.65 a	25.67 cde	31.33 bc	338.34 g
3+17	1.21 b	12.82 ab	33.66 a	31.33 bc	438.59 d
3+31	1.45 ab	15.23 ab	20.00 fg	29.33 cd	312.27 i
3+45	1.96 ab	13.88 ab	24.66 de	33.66 ab	338.34 g
17+31	1.66 ab	12.59 ab	22.00 ef	31.66 bc	476.18 c
17+45	1.45 ab	12.95 ab	26.00 cd	30.33 bcd	338.34 g
31+45	1.30 b	15.55 ab	18.66 fgh	30.00 cd	325.81 h
3+17+31	1.71 ab	14.15 ab	25.00 cde	30.66 bcd	476.18 c
3+17+45	1.70 ab	11.10 b	24.33 de	29.33 cd	325.18 h
17+31+45	1.66 ab	13.26 ab	19.66 fgh	29.33 cd	563.09 b
3+17+31+45	1.58 ab	9.13 b	18.00 gh	27.33 d	626.56 a
Control	2.10 a	23.56 a	31.00 ab	35.66 a	162.90 j

[a]Mean of 3 replications; 20 plants/treatment/replication; 0-no damage, 1-eggs laid on leaves/no tunnels, 2-mines on leaves, 3-tunnels on leaves and stems, 4-stunted growth/heavy stem damage. [b]Mean of 4 weeks; average of 3 replications; 20 plants/treatment/replication. [c]Mean of 3 replications; per 100 pods/treatment/replication. [d]Based on yield/13.3 m². Means followed by the same letter are not significantly different at 5% level, DMRT.

Table 2. Reduction of insect pest damage by appropriate timing of insecticidal application at indicated growth stages of mungbean, wet season; UPLB, Philippines, 1977.

Spray schedule	Defoliation[a]	Pod damage[b] pod fill	Pod damage[b] maturity	Yield[c]
(DAE)	----mm²----	------------ %	------------	- kg/ha -
3	26.7 bc	27.7 abc	29.0 bcd	74.1 cde
17	18.2 bc	28.7 abc	29.0 bcd	49.9 e
31	29.4 b	24.0 c	25.7 cd	91.6 abcd
45	41.9 a	34.7 ab	37.7 ab	51.2 de
3+17	15.7 c	23.7 c	24.7 cd	71.1 cde
3+31	17.4 bc	25.7 abc	24.3 cd	125.7 ab
3+45	18.2 bc	26.0 abc	26.3 cd	91.4 abcd
17+31	17.2 c	25.0 bc	26.7 cd	93.7 abcd
17+45	20.6 bc	28.7 abc	31.0 abc	84.7 bcde
31+45	16.1 c	26.7 abc	28.0 cd	138.3 a
3+17+31	14.8 c	25.0 bc	26.0 cd	106.4 abc
3+17+45	17.4 bc	27.0 abc	29.0 bcd	73.0 cde
17+31+45	15.6 c	23.3 c	24.3 cd	72.2 cde
3+17+31+45	14.6 c	20.3 c	21.0 d	102.7 abc
Control	50.7 a	35.3 a	38.3 a	55.1 de

[a]Mean of 4 weeks; average of 3 replications; 20 plants/treatment/replication. [b]Mean of 3 replications; per 100 pods/treatment/replication. [c]Based on yield/12.5 m². Means followed by the same letter not significantly different at 5% level, DMRT.

yield and damage trends were concerned. However, there were indications that during the wet season spraying frequency could be effectively reduced to 2. Apparently microbial control exerted its toll on most insect pest species. Likewise, observations indicate that the intensity of pest infestation is generally low during the wet season.

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Plant Parasitic Nematodes of Mungbean in Philippines

M.B. Castillo & J.A. Litsinger

INTRODUCTION

Past studies have shown the susceptibility of mungbean to root-knot nematodes, *Meloidogyne* spp., under controlled conditions in the Philippines (2). Madamba obtained a 12.4% increase in mungbean yield from soil fumigation with Vydate at the rate of 4.58 ℓ a.i./ha (11).

This paper is a summary of our subsequent findings, some of which have already been published. We hope that this compilation will create an awareness of nematode pests as among the major deterrents to increased yields of mungbean and other crops.

DISTRIBUTION AND POTENTIAL IMPORTANCE OF PLANT PARASITIC NEMATODES.

Among the plant parasitic nematode genera found associated with mungbean, *Rotylenchulus* and *Meloidogyne* appear to be the only important pests of the crop based on abundance, distribution, and experimental results (1). In upland areas, mixed populations of these 2 genera were encountered in almost any field where mungbean was grown, and heavy root infections were frequently associated with crop decline (5,6). Conversely, very low nematode populations were observed in lowland areas, where mungbean usually follows paddy rice. Five pathogenic species were identified: *M. acrita, M. arenaria, M. incognita, M. javanica*, and *R. reniformis* (reniform nematode).

In simultaneous pot, microplot, and field experiments, yield reductions on mungbean grown in soil initially infested with approximately 1,200 *R. reniformis* and 90 *M. acrita*/hill were 63.9, 69.8, and 61.5%, respectively. In soil initially infested with approximately 600 *M. acrita* only, yield reductions were 40.5 and 28.0% in pot and field, respectively (10). In the *R. reniformis-M. acrita* experiment, the density levels of the nematodes at harvest time (457 *R. reniformis* and 22 *M. acrita*/250 cc soil and 1 g root sample) were lower in more than 50% of the farmers' fields in the upland areas recently surveyed (8,9). This indicated the potential threat that nematodes impose on mungbean and other susceptible crops in those areas.

SYMPTOMS OF DAMAGE CAUSED BY ROOT-KNOT AND RENIFORM NEMATODES

Below-ground

Root-knot nematodes cause the formation of characteristic galls or swellings on the roots of mungbean and other susceptible crops. There is usually a stimulation of root growth due to formation of galls at low infection levels, and a depression of root growth accompanied by necrosis at high infection levels. Inside the vascular cylinder, where most feeding occurs, giant cells which block and disrupt the vascular tissues are formed, thereby reducing the nutrient and water uptake from the soil by the roots.

Reniform nematode-infected roots are usually necrotic, with severity increasing with infection level. Nematode feeding destroys epidermal cells and causes discoloration and death of cortical tissues.

Root injuries caused by root-knot and reniform nematodes serve as entry points for secondary invaders, such as fungi and bacteria, which may amplify the damage. A massive nematode invasion of newly-germinated seedlings may cause failure of the seedlings to emerge.

Above-ground

Like other crops deprived of a normally functioning root system or suffering from mineral or moisture deficiency, mungbean plants attacks by root-knot and/or reniform nematodes initially show leaf chlorosis, particularly when under moisture stress (10). Leaves of less severely attacked plants turn green again a few days after irrigation. Chlorosis of more severely attacked plants is followed by stunting and/or death, depending on infection levels. Early flowering is stimulated by heavy root infections by both *R. reniformis* and *M. acrita*. The pods produced, however, are fewer and shorter than those of nematode-free plants. This and the reduction in plant stand result in decreased yield.

POPULATION DYNAMICS OF RENIFORM AND ROOT-KNOT NEMATODES

In a well-drained upland field, 2 croppings of corn (DMR-2) or sorghum (Cosor-2), or 3 clean fallow periods checked the population of *R. reniformis*, while 3 croppings of mungbean (MG-50Y) or soybean (TK-5) or 2 croppings of sweet potato (BNAS-51) favored population build-up, with nematode counts increasing with number of croppings (Fig. 1)(7). Apparent but less increase also resulted after 2 croppings of bush sitao (Los Baños #2) or peanut (CES 101).

In a nearby-field with poorly-drained soil, we studied the population behavior of the *R. reniformis-M.acrita* complex during 2 successive wet season and one dry season plantings of mungbean (MG 50 10A), soybean (TK-5), cowpea (EG #2), and peanut (CES 101). Six months prior to the conduct of the experiment, the field was divided into plots, where different treatments were randomly applied. These treatments included growing crops with varying susceptibilities to

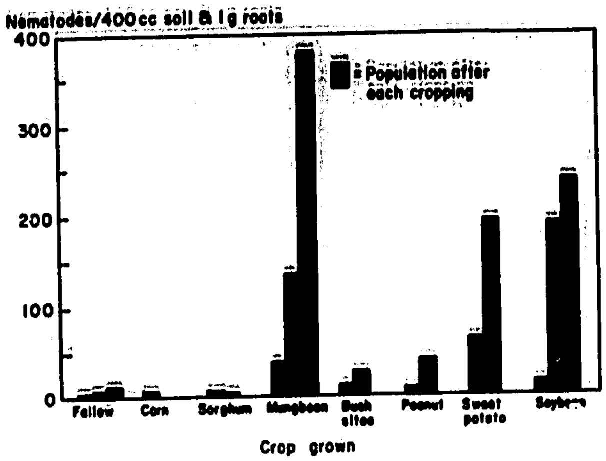

Fig. 1. Average numbers of *Rotylenchulus reniformis* recovered from successively monocultured crops; Philippines, 1976.

nematodes, soil fumigation with Carbofuran 3G, and transplanting of nematode-infected mungbean plants. Through these preliminary treatments, 4 different nematode population levels, which were considered as the initial levels, were obtained at the start of the experiment. Subsequent nematode determinations were made at 1-2 months after planting and at last harvest for each cropping. Processing of composite soil and root samples was through the sieving-Baermann funnel and root staining techniques. To account for nematode eggs in the soil, the sieved soil was assayed (9). Nematode populations were erratic during the 2 wet season plantings, particularly during the second (Table 1), except in Nemacur-treated check plots where populations were maintained at very low levels. The intermittent soil saturation resulting from frequent heavy rains, and its interaction with other undetermined factors probably account for the irregular population densities observed. Surprisingly, *M. acrita* was encountered in considerable numbers only during the first cropping, after which its population was reduced to almost nothing. Over all levels, the mean density peaks of this nematode/300 cc soil and 1 g root sample were 89, 4, and <1 for the first, second, and third cropping periods, respectively. Populations of *R. reniformis* increased geometrically with time of cropping during the dry season planting. During this season, preplanting populations of only 13-21 *R. reniformis*/sample caused yield reductions as high as 75%. It appeared that the limited capacity of the roots to function due to nematode injuries was aggravated by moisture deficiency. Conversely, the much lower yield losses during the first and second wet season plantings, despite the very high nematode population density during the former, were probably attributable to the compensatory effect of the abundance of moisture.

Trends in the data obtained from soybean and cowpea, which are also susceptible to both *R. reniformis* and *M. acrita*, were generally identical

Table 1: Behavior of 4 initial population levels of *Rotylenchulus reniformis* - *Meloidogyne acrita* complex during two successive wet season (WS) and one dry season (DS) plantings of mungbean and its effect on yields in a poorly-drained soil; IRRI, Philippines, 1976-77.[a]

No. of *R. reniformis* and *M. acrita* collected/300 cc soil & 1 g root				Yield loss[c]
before planting[b]	1 mo. after planting	2 mo. after planting	last harvest	--- % ---
FIRST CROPPING (WS)				
3 (check)[d]	1		12	
49	51	-	721	29*
213	558	-	1,466	27*
479	268	-	1,244	23*
SECOND CROPPING (WS)				
1 (check)[d]	1	7	0	-
63	24	288	57	19*
43	17	179	68	11*
27	38	1034	202	18*
THIRD CROPPING (DS)				
0 (check)[d]	0	4	1	
18	52	186	308	63*
13	45	219	544	69*
21	49	203	675	75*

[a]Data are means of 4 replications. [b]Data for the first cropping were the initial population levels. [c] * denotes significant at 5% level. [d]Soil treated with Nemacur (19.3 kg a.i./ha).

with those obtained from mungbean; the minor differences appear due mainly to the differences in crop susceptibility. Data obtained from peanut also reflect the crop's susceptibility to *R. reniformis* and resistance to *M. acrita*.

CONTROL OF ROOT-KNOT AND RENIFORM NEMATODES

Chemical control

Carbofuran 3G, an insecticide-nematicide chemical, when incorporated into the soil before planting and at 45 days after planting at the rates of 1.0 and 6.0 kg a.i./ha, respectively, controlled *R. reniformis* on mungbean and other crops (7).

Preplant soil application of Nemacur, a contact nematicide, at the rate of 19.3 kg a.i./ha consistently controlled *R. reniformis* and *M. acrita* during the 3 successive croppings of mungbean, soybean, cowpea, and peanut earlier discussed.

Control through cultural and management practices

We evaluated the efficiency of several cultural and management practices to control *M. incognita* on a succeeding tomato crop. The results are shown in Figure 2. It would appear that at least 2 successive croppings of corn, *T. erecta*, tomato with *T. erecta* or *C. juncea* intercrop, or tomato with a soil application of chicken dung or rice straw compost, or 3 clean fallow periods were needed to significantly reduce the nematode population.

In well-drained farmers' upland fields, the effect of crop rotation on populations of *Rotylenchulus* spp. and *Meloidogyne* spp. is shown in Table 2. A nematode survey in these fields showed that successive croppings of susceptible pulses (mungbean, cowpea, soybean, peanut, lima bean, and hyacinth bean) and solanaceous (tomato and eggplant) crops, for 3 years perpetuated the pests. One and 2 croppings of the resistant cereals (rice and corn) preceding a susceptible

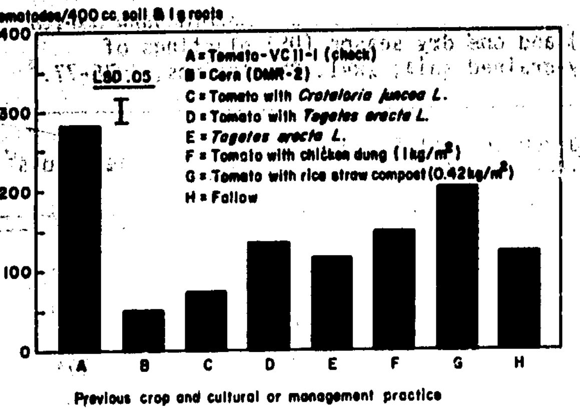

Fig. 2. Average numbers of *Meloidogyne incognita* in soil and roots of tomato after successive use of certain cultural and management practices for 3 growing seasons; Philippines, 1976.

crop during each cropping year gave fair nematode control, with the latter providing better control than the former. Cropping cereals for 2½ years before a susceptible crop kept the populations at low levels. The suppressive effect of prolonged cropping of cereals, however, appeared to last for only one cropping when 2 successive croppings of susceptible crops followed a 2-year cropping of cereals which resulted in high nematode counts.

In pot experiments, we obtained significant reduction in *R. reniformis* and *M. incognita* populations on mungbean and tomato, respectively, due to flooding for one, 4, and 7 days (4). To determine the effect of flooding on nematode populations in farmers' fields, a survey was conducted in rainfed or partly irrigated lowland rice

Table 2. Effect of crop rotation on populations of *Rotylenchulus* spp. and *Meloidogyne* spp. in well-drained upland fields of Batangas, Pangasinan, and Iloilo, Philippines, 1975-77.

Cropping pattern[a]	Nematodes collected/250 cc soil & 1 g roots[b] *R.* spp.	*M.* spp.	total
S - S	957	266	1,223
C - S	280	458	738
C - C - S	106	276	382
C (2.5 yrs.) - S	4	45	49
C (2.0 yrs.) - S - S	398	398	796

[a]Over a 3-year period; S=susceptible pulse and solanaceous crops; C=resistant cereals (rice and corn). [b]Collected from the last crop in the cropping pattern; averages of 10-60 composite samples from 1-8 plots.

Table 3. Population of *Rotylenchulus* spp. and *Meloidogyne* spp. in a 3-year old rainfed or partly irrigated cropping pattern rice-field legume/vegetable-fallow under different environments; Philippines, 1976.[a]

Environment	Duration of flooding	Nematodes collected/200 cc soil & 1 g roots[b] *R.* spp.	*M.* spp.	total
Non-flooded upland fields	0	44	268	312
Isolated paddies in drainage ways among upland fields	2-3 mos./yr	1	7	8
Highly intermittently flooded paddies	few hrs. to few days/ flooding period	0	4	4
Normal rainfed paddies	3 mos./yr.	1	1	2

[a]Field legumes=mungbean and cowpea; vegetable=eggplant, bottle gourd and bitter gourd. [b]Collected from field legumes or vegetables; averages of 4-28 composite samples from 1-7 plots.

area of Pangasinan, where the different rice-growing environments have distinct durations of flooding. Nematode counts obtained from the dominant cropping pattern rice-field legume/vegetable-fallow indicated that flooding controlled the populations of *Rotylenchulus* spp. and *Meloidogyne* spp. (Table 3) (5). The highest populations were detected in non-flooded upland fields (with 2-3 mos. of flooding/yr.) yielded surprisingly low populations.

Data on nematode recoveries from upland and lowland areas of Iloilo concurred with earlier observations (6). Successive croppings of field legumes (mungbean and cowpea) and solanaceous (tomato and eggplant) crops favored the build-up in populations, particularly of *Rotylenchulus* spp. while reduced populations were associated with cropping of flooded rice for 1-3 growing seasons. It appeared that one cropping of paddy rice a year was sufficient to control the nematode attacks on the succeeding field legume. (Table 4).

Control through resistant varieties

All the hundreds of locally-available mungbean varieties, accessions, and lines, and those from AVRDC, which were screened for resistance to root-knot nematodes, were found susceptible. However, a multifoliate mungbean mutant showed some resistance to *M. acrita, M. incognita,* and *M. javanica*, and susceptibility to *M. arenaria* in preliminary pot screenings. Field experiments are currently under way to confirm these observations and to determine the mutants' reaction to *R. reniformis*.

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Table 4. Populations of *Rotylenchulus* spp. and *Meloidogyne* spp. in selected cropping patterns in rainfed upland and lowland fields; Iloilo, Philippines, 1977.

Cropping pattern[a]	Nematodes collected/300 cc soil & 1 g roots[b] *R.* spp.	*M.* spp.	total
UPLAND			
Continuous susceptible crops	587	41	628
LOWLAND			
Rice-field legume	1	3	4
Rice-fallow/ratoon-field legume	6	8	14
Rice-rice-field legume	1	0	1
Rice-rice-ratoon-field legume	0	0	0

[a]Over a 3-year period; susceptible crops=mungbean, cowpea, tomato, and eggplant; field legume=mungbean or cowpea. [b]Collected from the last crop in the cropping pattern; averages of 20-90 composite samples from 4-16 plots.

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Discussion

Lawn: Is it possible that in your screening for aphid resistance, differences were related more to palatability than to resistance per se? If this were the case, some of the apparently resistant lines could be infested in the field only in the absence of more palatable genotypes.

H.S. Chiang: The mechansim of resistance includes non-preference, antibiosis, and tolerance. If the resistance is caused by non-preference, it is possible that the plant may be attacked in the absence of more papatable genotypes.

Ballon: Dr. Rejesus, don't you think that the use of chemicals to control insect pests is overused? What are the prospects of implemeting biological measures to control insect pests.

Rejesus: I think you mean to say "overemphasized", not overused because, actually, farmers are not using enough insecticides on their farms. Regarding biological control measures, we have not accumulated sufficient information to warrant field application. There is not enough support for studies in this direction and biological control research cannot operate under short term conditions. Perhaps, in another two more decades, we will be practicing biological control.

Litsinger: I would like to add that biological control is very desirable but it is a long term effort. We have very few people conducting research on it. In our travels in the country, we noted that the farmers' practice of incorporating rice stubble in the soil, and even mulching, reduce beanfly infestation. But so far, we have not come across any explanation for this, except perhaps, the effect of pure obstruction.

Ramanujam: You have recommended breeding for resistance to *Heliothis* as an important objective. What is your assessment of obtaining genetic resistance to such a polyphagous pest? Are *Heliothis* resistant strains known in any genotype of cultivated plants?

Litsinger: We have found field resistance to *Heliothis* in cowpeas (V 59-14) at the IRRI and UPLB Experiment Stations. We should try to find resistant lines by screening our mungbean germplasm. Who knows what we will find but we surely will not find it unless we look.

Aspe: Would you recommend granulated insecticides for better insect control?

Litsinger: Farmers get better results with granulated insecticides. However, they are not effective in lowland areas where pH is 7 to 8 as a result of flooding. The soil is almost a gravel consistency which does not allow compaction and activation of granules. Another limitation of granules is the high amount of recommended application which the farmers are not always happy about. The granules can be washed off also by flood water so that immediate absorption by the plant is required.

Wood: Why do you think minimum tillage leads to such a marked reduction on beanfly infestions.

Litsinger: Evidently the host-seeking responses of the beanfly are obstructed by rice stubble. This finding is not new. In Indonesia it is well-known that weedy fields have less beanfly infestation. Even rice straw mulch is effective.

Park: Dr. Ramirez, could you say that only P x #5 is responsible for the resistance to the *Cercospora* leaf spot. If not, isozyme testing may not detect resistant lines which are controlled by factors or enzymes other than P x #5.

Ramirez: The results of this particular experiment indicate that P x #5 is a resistance factor and may, therefore, be used as a selection index. This does not preclude, however, other chemical compounds as resistance factors. Further studies along this line are being pursued.

Park: May we know why disease resistance for *Cercospora* leaf spot seems to break down as the plants reach pod maturity stage?

Ramirez: This might be due to the advanced stage of the disease or to the occurrence of chemical resistance factors during the different stages of the mungbean's life cycle.

Ramanujam: What genetic factor is responsible for the differences in the results of tests conducted by you, Dr. Benigno, and Dr. Ikawa?

Soria: No specific line was used as a host plant. Dr. BEnigno and I used the same variety.

Konno: Do nematodes affecting soybean also attack mungbean?

Castillo: If you are referring to the soybean cyst nematode, we have not observed it yet in the Philippines.

Dolores: What is the mechanism in manure which is responsible for controlling nematodes?

Castillo: We don't have any idea, what the mechanism is. However, following are the probable reasons why organic manuring controls nematodes: direct toxicity of the products of decomposition; buildup in populations of matural enemies of nematodes; and, increase in vigor of treated plants due to increased soil fertility, which enable them to resist nematode infections.

Litsinger: How many mungbean diseases do you suspect are transmitted in seed, Dr. Yang? What precautions should be observed in shipping seeds from place to place?

C.Yang: Dr. Grewal mentioned in his paper that are about 7 to 9 seedborne diseases affecting mungbean. These are bacterial and viral in nature. I suggest that we comply with the seed certification regulations before shipping and insist on s treatment. However, these are generally easier said than done, especially when large collection of germplasm are involved.

Wood: Would you please comment on the risks to local commercial production posed by inoculating field sowings of mungbean accessions.

C.Yang: There is a certain amount of risk involved when inoculating field screenings of mungbean for disease resistance. However, as a rule of thumb, any disease screening nursery or screening field for any crop must be located far away from local commercial production; therefore, the choice of location for a disease screening nurser is mandatory, taking precedence over all other considerations.

Herrera: In your trials, Dr. Quebral, did you include Benlate in both pot and plot experiments

Quebral: Yes. However, reinfection occured when the roots outgrew soil contact. Contamination occured with exposure of the roots to the spore bearing air. I also mentioned in my presentation that the controlling effect of Benlate would be strengthened if it could be manufactured in granule form to enhance its activity when mixed with the soil.

Legaspi: Since mungbean roots penetrate deep into the soil, how deep should Benlate be incorporated to be feective?

Quebral: Our plot experiment incorporated Benlate only in the first 3-4 inches.

Grewal: Dr. Yang, do you think *Cercospora* & powdery mildew will develop resistance to new systemic fungicides like Benlate and Bavistin in the next few years? If so, what approach would you suggest to check this tendency?

C.Yang: I believe that, in time, the pathogens will develop resistance to these chemicals since there has been ample documentation about the metabolic breakdowns of Benlate. A long-range continuous screening program for fungacides (systemic or otherwise), just as with the screening for varietal resistance to disease, should be carried out. In fact, AVRDC, besides screening for varietal resistance, also has a program for evaluating fungicides and pesticides.

Varietal Improvement

-continued

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Physiological Basis for Mungbean Yield Improvement

C.G. Kuo, L.J. Wang, A.C. Cheng, and M.H. Chou

INTRODUCTION

The objective of mungbean physiological work at AVRDC is to determine physiological or morphological factors responsible for yield variations among varieties. We expect that genetic variations in physiological processes can be used to facilitate breeding higher-yielding varieties by improving criteria for selecting parents and/or by providing more effective selection criteria.

VEGETATIVE GROWTH

Although mungbean yield is directly determined during the post anthesis period, the crop's potential is largely dependent on its earlier growth. Growth before anthesis is very insufficient in terms of dry matter production. Evidence for this insufficiency is provided by the fact that the leaf area index (LAI) of mungbean increases very slowly until the beginning of flowering (3).

LAI is important as a determinant of dry matter production and, hence, yield. Therefore, the ideal foliar development of a crop would be the immediate attainment of the optimum LAI upon seed emergence. One of the major limitations to high mungbean yields is the length of the time required from planting until the optimum leaf area is produced. Higher LAI values can usually be achieved by increasing plant population density and nutritional supply. However, LAI values tend not to respond well to increased population density or nitrogen fertilization at the vegetative stage (3). Greater growth before anthesis, obtained by improved cultural methods and by development of new varieties with this capacity, is desirable.

LIMITING FACTORS FOR SEED YIELD

Further increases in mungbean's yield potential would undoubtedly be assisted by increased understanding of the physiological processes which limit yield most: photosynthesis (source), translocation, and sink capacity. The relative impact of these limitations will, of course, vary with variety and growing conditions, and especially with the sequence of events during inflorescence development and the seed-filling stage. In adapted high yielding varieties, sources, translocation, and sink capacities for assimilates may well be in equilibrium, and must be raised in a coordinated way for yield to be increased.

PHOTOSYNTHESIS AS A LIMITATION ON YIELD

Investigations into the translocation of ^{14}C-labelled assimilates have shown that the carbohydrate in the seed is chiefly derived from photosynthesis during the reproductive period (3). Carbon assimilated early in the life cycle has virtually no direct relevance to seed development, so carbon fixed during reproductive development must be relied upon to furnish the seed requirement.

Photosynthetic leaves at mungbean's flowering nodes are deeply committed to the nourishment of subtended racemes (2), and this assemblage has been referred to as a "nutritional unit" (1), or a "production unit" (2). This is the "source-sink" mechanism in its simplest form. We may consider the mungbean ideotype as a sequential stacking of production units progressively up the main stem. Accordingly, the most likely way to improve the carbon nutrition of seeds would be to increase these production units and/or photosynthetic returns from the trifoliate with pod-setting racemes.

Seed yield may also bear a close relationship to the duration and rate of photosynthesis after anthesis. Shading or reduction of leaf area during the period after anthesis reduces yield substantially (3). Exposure to abundant solar radiation during the reproductive period improves mungbean yield (Fig. 1) which implies that increased photosynthesis during the reproductive period can result in increased seed yield. One might also

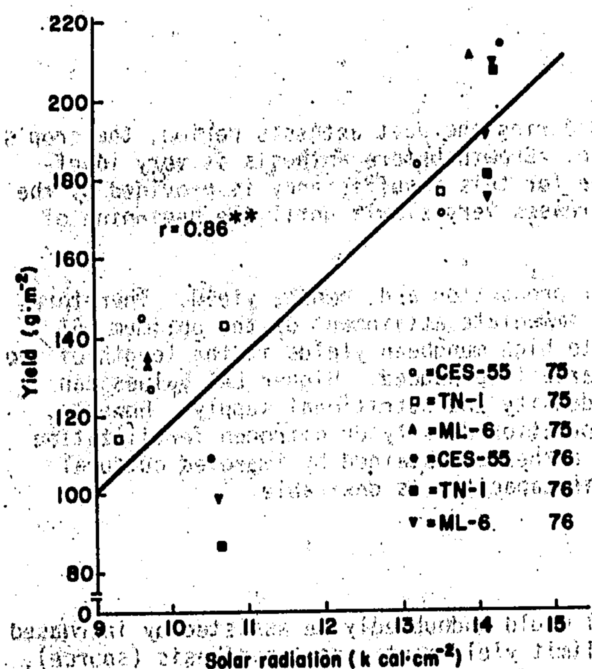

Fig. 1. Relation between seed yield and solar radiation in the period of 30 days from the anthesis of each mungbean variety.

expect to find higher photosynthetic rates/unit of leaf area among higher yielding mungbean varieties. Under a light intensity of 5×10^4 μW/cm^2/min, we demonstrated that individual leaves of high yielding variety PHLV-18 had a net photosynthetic rate, measured by infrared CO_2 analyzer, about 30% higher than those of medium or low yielding varieties, ML-6 and CPI-30755A at flowering stage (Fig. 2). This is also supported by the measurement of net assimilation rate (NAR) (Fig. 3).

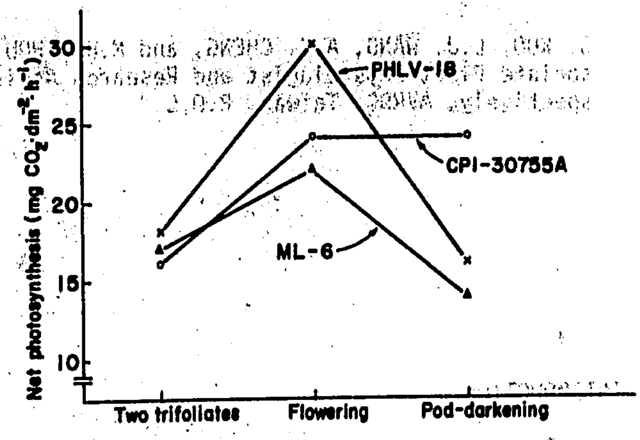

Fig. 2. Relation of growth stage of mungbean and net photosynthesis.

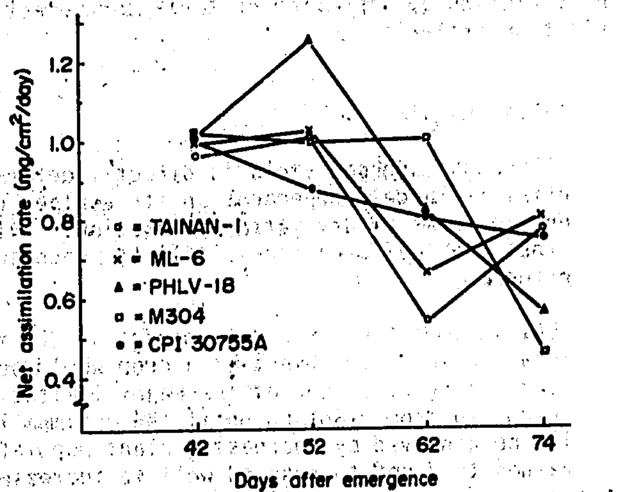

Fig. 3. Relation of growth stage of mungbean and net assimilation rate.

The infrared CO_2 gas analysis and NAR measurement had sufficient sensitivity to identify genetic variation in mungbean. However, because the photosynthetic rate tends to vary with environment, and measuring NAR is time consuming, some more easily measured and stable characters might be a better selection index. Wareing et al. (10) suggested that the activity of ribulose diphosphate (RuDP) carboxylase is rate limiting for photosynthesis under many conditions. Frey and Moss (6) also found genotypic variations in RuDP carboxylase activity in barley. Similarly, RuDP carboxylase activity from the top third fully expanded mungbean leaves at the flowering stage were found to be positively correlated with specific leaf weight (SLW) measured at the same growth stage (Fig. 4), or the final yield (3). Therefore, a biochemical process such as RuDP carboxylase activity may be amenable to genetic manipulation, and a sufficiently rapid and economical method of measuring SLW might be used as a routine screening procedure.

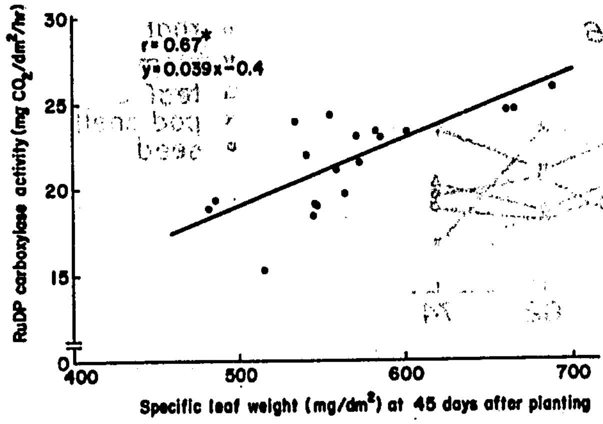

Fig. 4. Relation of specific leaf weight and RuDP carboxylase activity of mungbean.

TRANSLOCATION AS A LIMITATION ON YIELD

The ultimate partitioning of dry matter between reproductive and vegetative parts is indicated by the harvest index (HI). And one of the most fundamental factors affecting this is the capacity to mobilize photosynthate to the plant organs having economic value. In general, HI was higher for the earlier-maturing cultivars and decreased progressively with genetic lateness of maturity among varieties (Fig. 5). This general inverse relationship between HI and the length of vegetative growth may be attributed in part to several factors. Firstly, a vegetative growth period in excess of that necessary for the formation of closed canopies in the particular agronomic conditions resulted in further dry matter production, particularly in stems and leaves.

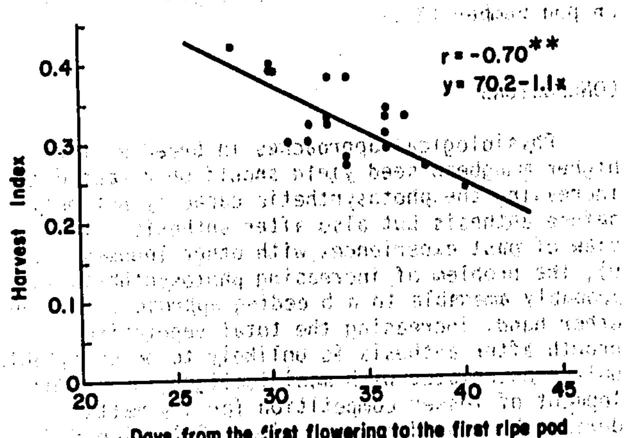

Fig. 5. Relation between maturity period and harvest indices of 20 mungbean varieties.

without a parallel increase in seed yield. In some instances, extended periods of vegetative growth resulted in reduced seed yield due to increased lodging and senescence of lower shaded stems and leaves. Secondly, there is a positive correlation between HI and SLW at the early reproductive stage (Fig. 6). This implies a higher proportion of leaf dry matter to be mobilized during the early reproductive phase of development, thereby enhancing HI. On the other hand, sucrose, which accounts for 90-95% of the translocate in soybean (5), has been found to accumulate to a greater extent in the stems and leaves of high yielding mungbean varieties (PHLV-18 and M-304) after anthesis (Fig. 7). This also implies that there is more mobilizable carbohydrate available for translocation to the sink in the high yielding varieties.

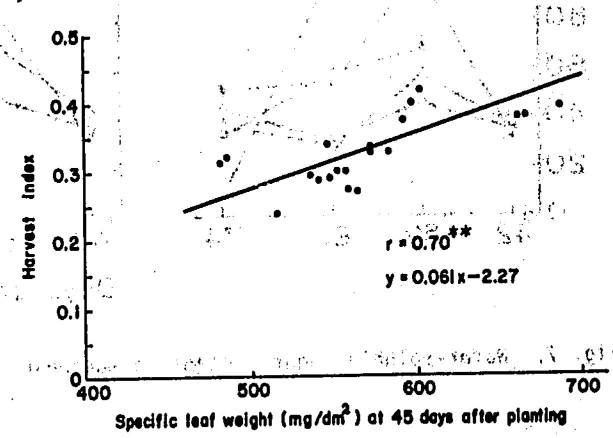

Fig. 6. Relation between specific leaf weight measured at 45 days after planting and harvest indices of 20 mungbean varieties.

Physiological processes (e.g. photosynthesis) or morphological characters (e.g. SLW), for which the use of genetic variability can be considered in breeding for higher yield, are positioned near the beginning of the process which forms yield-components. Measuring only economic yield is the opposite extreme; it considers only a single, economically important output from the process. From a physiology-oriented plant breeder's viewpoint the all-inclusive outputs of the yield process, and also the most easily measured, are the biological yield (net dry matter accumulation) and partitioning (HI). Economic yield is not always closely correlated with biological yield because of inefficient partitioning. Thus, measurements of HI can help identify and define the translocation capacity, and, thereby, help identify varieties with high partition potential (9).

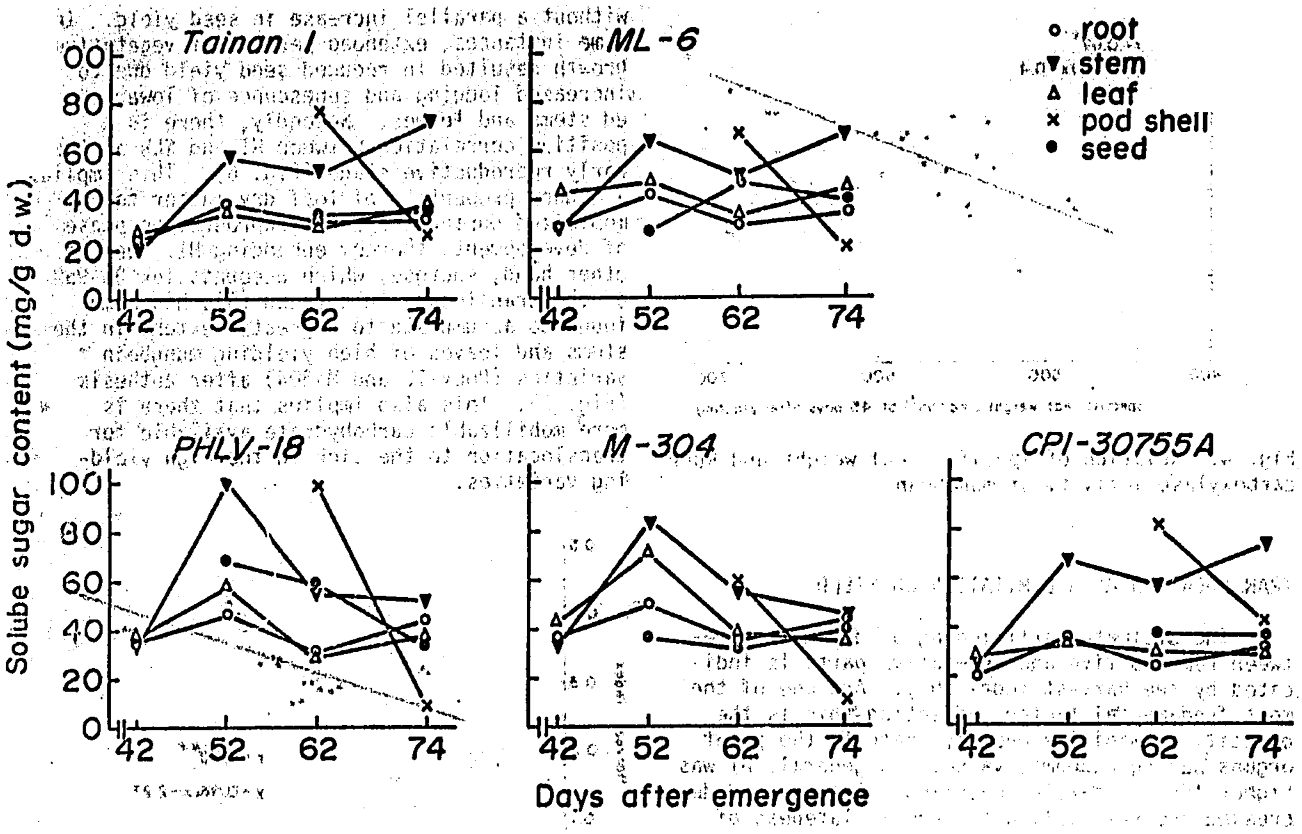

Fig. 7. Water-soluble sugar content in mungbean plant parts in relation to days after emergence.

SINK CAPACITY AS A LIMITATION ON YIELD

Mungbean sink capacity depends on the number of pods/unit area, the number of seeds/pod, and the individual seed size (2). The relative magnitude of these yield components varies substantially with growing conditions at the various stages in crop development, with such features of agronomic practices as population density and variety. In some cases pod number may be the dominant component (2,7); in others, seed size (3). Inverse correlations between pod number and population density or 1000-seed size have been found, and these support the view that there is little impact on yield in raising one component while another decreases (1). However, these compensating mechanisms may also be due to hormonal interactions such as those found in a related *Vigna* species, cowpea (8), rather than to a limited supply of photosynthates. Little is known of the role of growth regulators in mungbean but preliminary experiments with several growth regulators show that kinetin has a promotive effect on pod number (3).

CONCLUSIONS

Physiological approaches in breeding for higher mungbean seed yield should be directed to increasing the photosynthetic capacity not only before anthesis but also after anthesis. In view of past experiences with other legumes (4, 9), the problem of increasing photosynthesis is probably amenable to a breeding approach. On the other hand, increasing the total vegetative growth after anthesis is unlikely to be profitable unless associated with modifications in the development of lesser competition for dry matter during the reproductive period. Selection for varieties with high efficiency in mobilizing resources and current photosynthates to seeds is also desirable.

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Biometrical Basis for Yield Improvement in Mungbean

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Mungbean is likely to play an increasingly important role in protein nutrition within developing countries, expecially where the diet is cereal-based. Because of the great flexibility in terms of adaptation to seasons and farming patterns, mungbean is likely to contribute significantly to the grain legume production and consumption in these areas. Such characters as adaptability and yield are the results of several complex interactions. It is unlikely that such complex traits could be attributable to a small number of genes and, consequently, their analysis calls for biometrical methods. This report examines the extent of genetic diversity, the nature of the attributes resulting in higher yield, and the genetic control of such characters in mungbean grown in India.

ANALYSIS OF DIVERGENCE

We examined the variability existing in 10 elite mungbean varieties and their F_1's using principal components and generalized distance analyses to assess the divergence between populations when a complex of quantitative attributes are considered simultanously. Our study comprised yield components, developmental (phenological) characters, and quality characters.

A scatter diagram for the 35 populations used the first and second canonical vectors as coordinates. The clusterings obtained from the generalized distance analysis were superimposed on this. Such analyses can be used to classify biological populations and to identify factors influencing their divergence. The 10 parents fell into 8 well-separated clusters, the inter-cluster distance being appereciable in most cases. The 25 hybrids fell into 14 different clusters, many of which contained 2 or only one hybrid, often considerably separated from the clusters containing the parents. The extent of divergence found in this limited genotype sample contrasts with the findings in other material. In wheat, for instance, a much larger number of genotypes, including products of extensive hybridization, fall into only 4 or 5 clusters (6). It thus appears that variability is not lacking in mungbean, and it should be possible, by appropriate intercrossing, to generate a gene pool possessing immense genetic variability.

PLANT TYPE NEEDED FOR HIGHER YIELDS

The lack of a concept of the morphological-physiological framework which would lead to high grain yield, rather than genetic variability *per se*, might be the major reason for the limited progress made earlier in breeding high yielding mungbean varieties. One way to obtain relevant information for grain legumes would be to compare genotypes with differing yield levels. The availability of heterotic crosses provides such a comparison. Among the 25 hybrids studied in the 1971 monsoon season, some outyielded the top-yielding elite parent by 50-82%. In the 1974 monsoon season, 4 hybrids along with the parents were grown under 2 different environments, Khandwa in M.P. (black cotton soil) and New Delhi (sandy loam soil). Heterosis over the respective better parent ranged from 12-40%; the magnitude was similar at both locations (3).

Table 1. Comparison of heterotic mungbean hybrids with best parent grown in the monsoon season, India.

Character	Hybrid					Best parent
	K.11 x BR 2	K.11 x T.44	K.11 x J.781	BR 2 x J.781	BR 2 x T.44	
Yield/plant (g)	10.3	9.3	8.5	9.4	9.3	5.7
50% flowering (days)	43.0	39.0	43.0	51.0	44.0	48.0
50% maturity (days)	81.0	67.0	68.0	81.0	74.0	70.0
Pods/pl.	27.0	26.0	20.0	19.0	28.0	14.0
Protein (%)	26.7	26.1	26.3	26.3	27.0	26.7
Branches/pl.	2.1	1.4	1.8	2.5	1.7	2.0
Leaves/pl.	17.0	15.0	14.0	16.0	14.0	17.0
Inflor/pl.	4.6	4.0	2.2	3.7	3.8	4.3

In Table 1, the F_1's of the first set are compared with the top parent in respect to yield and yield components, while the data for the second set is in Table 2. Such comparisons suggest that the heterotic hybrids:

1. flower earlier;
2. show no consistent trend in maturity;
3. possess larger numbers of pods/plant;
4. have slightly larger numbers of seeds, which may be smaller in size;
5. possess equal numbers of branches/plant;
6. have greater numbers of leaves and inflorescences; and,
7. show no particular pattern in respect to protein content.

The analyses, as well as a correlation analysis of an F_2 population of 1500 individuals (4), clearly pinpoint the relationship between larger numbers of pods/plant with larger numbers of slightly smaller seeds/pod and increased yield. Increasing the number of leaf axils, especially inflorescence subtending axils, and looking for shorter internodes and for flowering at an earlier internode may achieve the desired increase in pod number. Another approach would be to look for better pod set, combined, if possible, with a larger inflorescence.

Table 2. Comparative performance for yield and 8 yield components of 5 heterotic F_1's and the respective better parents at Khandwa in M.P. and New Delhi; India.[a]

	T.44 x J.45		P.B. x R.1		B.1 x J.45		B.1 x T.44	
	A	B	A	B	A	B	A	B
Yield/plant (g)	10.2(10.4)	9.2(9.3)	8.3(8.92)	6.1(6.2)	11.7(11.1)	9.5(9.0)	7.2(7.7)	5.3(6.0)
50% flowering (days)	40(40)	56(56)	- (-)	- (-)	46(45)	56(56)	39(39)	44(44)
50% maturity (days)	57(57)	86(86)	62(-)	- (-)	72(71)	86(85)	62(62)	69(69)
Pods/pl.	27(26)	23(23)	20.4(21.9)	17.8(18.4)	28(26)	22(23)	22(23)	19(19)
Protein (%)	28(27)	26(26)	25.5(25.8)	25.3(25.4)	25.5(26.4)	25.0(25.1)	24.5(26.4)	26.5(27.2)
Branches/pl.	2.6(1.8)	2.3(1.9)	1.8(1.6)	1.5(1.7)	2.3(-)	2.1(-)	1.9(-)	1.7(-)
Leaves/pl.	11.7(11.2)	10.8(10.7)	9.9(9.8)	8.5(8.8)	12.3(11.2)	10.9(10.6)	10.9(11)	9.9(10)
Inflor./pl.	6.2(5.6)	5.2(5.1)	5.3(5.2)	3.9(4.2)	6.7(5.6)	5.6(5.0)	5.3(5.4)	4.6(4.6)
Seed weight (g)	3.2(3.3)	3.3(3.4)	3.4(3.3)	2.9(2.8)	3.5(-)	3.3(-)	2.7(2.8)	2.6(2.6)

[a]Figures in parentheses are for New Delhi; (-) indicates difference between F_1 and better parent not significant; A = hybrid: B = better parent.

Table 4. Estimates of genetic components for yield and yield components in different mungbean crosses; India.[a]

	Yield/pl.	Days to flower	Days to mature	Branches/pl.	Leaves/pl.	Inflor/pl.	Pods/pl.	Seed weight
				T.44 x J.45 (Early x Late)				
d	-1.92* (-1.60)	-8.25* (-8.31)	-10.09* (-10.07)	-0.46* (-0.14*)	-1.10* (-1.06)*	-0.59* (-0.64)*	-3.21* (-2.34)*	-0.21* (-0.27)*
h	3.16* (1.36*)	1.60* -0.71	-3.26* (-3.53)	0.15 (0.06)	0.54 (0.32)	0.49 (0.39)	2.74* (1.41)	0.30* (0.26)*
i	0.16 (1.31)*	-7.72* (-9.25)*	-7.97* (-3.19)*	-0.57* (-0.27)	-1.43 (-1.21)*	-1.10* (-0.69)*	-4.61* (-4.28)*	0.14 (0.11)
l	-2.37* (2.42)*	-2.06* (-1.01)	-11.28* (-12.05)*	0.29* (0.24)*	0.05 (0.47)	0.05 (0.45)	0.72 (0.45)	0.05 (0.26)
				P.B. x R.1 (Early x Early)				
d	1.37 (0.91)*	0.16 (0.02)	4.33* (4.47)*	0.27* (0.31)*	0.45 (0.55)	0.16 (0.29)*	3.72* (3.02)*	-0.44* (-0.51)*
h	0.58 (1.06)*	-1.46 (-1.20)*	4.44* (-3.82)*	0.16 (0.06)	1.04 (0.38)*	1.02* (0.01)	4.00* (0.96)	0.48** (0.07)
i	-0.58 (-2.50)*	-1.76 (-0.66)	-4.14* (4.03)*	-0.35 (-0.20)*	-0.81 (-1.14)*	-0.50* (-0.87)	-3.39* (-4.60)*	0.16 (-0.02)
l	-0.08 (2.80)*	0.32 (1.09)	14.24* (13.30)*	0.34 (-0.24)	0.02 (0.58)	0.08 (0.58)	-0.45 (0.38)	0.10 (-0.18)
				B.1 x J.45 (Early x Late)				
d	-0.06* (-1.59)*	-6.24* (-6.21)*	-8.67* (-8.55)*	-0.22* (-0.07)*	-0.50* (-0.28)*	-0.36* (-0.28)*	-1.75* (-1.81)*	-0.35 (-0.01)
h	0.17 (1.58)*	1.02 (1.57)	0.87 (3.68)	0.12 (-0.01)	0.68 (0.33)	0.57 (0.36)	2.42 (1.38)*	0.28 (0.16)
i	-0.06 (-2.42)*	5.40* (5.42)	6.39* (5.28)	-0.30 (-0.10)	-1.15* (-0.51)	-1.12* (-0.47)	-5.29* (-4.32)	-0.15 (-0.08)
l	0.21 (0.69)	11.62* (8.69)	16.93* (11.41)*	0.10 (-0.06)	0.34 (-0.10)	0.21 (-0.13)	1.04 (-0.50)	0.98* (0.001)
				B.1 x T.44				
d	0.28 (0.06)	2.09* (2.09)*	1.89* (1.51)	0.08 (0.03)	0.71* (0.77)*	0.34* (0.27)*	1.21* (0.85)*	-0.16 (-0.10)
h	1.37* (1.58)*	5.00* (5.06)	7.22* (7.21)*	0.44* (0.11)	0.35 (0.42)*	0.28 (0.29)	1.14 (1.90)*	0.30* (0.06)
i	-0.31 (-0.23)	10.17* (8.20)*	12.21* (12.65)*	0.19 (0.03)	-1.29* (-1.09)*	-0.76* (-0.73)*	-3.20 (3.05)	0.30 (0.02)
l	-4.42 (-5.46)*	-20.17* (-19.92)*	-27.28* (-27.73)*	-1.41 (-0.39)	-0.82 (-1.07)	-0.77 (-0.90)	-3.28 (-5.68)	-0.01* (-0.21)

[a]Figs. in parentheses relate to New Delhi; * Significant 5% level.

GENETIC BASIS OF YIELD AND YIELD COMPONENTS

A knowledge of the genetic control of the characters is of obvious importance in organizing a breeding program. Biometrical methods are now available, based on first order and second order statistics, for such analyses. We made a partial diallel analysis for the combining ability of 25 crosses between 10 elite parents using factorial design IV of Fyfe and Gilbert (1). We also used Hayman's (2) generation means approach utilizing 4 generations of 5 hybrids involving 5 different parents, 3 of which were early maturing and 2 medium late. Table 3 shows the results of the PDC analysis (5). The variance for general combining ability (GCA) (which can be equated with fixable genetic variance) was predominant for developmental characters such as number of leaves, days to flowering, and days to maturity. However, a significant specific combining ability (SCA) component was also present. Among yield components, seed number/pod and seed weight showed appreciable GCA variance, while for branches/plant variances due to GCA and SCA were equally important. The harvest index showed only variance due to GCA; however, the general variability for this character was limited in material used.

Table 3. Analysis of partial diallel involving 10 parents and 25 F_1's for yield/plant and yield components.

	Mean square due to		
	GCA	SCA	error
Yield/plant (g)	6.47**	4.15**	2.56
Days to flower	17.87**	4.38**	3.73
Days to mature	65.71**	20.79**	3.49
Branches/pl.	0.39**	0.24**	0.34
Leaves/main stem	5.20**	1.73**	1.48
Inflor/main stem	0.30**	0.20**	0.15
Pods/pl.	31.15**	21.11**	23.42
Seeds/pod	2.15**	0.62**	0.74
Seed weight (g)	0.45**	0.10	0.17
Harvest index	0.003**	0.001	0.002

**Significant at 1% level.

The generation-means approach permitted the estimation of 4 genetic parameters for each of 4 crosses: "d" - a joint estimate of the fixable additive effects and the additive x additive epistatic effects; "h" - an estimate of the dominance effects; "i" - an estimate of the additive x dominance effects; and "ℓ" - an estimate of the dominance x dominance effects. Of the two epistatic effects, "ℓ" is inaccurately estimated while those of "i" are more reliable. The results are shown in Table 4. Yield/plant exhibits significant main effects ("d" and/or "h") as well as epistatic effects ("i" and/or "ℓ") at both locations. This is true also of the yield components, pods/plant and 100 seed weight, while seeds/pod showed no significant genetic effects. The morphological attributes, such as branches/plant, leaves/main stem, and inflorescences/main stem, also show a similar picture.

Both approaches broadly agree in showing a mix of genetic effects. Additive effects are appreciable for most of the characters while dominance effects and epistatic effects are present but not as consistent. Conventional methods of breeding high yielding genotypes of self-pollinated crops might, therefore, be profitable. It would, however, be essential to avoid too rapid a fixation of the genes. A policy of intermating in the F_2, and possibly in the resulting generations, might avoid this and provide better selection. Another approach would be to synthesize a broad-based gene pool by a series of multiple crosses among the elite types. Selection in the resultant population may make possible the isolation of some desirable genotypes; avoidance of rapid fixation by suitable intermating would also be desirable.

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The Mungbean Breeding Program at The Asian Vegetable Research and Development Center

H.G. Park & C.N. Yang

INTRODUCTION

Mungbean, an ancient and well-known leguminous crop of Asia, is popular because of its nutritional quality and its suitability in multiple cropping systems. Mungbeans are often fed to babies, convalescents, and the elderly, or used when ending a long fast, owing to their digestibility, high protein (24%), and freedom from the flatuent effects commonly associated with other pulses. The importance of high plant protein in the predominantly starchy diets of developing countries cannot be over-emphasized. Because of its short growth duration (2-3 months), mungbean is a suitable crop in rotation with stable cereals such as rice, wheat, and corn, or intercropped with sugarcane, for example.

Mungbean is consumed in many forms, including boiled dry beans as dahl (a porridge eaten with rice), sprouts, bean cake, confectionaries, noodles, and green beans.

Mungbean is annually cultivated on about 2.5 million ha mostly in India, from where it originated. However, farmers' yields, ranging from 0.3-0.7 t/ha in India and Taiwan, respectively, clearly reflect the present state of tropical mungbean production. As a secondary or catch crop between major cereal plantings, mungbean has been traditionally grown under marginal environments, especially under water and temperature stresses. Like other leguminous crops, the mungbean is an undisciplined and erratic producer. Yields from the same variety will vary widely depending on season and environment. Such uncertainty makes it difficult for a subsistance farmer to risk his limited resources on mungbean production, resulting in very low input management. Without receiving proper management and protection, it is even harder to expect the crop to fully express its genetic yield potential. Furthermore, the native varieties in use are characteristically low-yielding, shattering, prone to lodging, and do not uniformly mature, but they do possess a few resistant characters against damaging diseases, pests, and unfavorable environmental conditions.

The mungbean has never received the kind of research attention that has been given to most other important food crops. AVRDC, recognizing the potential for mungbean in the tropic and the need for additional sources of protein, started an intensive improvement program in 1972 with a coordinated multidisciplinary approach.

As one of the international agricultural research centers, AVRDC's sub-tropic location i south-western Taiwan makes it possible to plant 3 crops a year under distinctly different sea sons ranging from hot, humid summers to cool winters, and from heavy monsoons to long periods without rainfall. A heavy incidence of seasonal diseases and pests allows breeders to screen and select breeding materials efficiently. Under these conditions, rapid and efficient advances can be made in developing high yielding, uniform maturing, nutritionally balanced varieties with multi-resistances, and responsiveness to higher cultural inputs.

GERMPLASM COLLECTION, MAINTENANCE, EVALUATION AND DISTRIBUTION

During the last 5 years, AVRDC has obtained 4,151 mungbean accessions and 397 related *Vigna* species such as black gram, ricebean, and adzuki bean from 45 countries. To our knowledge this is the largest single collection of these particular species in existence.

This entire collection has been evaluated for yield, yield components, sensitivity to photoperiod, and other agronomic traits, and screened for resistance to major diseases and pests. Screening for environmental stresses such as low temperature and drought have not been done on a large scale yet.

From this large collection, some 400 promising accessions were more intensively evaluated under 2 different seasons. We observed large genetic variability for most traits under study. For example, yields ranged from 0.1-2.2 t/ha the weight of 1000 seeds varied from 20-94, the number of seeds/pod from 6-16, and number of pods/plant from 6-49. Maturity and plant height also showed wide variations. Seasonal effects were clearly evident.

From replicated yield trials of 20 elite cultivars over 6 different seasons during 1975 and 1976, 3 cultivars produced an average of 1.7 t/ha with a maximum yield of 2.7 t/ha at 62 days after sowing. This was recorded in a summer season, and it was clear that mungbean flourishes under hot summer weather when moisture is adequate. The average yield of these cultivars is about triple that obtained by farmers.

One of the increasingly serious problems in mungbean farming is the laborious harvest. From 3-5 hand-pickings are necessary because of uneven maturity and shattering. We observed that several lines from the Philippines and Korea, like PHLV #18, matured fairly uniformly, and one can expect to harvest 80% of its yield at one picking about 60 days after sowing. The maturity is delayed a week or so under cool spring or fall seasons.

In a series of screenings for photoperiod, about 40% of the 2,844 accessions tested were insensitive to daylength differences of 12 vs 16 hrs of light, which indicates that development of a widely adapted variety is possible.

Among many diseases, *Cercospora* leaf spot (*Cercospora canescens*) and powdery mildew (*Erysiphe polygoni*) are the most common diseases in all mungbean growing areas. These can cause yield losses as high as 50%. However, there are more devastating diseases, but they are localized: mungbean yellow mosaic virus in India, mungbean scab in Indonesia, and anthracnose in the southern Philippines.

Our pathologists have identified 4 highly resistant lines to powdery mildew out of 3,435 accessions tested and 14 lines resistant to *Cercospora* leaf spot from 2,742 accessions. Resistant sources to root rot (*Rhizoctonia solani*) and mungbean mottle virus were also found.

In the case of insect pests, we are still looking for stable resistant sources for beanflies (*Melanagromyza* spp.) and cowpea weevil (*Callosobruchus chinensis*) which are very serious pests on seedlings and beans in storage, respectively. We screened 2,640 accessions for beanfly resistance. Entomologists have found 13 lines highly resistant to cowpea aphids (*Aphis craccivora*).

Most of the desirable agronomic traits were found among collections from the Philippines and Korea, while all disease resistant sources can be traced to Indian lines except cowpea aphid resistance. Therefore, our hybridization has emphasized the recombination of these traits between Philippine and Indian lines.

Even though mungbean is a self-pollinated crop, we found that natural out-crossing could be as high as 13% in certain genotypes, which suggests that some care is needed to maintain germplasm.

As the end of 1976, 8,700 mungbean seed packages, both germplasm and breeding lines, were distributed to cooperators in more than 30 countries. AVRDC offers full access to its germplasm, breeding lines, and populations to every scientist who is interested in mungbean research.

HYBRIDICATION AND SELECTION

Crossing blocks composed of 60-100 F_1's are carefully selected following evaluation and screening of the world collection, and are planted each season. By August, 1977, we had made 2,109 sucessful crosses. The introduction of resistant sources from Indian lines to high yielding and uniformly maturing Philippine and Korean lines is our major concern in this hybrid program. About 60% of the pollinations are successful with an average production of 6 seeds/pod. We did not notice any difficulty in making crossings among different groups of mungbean.

More than a half million segregating plants are annually planted in 3 distinctively different seasons as mentioned earlier. About 5,000-6,000 single plants are selected from these annually. No fungicide is applied for all segregating materials but, rather, pathologists help us to artificially inoculate the fields. Besides artifical inoculation, the most susceptible variety is planted as a source of inoculum in every seventh row in order to increase the incidence of disease, so problems of escape will be minimized. Minimum insecticide is applied.

Selection for resistance to powdery mildew is emphasized in the spring and fall crop during which the disease occurs most severely, while we select against *Cercospora* leaf spot in the wet summer season.

Data from the first advanced yield trial for summer, 1977 are not analysed yet. We are confident that a significant breakthrough in mungbean yield will be realized in the near future.

ROLE OF AVRDC IN MUNGBEAN IMPROVEMENT

AVRDC is fully aware that the improvement of mungbean production in farmers' fields cannot be realized without active and sincere cooperation between our program and national and regional programs.

AVRDC has solicited interest from any scientist wishing to cooperate in this endeavor. For our part, all germplasm and breeding materials will be available upon request. Besides these plant materials, we are anxious to exchange and disseminate research information. Our library has collected 1,451 reprints on mungbean research, which is definitely the largest collection of references on this crop, and these are available at minimum charge.

In August, 1977, AVRDC co-sponsored the First International Symposium on Mungbean. More than 100 delegates from 45 institutions in 16 countries participated.

We also coordinate the International Mungbean Nursery which was initiated by Dr. Poehlman, University of Missouri, in 1972.

The training of 6 young mungbean scientists from several Asian countries has been completed at AVRDC, and the importance of such training for successful regional cooperation cannot be over-emphasized.

I would like to finish this presentation by introducing a remark made by Dr. Chandler, first director of AVRDC. He said,"AVRDC has initiated a high-level research program directed toward bringing the mungbean out of it semi-wild state into that of a truely domesticated crop, capable of responding to modern crop management." Thank you.

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Mungbean Varietal Improvement Program of The Bureau of Plant Industry

F.B. Ballon, B.M. Legaspi, and E.M. Catipon

INTRODUCTION

The Philippines is one of the Asian countries having malnutrition problems, and mungbean is one of the legume crops being recommended as a supplemental food to overcome them. Mungbean is accepted by Filipinos as a vegetable when cooked either as dry, sprouted, or fresh beans, or as processed products such as noodles and confectionaries. It is regarded as the poor man's meat because of its protein content. (Table 1).

Although commonly grown by Filipino farmers, the national average production of mungbean is very low despite improved varieties and available technology. As a result, the country must import mungbeans (Table 2).

The general objective of this paper is to present the mungbean varietal improvement program of the Bureau of Plant Industry (BPI).

VARIETAL IMPROVEMENT PROGRAM OF THE BPI

In 1956, the Department of Agriculture, through the BPI, launched a varietal improvement program under a bilateral agreement between the defunct National Economic Council (now National Economic Development Authority) and the International Cooperation Assistance (now U.S. Agency for International Development). The objectives of the program are:

1. to develop high yielding, semi-dwarf varieties with uniform maturity, bigger glossy non-shattering seeds suitable for mechanized harvesting, and a wider range of regional adaptibility; and,

2. to develop varieties with higher nutritional value (carbohydrate and protein content).

When the program started, most of the available local varieties were badly mixed. Isolation and purification was conducted on the basis of outstanding characteristics essential for breeding. The promising selections were further purified, evaluated, and named after the region or town of origin. Eventually the nomenclature was simplified and the following selections resulted:

Table 1. Area planted and average yield of dry mungbeans in the Philippines.

Crop year	Area planted	Production	Average yield
	---- ha ----	---- mt ----	---- kg/ha ----
1956	48,300	28,488.2	590
1957	49,600	29,506.0	595
1958	52,620	32,051.9	609
1959	53,900	33,797.0	627
1960	54,770	30,016.2	548
1961	49,120	24,957.0	509
1962	51,330	24,344.3	474
1963	47,630	18,991.7	399
1964	47,710	19.986.1	419
1965	43,610	18,337.3	420
1966	42,340	16,780.2	396
1967	55,540	14,099.4	397
1968	38,060	16,274.3	428
1969	36,500	15,301.6	419
1970	38,130	15,900.7	419
1971	36,900	16,252.3	440
1972	37,850	17,438.7	461
1973	39,980	19,121.9	473
1974	37,480	16,064.0	428
1975	39,320	21,617.8	550

1. Glossy Green S-1 - large glossy green seed, 52-54% carbohydrate, stable yield throughout the year, and 50-70 cm tall.

2. Glabrous Green - small glossy green seed, small pods devoid of pubescence, very prolific with most of the pods borne on the upper part of the plant, 40-45 cm tall, resistant to lodging, non-shattering and uniform maturing, very susceptible to *Cercospora* leaf spot, 54-58% carbohydrate, 22-26% protein, and small oval leaves.

3. Dull green 28-1 - highest number of seeds/pod (16-21) and the longest pod among the purified strains (16-20 cms), medium dull green seed, 54-56% carbohydrate, 20-24% protein, 90-105 cm tall, and broad leaves.

4. Ilag S-6A - glossy yellow, medium to large seed with 54-55% carbohydrate, and 22-25% protein.

5. Iloilo yellow - small glossy yellow seed 56-58% carbohydrate, 24-26% protein with high carotene, small pods, highly shattering, 80-90 cm tall, susceptible to leaf spot disease, and broad leaves.

6. San Pablo yellow - identical to Iloilo yellow except the seed is mixed glossy and dull yellow.

Table 2. Importation of mungbean in the Philippines.

Year	Quantity	Value
	--- mt ---	-- US$ --
1965	2.5	88.00
1966	187.7	6,086.00
1967	1853.7	39,439.00
1968	2608.7	5,470.00
1969	n/a[a]	n/a
1970	104.1	3,255.00
1971	1333.4	27,229.00
1972	3494.1	102,273.00
1973	n/a	n/a
1974	48.0	15,543.00
1975	310.0	n/a

[a]Data not available.

The breeding program yielded the improved varieties discussed below. For systematic indexing of the improved lines, initials were assigned to each: MG-mungbean glossy, MD-mungbean dull, and MY-mungbean yellow. The color describes the phenotype of the seeds. These improved varieties yielded an average of 1.2 t/ha. The parents yielded only a maximum of .6 t/ha.

1. MG 50-10A, a cross between Glossy Green S-1 and Glabrous Green, yields an average of 1.2-1.5 t/ha in high density plantings during the dry season in soil high in P and K. About 55-60 cm tall during the dry season, it is resistant to shattering, with uniform maturity in 60 days. In the wet season, it grows about 70-75 cm tall and matures in 60-70 days. Pods are developed on the upper-most part of the plants. Seeds are medium large (8-10 grams/100 seeds), glossy green, and 60-68% carbohydrate and 21-26% protein.

2. MD 15-2, a cross between S-1 and 28-1 is locally called "Super Mungo" because it possesses 16-20 cm pods and 16-21 seeds/pod. Ranging between 75-100 cm tall and maturing in 67-70 days, the yield is 0.9 and 1.2 t/ha during the wet and dry seasons, respectively. Weighing 100 g/100 seeds, this variety is resistant to shattering and suitable for planting in rotation with rainfed lowland rice.

3. Glabrous No. 3 and MY-17 are sister lines from the cross between MG 50-10A and Ilag S-6A. Glabrous No. 3 has pods devoid of pubescence. The plant averages 55-65 cm tall and produces glossy green seeds (11-12 g/100 seeds) which are non-shattering and contain 58-68% carbohydrate and 24-26% protein. Glabrous No. 3 has attained average yields of 1.5 t/ha in Cotabato in soil rich in P and K, and 1.2 t/ha with medium soil fertility.

MY-17 produces the biggest seeds among the yellow seeded improved varieties, and the largest pods devoid of pubescence. Averaging 75 cm tall and maturing in 60-70 days, this variety is resistant to shattering and contains 60% carbohydrate and 24-26% protein. Both varieties are popular among farmers for their suitability as a green vegetable. Manual threshing of the dry pods is convenient. These improved varieties were preferred by the common insect pests such as *Prodenia litura*, *Heliothis armigera*, *Nephotettix viriduala*, bean fly (*Melanagromyza phaseoli*), Aphids (*Aphis* sp.), spotted lady bird (*Epilachna philippinensis*), and the bean pod borer (*Eliella zinckenella*). Both are susceptible to powdery mildew and *Cercospora* leaf spot diseases.

FUTURE PROGRAM OF THE BPI ON MUNGBEAN VARIETAL IMPROVEMENT

1. Increase the germplasm collection of indigenous wild cultivars and exotic varieties from the leading mungbean research institutions to provide a wider genetic base.

2. Incorporate genes for pest and disease resistance.

3. Intensify crossing to build a diverse gene pool.

4. Speed up development of varieties to attain homozygosity.

5. Grow segregating populations in different regions under different agro-climates exposed to various prevalent major pests and disease

6. Develop high yielding varieties resistant to lodging with uniform maturity, a certain degree of dormancy, stable yield, and better nutritive value.

7. Utilize an inter-disciplinary approach between plant breeders, bio-chemists, and nutritionists to identify outstanding lines for nutritional value.

For confirmation of the data obtained from the station, farmer's fields trials will be carried out on both the use of improved varieties and development of good cultural methods. Technology will be immediately transferred to the farmers.

Once new high yielding mungbean varieties are available, good cultural technology has been transferred to the farmers, and crop protection has been developed, a national action program will be spearheaded by the NFAC to increase production rapidly. A realistic policy of grain pricing will be established and guaranteed by the government to stimulate farmers, and to assure them an acceptable return on their investment.

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AVRDC Philippine Outreach Program Mungbean Studies

B.M. Legaspi, E.M. Catipon, and J.N. Hubbell

Because mungbean is an important agricultural and industrial crop in the Philippines, the development of early, uniform maturing, stable, and high yielding cultivars with disease resistance and improved nutritional quality is a top priority research concern. Mungbean research was bolstered by the establishment, with Asian Development Band funds, of the AVRDC Philippine Outreach Program (POP) in May, 1975. Administered by the Department of Agriculture through the Bureau of Plant Industry (BPI), and supported by the Philippine Council for Agriculture and Resources Research (PCARR) and the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), the AVRDC/POP is located at the BPI Economic Garden in Los Baños, 62 km south of Manila at 121°15'E longtitude and 14°10'N latitude. The soil at the station is fairly fertile clay loam with an elevation of about 15 m above sea level. Temperatures range from 21°C in January to 33°C in May. Precipitation averages 39 mm in the drv season (Jan-Apr) and 230 mm during the rest of the year.

The objectives of the AVRDC/POP mungbean project are:

1. To identify promising AVRDC mungbean materials under various environments,
2. to screen mungbean materials for major diseases and pests under field conditions, and
3. to increase mungbean materials for future additional evaluation.

The AVRDC/POP has now conducted 10 mungbean studies covering various aspects of the evaluation and selection of cultivars and segregating lines. Seven of these studies have been completed.

SEGREGATING MUNGBEAN LINES

Ten F_2 segregating mungbean lines from AVRDC were screened for yield and resistance to *Cercospora* leaf spot. Each line was planted on June 4, 1976 on average 52.2 m² plots. Individual plants were selected by: (a) desirable plant type, (b) high bean yield, (c) high number of pods/plant, (d) relative resistance to *Cercospora* leaf spot, and (e) uniform and early maturity.

The selections will be planted in progeny rows for further evaluation and purification.

Table 1. Mungbean accessions index.

AVRDC acc.no.	name	Country of origin
573(F4)	MU-6/um 231	AVRDC
1066	Phil. Col. # 1	RP
1133	M 194	India
1380	EG-MG-6D	RP
1381	MG 50-10A (G)	RP
1387	CES 55	RP
1399	CES 28	RP
1829	M 857	India
1854	M 882	India
1944	MG 50-10A (Y)	RP
1948	CES 87-17	RP
1954	S-8	India
2010	V 2010 (M-317)	China
2013	Tainan #1	Taiwan
2027	Barsati 1-23	India
2016	Q 10601	Australia
2184	Phil. #18	RP
2210	PI 286298	RP
2272	ML-5	India
2273	ML-6	India
2367	Klish-na 11	India
2773	LM-689 (ML-3)	India
2779	LM-697	RP
2808	Local CV-1	Taiwan
2984	Kyungkhaerae 5 (M-350)	Korea
3156	ML-6	India
3179	Mehr (48-071-10807)	Iran
3197	Mehr (48-071-10827)	Iran
3372	Shinning Moong 1	India
3404	M 7-A	Thailand
3405	OSU M-967-71-17	USA
3476	CES ID-21	RP

UNIFORM YIELD TRIAL

Ten mungbean accessions selected at AVRDC with potential for good performance in the Philippines were planted during the 1976 wet season. In spite of the uneven stand produced by early heavy rains, the yields were satisfactory. The highest yielding accessions were 2273 (2461 kg/ha) and 2773 (2415 kg/ha) which yielded 174% and 171%, respectively, of the local check, 1381 (see Table 1 for accessions index). The componen that contributed to the high bean yield was the number of pods/plant. The seed sizes, however, were smallest (32-25 gms/1000 seeds) among the entries. Maturity was uneven due to the large percentage of bean yields on the third and fourth harvests. Accessions 1380, 2013, and 2184 showed more uniform maturity through high yield during the first and second harvests. Accession 2013 ranked third in bean yield with 1953 kg/ha or 138% over the check.

YIELD TRIAL OF ELITE SELECTIONS

Twenty mungbean cultivars and AVRDC hybrids selected for yield were evaluated in 1975. The field performances of the entries were greatly affected by the unusually heavy precipitation during the crop's vegetative and pod development stages. Bean yields ranged from 30-240 kg/ha with a grand mean of 107 kg/ha. Significant yield differences existed between high yielding entries 2210, 1948, 1399, 2773, and 2984 (143-240 kg/ha) and the local check, 1387 (113 kg/ha). The pods/plant, seeds/pod, and pod length, however, were not significant. Frequent rain favored the occurrence of *Cercospora* leaf spot. Only accessions 2773 and 2272 from India were not severly infected.

INTERNATIONAL MUNGBEAN NURSERY

The International Mungbean Nursery (IMN) trials aim to: (a) provide information on the range of adaptation of mungbean species and specific cultivars, (b) provide information on the characteristics of the mungbean plant influencing adaptation, and (c) serve as a means of disseminating superior cultivars to mungbean research workers.

The BPI Economic Garden cooperated in the Third (1974) and fourth (1975) IMN trials. The Fifth IMN (1976) was conducted jointly by the AVRDC/POP and the BPI Economic Garden Legume Research Project.

The Fifth IMN trial, with 30 mungbean cultivars, was planted on June 3 in a randomized complete block replicated 3 times. Each entry was sown in a single row 4 m long and 60 cm apart. Complete fertilizer (14-14-14) at 400 kg/ha was applied at planting and the crop was raised in an intended population of 250,000 plants/ha.

There was a significant difference in yield among the entries which ranged from 987-2218 kg/ha with a grand mean of 1520 kg/ha. The 5 highest yielding entries (3372, 2773, 3179, 2010, and 3405) had yields from 1848-2218 kg/ha or 119-143% over the local check, 1381 (1550 kg/ha). Of these entries, 3197 (from Iran) and 3372 (from India) showed relative uniformity in maturity. Both entries had high bean yields in the first and second harvests.

Although there were significant differences among the entries on all characters measured, these characters did not seem to contribute directly to bean yields. Thus, 3156 with the highest average of 57 pods/plant ranked 18th in bean yield, and 1944, which ranked 24th in yield, showed the biggest bean size of 80 g/1000 seeds. However, this entry had the least average number of pods/plant among the 30 cultivars.

A severe unidentified disease during the rainy season was observed on some of the mungbean entries. This disease manifests itself as numerous small chocolate-brown lesions with irregular margins, usually on the under surface of older leaves. With age, the lesions coalesce forming big brown blotches which become visible on the upper leaf surface. At this stage, the lesions become brittle, causing affected leaf tissues to break. The disease also affects the leaf petiole. Of the mungbean cultivars studied, 13 were immune to infection. All the cultivars from the Philippines were affected; the most susceptible was 1381.

YIELD TRIAl

Thirty-six high yielding mungbean cultivars selected from elite selections, uniform trials, and IMN studies conducted in 1975-1976 were evaluated in one yield trial on November 18, 1976. Complete fertilizer (14-14-14) was applied at 400 kg/ha at planting and the crop, at about 250,000 plant density/ha, was raised under rainfed conditions.

Except for the number of pods/plant, significant differences in bean yield and other yield components among the 36 mungbean cultivars were noted. The 5 highest yielding entries 3404, 2808, 2013, 1954, and 1387 gave computed bean yields of 1232-1343 kg/ha or 113-123% over the local check, 1381. Most of these cultivars matured in 60 days. Variety 1954, however, was small-seeded. Accessions 2272, 2773, and 3476 were most resistant to powdery mildew.

SCREENING FOR DISEASE RESISTANCE

Some of the most serious foliar diseases of mungbean are *Cercospora* leaf spot (*Cercospora canescens*) and powdery mildew (*Erysiphe polygoni*). The mungbean mottled virus (MMV) and the mungbean yellow mottled virus (MYMV) have so far been observed on introduced cultivars.

Cercospora leaf spot. In the Philippines, *Cercospora* leaf spot (CLS) is most severe during the wet season months of June-August. The disease can reduce yields of unprotected mungbeans by 47% during the warm wet season. The 1975 wet season screening of 27 mungbean accessions and hybrids previously selected in Taiwan for resistance to CLS showed 6 resistant entries.

In a uniform yield trial during the 1976 wet season, 2273 and 2773 were very resistant to CLS, and they showed the highest bean yield of 174% and 171%, respectively, over the check.

Powdery Mildew. Powdery mildew is a severe mungbean disease during the cool dry months. It occurs commonly from November through April in Taiwan, Thailand, and the Philippines. Yield reduction could range from 20-40%. However, when infection occurs at the seedling stage, the whole crop may be lost. A 1976 evaluation of 20 elite selections to powdery mildew, produced the 3 most resistant accessions, 2106, 2773, and 2013. Moreover, 2773 showed a bean yield 176% over the local check, 1387.

Virus diseases. Incidence of MYMV and MMV was very severe in the June, 1975 evaluation of AVRDC accessions and breeding lines grown under wet season and no-pesticide conditions. The spread of the virus disease appeared closely associated with the severity of the bean aphid infestation. Two screening studies for disease resistance were conducted on 127 mungbean entries. All plants with virus symptoms, whether infected with MYMV or MMV, were recorded as virus infected.

In the first screening, involving 27 selected accessions and breeding lines, 1066, 2779, and 573 F_4 were resistant.

The screening of 100 cultivars in 1975 identified 20 entries as most resistant to virus infection. Accession 1854, 1829, 2027, and 1133, besides being resistant to the virus disease, showed the highest computed bean yield (547-659 kg/ha) despite the no-pesticide treatments.

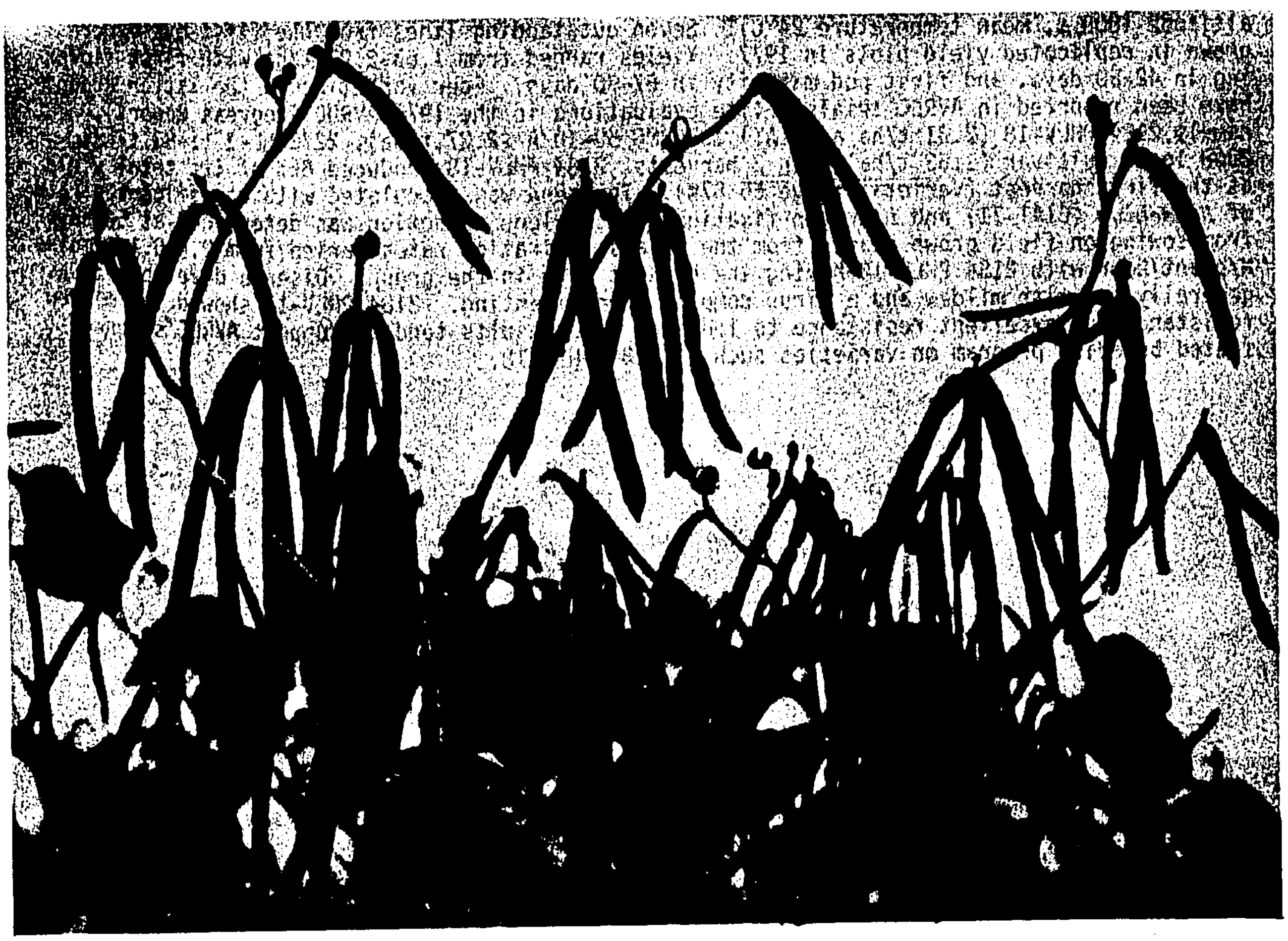
DISCUSSION

From the series of trials conducted on the AVRDC accessions and breeding lines, a number of entries with promising specific characters under the local agroclimatic conditions have so far been identified.

Yield. Accessions 2273 and 2773 both from India, consistently outyielded most entries including the local checks. However, their plant type is semi-prostrate and their late and uneven maturity may be unsuited for production under wet tropical conditions. Accession 2013 is a relatively stable, uniform maturing, and high yielding cultivar. However, it is susceptible to CLS and powdery mildew. The other cultivars that have shown promising bean yields are 2984, 3372, 3179, 2010, 3404, and 2808. Accessions 3372 and 3129 are relatively uniform maturing.

Reaction to diseases. Accessions 2773 and 2273 are highly resistant to CLS and powdery mildew. They are moderately resistant to the virus diseases. Breeding line 573 F_4 is resistant to both CLS and virus diseases, while 2367 is highly resistant but susceptible to virus infections. On the other hand, 1066 and 2779, while resistant to virus infections are susceptible to moderately resistant to CLS. Accession 2106 is highly resistant to powdery mildew.

In the past, the mungbean breeding programs in the Philippines have been centered on the development of high yielding cultivars under conditions of good cultural management. Under these programs, 7 cultivars have so far been developed. Their high bean yields can be attributed to increased number of pods, increased seed size, resistance to pod shattering, up-right growth habit, and early and relative uniform maturity. Most of these cultivars, however, are susceptible to insects and diseases. Our breeding objectives, therefore, have been modified to incorporate such qualities as the genetic resistance and tolerance to major pests and diseases of the AVRDC accessions.



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Preliminary Evaluation of Mungbean Material at CIAT

D. Liang, K.O. Rachie, and G. Giraldo

With only scattered small areas sown for limited local markets, mungbean production in Latin America is not of great importance. However, some national programs have shown interest in improved material. The International Center for Tropical Agriculture (CIAT) has collaborated with AVRDC in the evaluation of 69 germplasm collections at the CIAT station (latitude 3°N, altitude 1000 m, mean temperature 24°C). Seven outstanding lines from the first cycle were grown in replicated yield plots in 1977. Yields ranged from 1.63-2.27 t/ha with first flowering in 42-50 days, and first pod maturity in 67-70 days. Four varieties in the latter group have been reported in AVRDC trials (Elite evaluations in the 1975 AVRDC Progress Report), namely 2184 PHLV-18 (2.21 t/ha at CIAT),1380 MG 50-10 A (2.27 t/ha), 2273 ML-3 (1.83 t/ha), 2808 local cultivar (1.63 t/ha). In 2 harvests, 2184 PHLV-18 produced 86% of its total yield at the first harvest (varietal range 65-87%). The seed was inoculated with an efficent strain of *Rhizobium* (CIAT-71) and nitrogen fixation by acetylene reduction was determined at 56 days from sowing on field grown plants from the trials. Fixation rates varied from 2.4-8.1 μ moles N/plant/hour with 2184 PHLV-18 having the highest rate in the group. Disease development was generally low with mildew and a virus complex predominanting. 2184 PHLV-18 showed low mildew resistance but excellent resistance to lodging. The results tend to support AVRDC's concentrated breeding program on varieties such as 2184 PHLV-18.

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Mungbean Breeding Program of UPLB, Philippines

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INTRODUCTION

Mungbean, an important pulse crop in the Philippines and other Asian countries, is utilized as food in the form of dry beans, snap beans, sprouts, or manufactured products. In the Philippines, mungbean is planted as a dry land crop and, commonly, after lowland paddy rice. To some extent, it is intercropped with sugarcane and other slow growing crops. The total area planted in 1975 was 39,320 ha, with a total production of 21,617.8 t, or an average yield 550 kg/ha.

The low national average yields could be due to the traditional low management input given the crop, as well as to a host of biological factors associated with the use of low yielding varieties, impure seeds, and the occurrence of insect pests and diseases.

OBJECTIVES OF THE BREEDING PROGRAM

Breeding objectives include the enlargement of our germplasm collection, and the identification from this collection of specific gene sources for resistance to major insect pests and diseases, improvement to plant morphology and plant type, and the adaptive potential for high yield under various cropping conditions. From this gene pool, our interdisciplinary team, through hybridization and selection, breeds varieties with desired traits. The specific objectives are discussed below.

1. High seed yield. The development of mungbean hybrid varieties with yield potentials of about 2 t/ha (about twice that of traditional varieties) can be accomplished primarily by increasing seed size and number of seeds/pod, improving standability and reducing seed losses at harvest due to pod shattering, and increasing uniformity in pod maturation and disease resistance.

   One outstanding line selection, Pag-asa (CES 1D-21), was isolated from a cross between CES 87 and ML-5. Pag-asa is noted for its high seed yield, short stature, uprightness and non-lodging habits, earliness, uniform maturity of pods, and non-shattering tendency at maturity.

2. Resistance to disease and insect pests. *Cercospora* leaf spot (*Cercospora canescens*) and

powdery mildew (*Erysiphe polygouni*) are the most destructive mungbean diseases in the Philippines. Sources of resistance have been identified in Pag-asa for use in the breeding program.

We have identified 63 accessions immune to anthracnose, a highly destructive disease in Mindanao.

Our entomologists are now evaluating the germplasm collection to identify sources of resistance to: beanfly (*Ophiomyia phaseoli* tyron), bean aphid (*Aphis oraccivora* Koch), southern green stink bug (*Nezara viridula* Lin.), and bean weevil (*Callosobruchus chinensis*, Linn).

3. Earliness and greater uniformity in pod maturity. Maturity of less than 65 days is desirable. This provides greater flexibility in planting, increased cropping intensity, and fewer risks from environmental extremes. Uniformity in pod maturity will reduce labor costs by allowing one harvest and early removal of the crop.

Table 1. Mungbean accessions at the Institute of Plant Breeding, Philippines, 1976.

Source	No.	Source	No.
India	892	Ivory Coast	9
Philippines	413	China	8
Australia	95	Guatemala	4
Indonesia	89	Brazil	4
Taiwan	86	Madagascar	3
Iran	85	Korea	3
Thailand	73	Peru	3
U.S.A.	70	Burma	2
Afganistan	66	S. Africa	1
Pakistan	36	Cambodia	1
France	26	Ceylon	1
Vietnam	15	Congo	1
Hong Kong	13	Unknown	132
Turkey	11	TOTAL	2057

4. High seedling vigor and medium plant stature. To compete better with weeds during the early growth stages, varieties with high seedling vigor enable rapid crop establishment. Such varieties also take advantage of residual moisture in the lowland paddy and withstand lodging.

5. Seedcoat color and seed quality. Although yellow varieties are preferred by most Filipinos, we have observed an association between yellow seedcoat color, reduced seed size, and susceptibility to leaf diseases. This relationship is now under investigation.

6. Adaptation to intensive cropping. We are identifying agronomic traits associated with adaptation to specific growing conditions for use in multiple cropping systems.

Germplasm Collection

At present we have accumulated 2057 mungbean accessions from local and international germplasm collections (Table 1).

Accessions of related species - *Vigna mungo* (39), *V. umbellata* (40), and *V. angularis* (21) - are maintained in the collection not only for possible commerical production in the Philippines but also for interspecific crosses with mungbean.

SCREENING APPROACHES

In order to identifly varieties adapted to mono-cropping systems in upland and rice paddy conditions as well as mixed or intercropping with tall, slow growing crops, we have screened our germplasm collections and breeding materials as follows:

Upland monoculture

Mungbean culture in the upland generally follows the traditional practice of land preparation consisting of 1-2 plowings and harrowings. Furrows are 0.50-0.75 m apart. Seeds are drilled in the furrow, covered lightly with soil, and later thinned to the desired population. Basal fertilizer is applied.

Screening for disease resistance, improved plant type, standability, and high bean yield are conducted. In the past, disease screening and selection were done under natural epiphytotic conditions. Lately, screening is under artifically induced epiphytotic conditions.

Lowland paddy cultivation

About 48% of the total rice areas in the Philippines is rainfed. Under this condition, only one crop of rice can be planted each year.

We screened our germplasm collection for types that would adapt to lowland paddy conditions after rice is harvested and before the next year's rice crop is transplanted.

Mungbean planted after rice harvest, usually at the end of the rainy season, is characterized by excess moisture at the seedling stage and drought towards flower-initiation stage. Our experimental cultivation is based on zero tillage and complete reliance on residual moisture. Seeds are dibbled into the ground at the base of the rice stubble.

Fertilizer is applied and the area is mulched with rice straw in order to conserve soil moisture and prevent volatilization of fertilizer during hot days. Bean yield among varieties ranged from 25-2525 kg/ha with an average of 808 kg/ha. We indentified 27 high yielding accessions. The agronomic characters that were found to be essential in postrice cropping are:

1. rapid seedling establishment to take advantage of the residual moisture and improve competitiveness with weeds;
2. early maturity;
3. drought tolerance (varieties with deep, widespreading, and well-branched root systems have an advantage); and,
4. resistance to powdery mildew.

Conditions for mungbean planted before rice are characterized by excess water during the flowering to maturity period. The same cultural practices are followed as in post-rice screening except that mulching is dispensed with and spacing and population are modified. No tillage is practiced. Bean yield among varieties ranged from 30-3400 kg/ha with a mean of 833 kg/ha. Agronomic traits suited under this condition include:

1. early maturity;
2. moderate vegetative development and a sturdy stem (during the monsoonal rains and low solar radiation, mungbean tends to vegetate highly);
3. High percentage of pod and seed setting since flower abortion is excessive during the rainy season;
4. tolerance to water-logging; and,
5. resistance to *Cercospora* leaf spot.

Mixed cropping

In mixed cropping or intercropping, mungbeans may be planted commerically in the space under coconut, rubber, oil palm trees, or between rows of sugarcane and other slow-growing crops. Under this condition, light is limiting and potential varieties are screened for shade-tolerance. We constructed an 8 ft high bamboo structure that reduces sunlight to the ground by about 40%. Mungbean planted under partial shade gave only 368 kg/ha compared to 1149 kg/ha in the open, or a reduction of 68%. The number of pods/plant and seed size were greatly affected by shading. Powdery mildew was observed to be particularly bad under shade.

When grown as an intercrop with sugarcane, the average yield among accessions was about 455 kg/ha. We observed that shading was not a problem when mungbean was planted at the same time as sugarcane. However, competition for nutrients, water, and space may be important. Under this condition, shallow-rooted varieties may be advantageous and minimize competition with the main crop. Medium plant height, moderate vegetative growth, and erect habit are likewise essential.

The high yields shown by a number of accessions in each growing condition offer possibilities for isolating varieties that are condition specific. A strong interaction between varieties and conditions strengthens our position to select varieties for specific adaptation.

YIELD TESTING

All promising lines selected from the germplasm collection and those isolated from the breeding program are entered into preliminary yield trials. Selections from the preliminary trials are elevated to advanced regional yield trials conducted ~~in 25~~ representative locations in the country. Evaluation of varietal performance in these advanced trials serve as the basis for recommendation to the Philippine Seed Board for official release.

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Breeding Mungbean for Thailand Conditions

Soontorn Duangploy

INTRODUCTION

In Thailand, mungbeans are grown in upland areas, as a main crop, intercrop, or in rotation with other crops; and in lowland paddies, right after the rice harvest in order to utilize all possible soil moisture.

With a rapid increase in domestic and export demand the price of mungbean has risen in recent years. Mungbean now produces greater economic returns than most main crops. This will bring about an incentive for the farmer to grow more mungbean.

Recent mungbean adaptability trials, conducted in different parts of Thailand with introduced varieties and lines from AVRDC, have revealed the production problems discussed in this paper.

BREEDING FOR DISEASE RESISTANCE

Cercospora leaf spot (*Cercospora canescens*) is the most severe disease during the hot, wet season, and reduces yield up to 47%.

Powdery mildew (*Erysiphe polygoni*) is another severe disease, expecially in the cold, dry season. It can also cause considerable damage during the hot, wet season.

Mungbean yellow mottle and mungbean yellow mosaic virus (MYMV) have not been reported. However, a yellow leaf disease (as the farmers call it) has occurred during the past 2 years in Rajaburi province. The disease symptoms are similar to those of MYMV. Dr. H.C. Phatak at the Department of Plant Pathology, Kasetsart University, used the grafting technique for re-transmission, but could not produce any symptoms.

AVRDC sent a number of lines and segregating populations with resistance to these diseases to the Department of Agriculture, Ministry of Agriculture, and to the Agronomy Department, Kasetsart University. They are now being tested and screened for resistance at U-Thong Experiment Station and Suwan Farm.

BREEDING FOR INSECT RESISTANCE

There are a number of insects attacking mungbean, but those causing noticeable damage are beanfly, pod borer, and pea weevil.

Beanfly (*Ophiomyia phaseoli* Tryon or *Melanagromyzy sojae* Zehntner) can kill up to 85% of the seedlings. Beanfly tolerance lines from AVRDC are now being tested at U-Thong Experiment Station and Suwan Farm.

Pod borer (*Heliothis sp.*) can also severely damage mungbean, but a source of resistance has not been reported.

Pea weevil (*Callosbruchus chinensis*) attacks mungbean in storage. A resistant variety to this pest has not been found in our mungbean collection. It is known among farmers that, when mungbean and black gram are kept in storage together, only the black gram avoids weevil damage. So, it would be worthwhile if we could transfer this character into mungbean.

BREEDING FOR DESIRABLE AGRONOMIC CHARACTERS

Uniform maturity is one of the most desirable agronomic characters. Since most mungbean pods do not ripen at the same time, 5-6 pickings are required during harvests. This means increased production costs and labor problems. Now mungbean breeders are aiming at varieties which mature uniformly.

With the high demand and high price incentive, mungbean growing areas are increasing rapidly. Nationwide, mungbeans occupy land all year round in different cropping systems: intercropping, relaycropping, and crop rotation. Farmers plant mungbeans in various cropping systems not only to get the highest return, but also to maintain soil fertility, exploit the total environment effectively, stabilize the ecosystem, and increase biological control of pests. Breeders must develop mungbean varieties to fit into these cropping systems. Thus, early maturity is important to permit planting between 2 main season crops or to escape the shading effect of the taller and longer duration intercropped plants.

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Present Status of Mungbean Breeding in Indonesia

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Since the first PELITA (5-year development plan), the area planted annually to mungbeans averages 122,238 ha and ranks third among Indonesian food legumes. Mungbean production averages 58,727 tons annually, or 488 kg/ha - a very low yield (Table 1).

At the present time, the use of mungbean for food is better known than before World War II. Taste and lack of knowledge regarding preparation and use are among the causes of mungbean's slow expansion in Indonesia.

Area expansion for mungbean faces further difficulties. Harvesting procedures are impractical and tedious. The uneven maturation and shattering of the pods forces farmers to hand-pick the mature crop 3-5 times per harvest. Thus, in addition to high yield potential, even pod maturation and non-shattering characteristics should get priority in the breeding program in order to make mungbean more attractive to farmers.

VARIETAL DEVELOPMENT

Activities related to varietal development started in 1935 with the collection of local varieties, followed by yield comparison. Two varieties, Siwalik and Antaiio were considered good yielders and recommended to farmers.

In 1964, 3 varieties were introduced from Sri Lanka, one of which, MI (I) Jala, gave higher yield with even pod maturation. This variety was registered as 116 and recommended to the farmers in 1965. A BPI mungbean, MG 50-10A, introduced from the Philippines in 1969, is also a high yielder with even pod maturation.

Varietal development was slow because breeding was not coordinated with that of other pulses and, up to 1972, the germplasm collection did not have enough varieties to serve as the base for a breeding and selection program.

GERMPLASM COLLECTION

Our germplasm collection now contains a total of 2327 accessions, of which 39 are *Vigna mungo*. Most of these originated in India and the Philippines, and were received through AVRDC.

Table 1. Total mungbean area and production in Indonesia, 1969-1976.

Year	Area	Production	Avg. yield
	--ha--	-tons-	kg/ha
1969	87,962	40,518	461
1970	68,692	40,214	585
1971	104,431	52,900	507
1972	129,653	65,944	509
1973	155,721	70,762	454
1974	150,238	69,875	465
1975	134,762	60,632	458
1976	147,449	68,971	468

SCREENING AND HYBRIDIZATION

Accessions sent to CRIA Sukamandi in 1974 were screened for yield components and maturation (Table 2).

Table 2. Summary of yield components and maturity for 876 mungbean varieties at CRIA Sukamandi (wet season 1975-76, and dry season 1976); Indonesia.[a]

Characters	Wet season range	Dry season range
Pods/plant (no.)	11 - 152	5 - 105
Seeds/pod (no.)	4 - 17	6 - 17
1000 seed weight (g)	17.7- 72.0	16.5- 93.0
Plant height (cm)	18 - 129	14 - 93
First flower (d.a.s.)	22 - 50	25 - 43
First ripe pod (d.a.s.)	39 - 86	39 - 71

[a]CRIA Sukamandi: Longitude: 107°19'E; Latitude: 6°20'S. Elevation: 15.96 m a.s.l.

In most mungbean cultivars, the excessive abscission of flower buds and premature pods is inherent, suggesting that a high number of flowers and pods/plant are important characters in the development of high yielding lines.

Research results from 19 elite cultivars at AVRDC indicated a negative correlation between yield and number of days to first flower (1).

By grouping the accessions according to their first flowering, it appeared that most gave the first flowers between 28 and 33 d.a.s. It was observed that the time needed from the first flower to the first ripe pod not only differed among the accessions but also between the seasons.

Cultivar 129 showed its first flower at 31 d.a.s., and its first ripe pod at 49 and 52 d.a.s. in the wet and dry seasons, respectively It generally matures within 65 days in the wet season and within 60 days in the dry season. Taking this variety as standard, accessions should be selected which mature within this time period. This is very important in the existing cropping patterns which generally require short duration cultivars of legumes crops.

Besides the objectives of early uniform maturity and high yield potential, crosses have been made to achieve new cultivars which are resistant to scab.

Crosses between *Vigna radiata* and *Vigna mungo* exhibited a total flower drop in the F_1 generation The flower drop could only be prevented when the F_1 was back-crossed to *Vigna radiata*. These crosses were especially made in order to transfer the resistance to scab from *Vigna mungo* to *Vigna radiata*.

YIELD TRIALS

In the wet season 1975-1976, selected lines from 6 series of crosses were judged for yield/plant. From these, 4 series of crosses were selected having higher mean yields/plant (13.32 - 14.99 g). Lines having yields higher than the mean yield/plant of the cross concerned were multiplied to provide seeds for preliminary yield trials.

Yield trials were conducted with promising cultivars from the germplasm collection and also with cultivars received from the International Mungbean Nursery. These cultivars were compared with 116.

The 1975 and 1976 dry season yield trials, conducted in Cikeumeuh, Citayam, Muneng, and Mojosari substations indicated the presence of promising cultivars. Table 3 shows results from these trials with TM (Thailand mungbean) and Philippine cultivars in Muneng and Mojosari substations.

Table 3. Yields of mungbean cultivars in trials conducted in Muneng and Mojosari substations during dry season; Indonesia, 1976.

Cultivar	Yield Mungeng	Yield Mojosari
	------kg/ha-------	
TM - 72	937**	1407**
TM - 100	887*	1215
TM - 107	930	1296
TM - 108	948	1275
423 (RP, local var. 178)	911**	1622**
438 (RP, Dan Mo Kien Phong)	985**	-
467 (RP, CES 78; 366)	674	1382*
468 (RP, CES 87; 367	908*	1354
129 (RP, MG 50-10A)	704	1196
116 (RP, MI (I) Jala	600	1138

PESTS AND DISEASES

The most important pest is beanfly (*Agromyza phaseoli*), which attacks the seedlings, often causing yield reduction ranging from 10-90% (1).

In screening tests carried out in Bogor in September, 1975 and November, 1976, the percentage of dead plants/cultivar ranged from 8-93%, whereas the infestation ranged from 78-100% (4). Sixteen cultivars had average numbers of dead plants lower than 20%. Among them, cultivars 24, 116, 436, and 475 showed less than 10% dead plants.

Cercospora leafspot (*Cercospora* sp.) is commonly found in the farmers' crop as well as in the substation fields. Scab caused by *Elsinoe iwatae* Kajiwara and Mukelar, was first found in Cikeumeuh experiment station in 1955 and called the "leafcurl" disease. Until 1974, it was considered to be caused by a virus; however, the casual organism is now known to be the *Elsinoe* (3). The rust disease, *Uromyces apendiculatus*, usually occurs in the wet season crop. The mungbean mosaic virus is also found in Indonesia (2).

During 3 consecutive seasons beginning with the wet season 1974-1975, 100 mungbean cultivars were screened for resistance to scab and *Cercospora* leafspot in Muara, Cikeumeuh, Muneng, and Genteng substations.

For comparison, *Vigna mungo* 67 was used as resistant and 129 as susceptible checks. Among the cultivars tested, 18 consistently showed resistance to scab, and 23 to *Cercospora* leaf spot. Out of the these, 15 cultivars were consistently resistant to both diseases.

NUTRITIONAL VALUE

The nutritional value of mungbean for supplementing a rice diet is in supplying protein, iron, vitamins B_1 and B_2, and niacin (1). The average protein content of mungbean is 22.7%. The protein content of 129 is 21.66%. The protein analysis of 59 breeding lines and cultivars carried out by the Department of Physiology, CRIA, Bogor, indicated that crude protein varied from 21-30% with the mean of 25.30%. Thirty-three exceded this figure, and 24 exceeded 26%.

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Mungbean Breeding, Production, and Utilization in Iran

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Mungbean ranks fifth among the important pulses produced in Iran. From over 200,000 ha of land under food legumes (excluding soybean), between 25,000 and 30,000 ha is under mungbean production.

The average yield varies between 300-800 kg/ha in different regions and in different years The yield of some of the selected and newly released cultivars in experimental fields in some years reaches over 2,000 kg/ha.

Mungbean in Iran is cultivated on the central plateau, and in the southeast and southwest parts of the country, usually as a side crop. Seldom does one find a very large field, except on cooperative farms or at the newly established agro-industrial farms.

Mungbean with high protein content is used in the daily diet of many people, particularly the low-income people who use mungbean mixed with green vegetables or rice.

Mungbean breeding and development started with the pulse project in 1964. The first step was to collect different varieties and populations of the domestic cultivated types. Now we have a germplasm collection of over 850 accessions selected from domestic and foreign sources.

The collected materials have been carefully studied and evaluated, and selection of promising accessions has so far produced 3 varieties for release to farmers. The progenies of the hybrid material received from AVRDC, and the progenies of crosses made between domestic varieties, are tested and selected in preliminary yield trials conducted on the Agricultural College experimental farm at Karaj. In these trials, yields ranged between 84-1146, 533-1342, and 939-1665 kg/ha for 1971, 1972, and 1973, respectively. The mean yields for these years were 553, 987, and 1225 kg/ha, with accessions 11089 and 10257 from Iran, and 10307 from the USA, ranking highest for each respective year.

The best yielding lines from the preliminary trials are tested and selected in advanced yield trials conducted on experimental and college farms in all of Iran's important mungbean growing regions (Table 1). Following these trials, seeds produced by the pulse project will be increased and distributed to farmers by agencies of the Ministry of Agriculture.

In 1973, we joined the International Mungbean Nursery and received seeds from Columbia, Missouri, and later from AVRDC. The results of these yield trials are shown in Table 2.

Table 1. Advanced uniform yield trial; Iran, 1976.

Variety	Source	1974 Karaj	1974 Gorgan	1974 Tabriz	1975 Karaj	1975 Dezful	1975 Zarghan	1976 Karaj	1976 Dezful	1976 Meshed
		kg/ha								
10307	U.S.A.	766	1810	550	1105	999	531	816 (Partow)	1542	2168
10045	China	733	2832	560	1302	1016	512	1146	1601	2545
10104	India	652	2908	600	1324	1042	638	1450	1421	2310
10827	Iran	633	3052	590	1738					
10827	Iran	633	3052	590	1738	1053	378	614 (Mehr)	1533	2825
10075	India	441	3148	450	1579	1134	412	948 (Gohar)	1421	2200
M4	U.S.A.							1110	2425	
M118	India							1005	3123	
M374	India							881	1065	
M475	India							574	1763	
M1135	U.S.A.							1112	2195	

The main problem in these trials is the fluctuation of yield in different years and in different locations. This makes the final selection of varieties from the yield standpoint very difficult and we must consider other desirable characteristics as well as yield.

Studies for finding sources of resistance to diseases caused by nematodes, fungi, and viruses are also carried out at the College of Agriculture. Different varieties have shown different degrees of tolerance to the nematode *Meloidogyne*. In certain parts of the country this nematode is an important cause of yield reduction in mungbean and in other food legumes. Application of nematoxides is very effective for reducing the number of nematodes in mungbean.

Among the important diseases of mungbean is the seedling blight caused by *Rhizoctonia solani*. Mungbean varieties react differently toward this disease. On the college farm, infestation varies between 4-57%. To test the effects of fungicides, an experiment with 16 different chemicals was carried out. The mungbean varieties were planted in artificially infested soil and the seeds were treated with the chemicals. The results showed that fungicides like terraclor, thiabendazede, and pexon were very effective in controling the disease compared to the check.

Mungbean in Iran is very seriously infected by viruses. The Mungbean Mosaic Virus (MMV) is very closely related to Bean Common Mosaic Virus (BCMV) and tests are conducted with isolates of both. Most accessions in the mungbean collection have been studied for resistance to these viruses on the farm and under greenhouse conditions. The selected resistant lines are used in the mungbean breeding program. A few of these lines are:

Variety	Source
10005	USA
10707	Iran
10757	Iran
10783	Iran
10827	Iran
10855	Iran
10925	Iran
10914	Iran

Simultaneously with the breeding program studies, experiments for finding the best planting time, density, and fertilizer applica tions were also conducted. The best planting date for each region is almost known. For example, for the Karaj region where the colleg farm is located, the best planting date is about the first week of June, and the best plant density is 250,000 plants/ha. The fertilizer

Table 2. Performance of 2nd, 3rd, and 4th IMN's; Iran, 1976.

Variety	1973	1974	1975	1976	Variety	1973	1974	1975	1976
4	97	1350	1617	307	409	157	1623	1295	-
11	111	1217	1053	251	411	165	1022	1368	-
15	94	750	1308	-	416	77	742	-	-
76	84	1617	675	259	467	-	-	1078	264
90	114	958	1405	-	475	-	1090	1620	-
118	104	1200	1833	-	531	143	1217	1083	-
174	78	1275	-	-	533	98	642	1487	234
174	118	1218	-	-	543	52	812	-	-
194	113	1442	-	-	530	215	1778	1287	580
232	-	-	1450	248	1132	-	1552	1407	405
304	65	1433	1367	493	1133	-	1327	1540	603
317	-	1050	972	345	1134	-	1113	1397	-
333	-	833	1332	390	1135	-	1068	1528	-
350	64	862	995	298	1136	-	393	1060	-
325	-	-	1603	367	1845	-	-	947	310
374	128	767	1540	402	2069	-	-	633	197
394	-	-	923	90	2070	-	-	1150	314
408	85	1055	-	-	1956	-	-	1033	111

experiments show that all the released varieties respond to phosphate, using 150-225 kg/ha triple super phosphate has raised the yield an average 9%. The total protein content of all the promising varieties in the yield trials was measured and varies from 18.40-21.81%.

To summarize, the work for breeding and producing high yielding, disease resistant, good quality mungbean varieties has started in Iran.

Problems of low and inconsistent yield, susceptibility to diseases, and mechanization of production, especially harvesting, must be solved in our future program

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Recent Studies and Problems on Breeding and Cultivation of Adzuki bean in Japan

Shoshin Konno & Tomoaki Narikawa

PRODUCTION AND CONSUMPTION

Mungbean production in Japan is very small. In 1957, 277 ha in cultivated area produced 260 t in total production (950 kg/ha average yield). After that, it decreased year by year to about 130 ha and 130 t in 1965. We have no recent statistical data because the small production does not warrant a survey. Presumably, current planting is about 100 ha yielding 100 t or less. Almost all the mungbean consumed in Japan is imported from Thailand and Burma. This currently amounts to 40,000 t/yr, and is mostly consumed as bean sprouts (Table 1).

On the other hand, adzuki bean, an important legume in Hokkaido district of northern Japan, is similar to mungbean in growth habits, plant shape, ripening process, as well as in the seed components. The planted area and production of adzuki bean is very unstable from year to year depending on cool weather damage and fluctuations of the market price. It is cultivated on about 100,000 ha producing 140,000 t with 1.4 t/ha average yield in a normal year. About 20,000 - 30,000 t of adzuki beans are imported/yr, mostly from mainland China (Table 2). They are used mainly for making "ann" (bean paste for confection) (85%) and as boiled beans (5.8%).

BREEDING

Breeding of adzuki beans in Japan was started in 1894 with varietal yield trials at the Imperial and the Hokkaido Prefectural Agricultural Experiment Stations. Since 1935, breeding has also been conducted at branches of the Akita (Odate), Ibaraki (Ishioka), and Kumamoto (Aso) Prefectural Agricultural Experiment Stations with a government subsidy for breeding varieties having early maturity, high yield, good quality, and resistance to virus. But this breeding program was discontinued about 15 years later.

In 1973, Hokkaido Prefectural Tokachi Agricultural Experiment Station was designated as the adzuki bean breeding center by the government to breed varieties with early maturity, high yield, and resistance to cool weather damage and brown stem rot.

Table 1. Mungbean imports; Japan, 1965-1975.[a]

Year	Quantity	Value[b]
	(t)	(US$)
1965	33,083	6.45
1966	28,954	4.81
1967	37,215	5.54
1968	35,350	6.55
1969	33,510	7.11
1970	36,770	7.30
1971	39,651	6.67
1972	37,994	6.21
1973	51,419	10.30
1974	39,474	10.98
1975	40,185	12.81

[a]Ministry of Agriculture and Forestry, Japan.
[b]In million US$ calculated at ¥308=US$1.00 (1975).

Cool weather resistance

Cool weather at the early growth stages, retards vegetative growth, which in turn, delays flowering and reduces the number of flowers. The flowering stage is most susceptible to cool weather damage, which reduces pod number 11-20% and the average number of seeds/pod, 40-85%. If adzuki bean is subjected to cool weather at the ripening stage, maturity is delayed and the crop cannot mature before the first frost in autumn (5,6,8).

A test method for cool weather resistance subjects the progeny in early generation to a day temperature of 15° and 12°C at night, during 10 days after the first flowering (3).

Brown stem rot

Brown stem rot (*Cephalosporium gregatum* Allington and Chamberlain), a soil-born disease, has increased at Hokkaido in recent years. The fungus invades the vascular bundles in the roots and then climbs up to the stems and petioles turning the vascular bundles brown. The plant begins to wilt from about the end of flowering (middle-late Aug), followed by drying and defoliation resulting in serious yield losses (1,3).

Viruses and nematodes

Virus diseases and cyst nematodes are also important pests for adzuki bean cultivation in Japan. But we have found no resistant varieties. Crossing adzuki bean with mungbean which is resistant to nematodes has been tested (9,10).

GERMPLASM COLLECTION

At the present time, only 300 adzuki bean varieties are preserved in Japan (Table 3).

Table 2. Production and imports of adzuki beans in Japan, 1965-1975.[a]

Year	Plant area	Average yield	Production	Imports
	---ha---	--- t/ha ---	---t---	---t---
1965	108,400	1.00	107,900	23,833
1966	122,400	0.76	92,800	43,714
1967	112,600	1.28	143,600	35,371
1968	101,000	1.13	114,300	27,318
1969	91,700	1.04	95,500	26,781
1970	90,000	1.21	109,000	18,106
1971	99,600	0.78	77,700	38,982
1972	108,100	1.44	155,300	40,776
1973	101,800	1.42	144,100	30,816
1974	93,500	1.38	129,400	10,693
1975	76,300	1.16	88,400	1,201

[a]Ministry of Agriculture and Forestry, Japan.

Table 3. Major azuki bean varieties in Japan, 1977.

Variety	Origin	Release year	Release place	Plant height (cm)	Maturity at Tokachi	Seed size g/100 seeds
Chagara wase	Selected from a local var.	1914	Nat'l Hokkaido Agr. Exp. Sta.	28	Mid-Sept.	128
Wasetairyu 1	Pure line select. from Wasedairyu	1930	Tokachi Agr. Exp. Sta.	35	M-L-Sept.	177
Takara shozu	Local var.	1959	"	42	"	130
Hirkari shozu	Chagara wase x Wasetairyu 1	1964	"	45	L-Sept.	129
Iwate Dainagon	Pure line select. from local var.	1965	Iwate Pref. Agr. Expt. Sta.	64	L-Sept. (at Iwate)	170
Akatsuki dainagon	Noto shozu x Wasetairyu 1	1970	Tokachi Agr. Exp. Sta.	40	L-Sept.	189
Kotobuki shozu	"	1971	Hokkaido Centr. Agr. Expt. Sta.	39	M-L-Sept.	149
Sakae shozu	(Chagara wase x Wasetairyu 1)F_6 x Wasetairyu 1	1973	Tokachi Agr. Exp. Sta.	48	"	132
Akane dainagon	Noto shozu x Wasetairyu 1	1974	"	41	"	184
Hayate shozu	Takara shozu x Buchi shoryu key 1	1976	"	38	M-Sept.	114

Active germplasm collection is urgently needed to find parents for breeding pest resistant varieties and improving agronomical characteristics (number of pods, seed size, plant type, leaflet shape, and photosynthetic capacity).

CULTIVATION

Adzuki bean is planted in middle or late May and is harvested from the middle of September to early October. Planting density is normally about 60 cm between rows and 20 cm between hills. Each hill contains 2 plants (160,000 plants/ha). Fertilizer application is 20-30 kg/ha N, 80-120 kg/ha P_2O_5, 70-100 kg/ha K_2O, 30-40 kg/ha MgO, and 10 t/ha compost. Herbicides are common. Intertillage is conducted 3-4 times, and fields are hand-weeded twice.

Behavior at flowering and ripening are very important characteristics for adzuki bean cultivation. Tasaki (11) classified about 100 varieties in Japan into summer type (S_1, S_2), middle type (M_3, M_4), and autumn type (A_5, A_6, A_7), depending on their time of first flowering. Kawahara (2) classified 190 varieties into 19 ecotypes based on their number of days to first flowering and the ripening period (also see 4). Varieties with early maturity were shown to be less photosensitive to daylength than varieties with late maturity (7,12).

Absorption and movement of major inorganic nutrient elements in the growing processes of adzuki bean were studied by Yamauchi (14). The development of leaves at definite stages and the seasonal changes of nitrogen, phosphorus, and potassium content within each leaf were also examined in detail (15).

The average adzuki bean yield in Japan is about 1.4 t/ha, but skillful farmers are yielding more than 3 t/ha in normal years, and no less than 2 t/ha even in years with cool summers. From observation, these farmers: (a) use a rational crop rotation system, (b) apply organic matter or compost, (c) understanding the characteristics of the variety, (d) make sure of good seeds and a reasonable stand, and (e) carry out thorough pest control.

To increase adzuki bean yield, further fundamental studies on resistance to cool weather damage, and location-specific growth analysis of promising varieties is desired. Additional problems are associated with weeding, harvesting, and drying. Because every field crop, including adzuki bean, is always cultivated in a crop rotation system, experiments designed to solve these problems must take crop management into account.

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Interspecific Hybridization Among Four Species of The Genus *Vigna* Savi

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INTRODUCTION

Interspecific hybridization has played an important role in the evolution of flowering plants in nature (1, 10,16,18). Experimental hybridization is used to study the nature of isolating mechanisms operating between species and to study phylogenetic relationships. In plant breeding, interspecific hybridization has been used when desired characters are not found in the range of variation already present in the species. Other advantages of interspecific hybridization could be the possibility of producing hybrids with higher mutation rates or increased environmental adaptiveness (17), or combinations of new characters not present in either parental species (9,12). Therefore, interspecific hybridization is a promising tool by which a plant breeder can create genetic diversity.

The 4 species of oriental beans, *Vigna radiata* (L.) Wilzcek (mungbean), *V. mungo* (L.) Hepper (urd or black gram), *V. umbellata* (Thunb.) Ohwi and Ohashi (rice bean), and *V. angularis* (Willd.) Ohwi and Ohashi (adzuki bean), are major pulse crops in a large part of Asia and eastern Africa.

The purpose of this study is to determine the nature of reproductive barriers existing between these 4 species, and to assess the possibility of overcoming the barriers, which would allow the exploitation of germplasm resources beyond individual species boundaries in breeding this group of valuable beans.

MATERIALS AND METHODS

Three mungbean lines (U.S.P.I. 200840, 207504, 377231) and 2 lines each of adzuki bean (175240, 237689), black gram (174907, 208462), and rice bean (176369, 322571) were used as parents. Controlled pollinations of 20-50 flowers in all possible combinations with these 9 lines were made.

All crosses were made in the greenhouse from 9-11 a.m. during winter. We used a modification of Boling's mungbean hybridization technique (4).

Pollen fertility was estimated from the percentage of pollen grains that were stained uniformly by 0.5% cotton blue in lactophenol.

For cytological observations, flower buds were collected from 5-7 p.m., and fixed in a modified Carno-'s fixative of 6 parts chloroform, 3 parts absolute ethanol, and 1 part glacial acetic acid (5). Anthers from the buds kept in the fixative for more than one week were squashed in 1% acetocarmine and mounted with Hoyer's mounting medium following the Beek's Permanent Squash Method (2).

An attempt to induce amphidiploidy was made by treating the cuttings with colchicine (15).

RESULTS AND DISCUSSION

Interspecific pollinatio

In controlled selfings and inter-line crosses within species, there was a highly significant difference in pod set among species, but the differences between lines as receptor or pollinator were not significant except for the rice bean. The average pod set was 23.0% in adzuki bean, 31.8% in black gram, 61.4% in mungbean, and 44.7% in rice bean. As pistillate parent, 322517 had a higher percentage of pod set (68.8%) than 276369 (26.7%), but there was no difference between these 2 lines as pollinators. Pods that set also reached maturity.

The results imply that female and male reproductive systems function normally and that there are no post-fertilization obstacles to normal seed development in these 4 species.

Crosses between adzuki and black gram

In crosses of adzuki bean X black gram, 7.5% of the flowers crossed set pods. There was a significant difference in pod set on 2 lines of adzuki bean, but no significant differences between the 2 black gram pollinators. Much slower growing than in open-pollinated crosses, pods barely reached 2.5 cm before shedding 12 days after pollination. From 6 embryos cultured, only 2 etiolated seedlings developed which then died, and another formed only roots and callus.

The crosses of black gram X adzuki bean, with an average of 18.2% pod set, showed no difference between the 2 black gram lines or between the 2 adzuki bean pollinators. Pod growth was slightly retarded, and abortion usually occurred between 2-4 wks after pollination. Out of 19 embryos cultured at various ages between 13-26 days, only 7 grew into normal-appearing seedlings, 2 showed poor embryonic growth with callus, and 2 formed black callus only. The green normal-appearing seedlings started to show signs of wilting 1-3 wks after transplanting, and eventually died. Poor root system development was suspected as the primary cause of seedling mortality.

Because of the failure of hybrids to grow, these 2 species are assumed to be the most distantly related of the 4.

Crosses between black gram and rice bean

When the rice bean was used as female only, 4 pods out of 175 (2.3%) set. Pods grew very slowly and wilted 3 wks after pollination. From this cross, one embryo from an 8-day old green pod and 5 embryos from a 16-day wilting pod were cultured. Of these, only 3 formed callus without embryonic development.

This cross is not likely to be successful because of a strong barrier to fertilization as well as complete embryo abortion.

When black gram was used as the female, 69 pods (43.1%) set from 160 flowers pollinated. No difference in pod set on 2 lines of black gram was noticed, but the differential effect of rice bean pollinators was clearly shown. The hybrid pods developed normally, reached maturity, and contained some full-sized seeds which were slightly crinkled. When these seeds were soaked in water, they appeared normal but the cotyledons were highly distorted and the embryonic axes were poorly developed. Fourteen embryos taken from 10-14-day old green pods, and 20 embryos from mature pods were cultured. Nine apparently good seedlings were obtained; 3 from young pods and 6 from mature pods. Of the 9 apparently good seedlings, 7 died during early seedling stages and only 2 very weak dwarf plants from the 208462 (black gram) X 276369 (rice bean) cross survived with arrested growth for more than 3 months. They died before flowering.

Biswas and Dana (3) reported that they produced sterile hybrids by culturing embryonic axes of mature seeds from a certain black gram X rice bean cross. The hybrid plants, which were weak and stunted in growth during the winter became vigorous in the summer. Therefore, encouraging vegetative growth and trying other parental lines might effectively secure the hybrid plants up to flowering stage.

Crosses between adzuki bean and mungbean

When adzuki bean was used as the female parent, there was a significant difference in pod set between adzuki bean lines: 175240 set 33 out of 105 (31.4%), and 237699 set only 7 pods of 106 (6.7%). The difference between the mungbean pollen parents was not significant. Pod growth ceased in approximately 10 days when pod length reached 1.5-2.0 cm. Pods remained green for as long as 3 wks without further growth. Embryos barely reached the heart shape stage before degeneration. Eleven embryos or whole ovules 7-21 days old were cultured. Of these, only one embryo developed into an etiolated seedling which soon died; another embryo formed only callus. Embryos or ovules older than 10 days did not show any growth. Therefore, embryo abortion must precede the suspension of pod growth which usually occurs around 10 days after pollination.

When mungbean was used as the pistillate parent, pod set was significantly low on line 200840 (11.3%) compared to approximately 30% on the other 2 lines. Differences between the adzuki bean pollen parents did not appear. Pods grew slowly and usually shed in 1-3 wks after pollination. Embryos older than 1 wk were fairly large and appeared normal. Cultures of 26 embryos 9-19 days old produced 12 seedlings, of which 2 were etiolated and soon died, and the rest were apparently normal. During the early seedling stage 8 seedlings with poor roots died, but 2 hybrid plants reached flowering stage. These 2 hybrid plants were cultured from 19-day old embryos taken from a wilting pod from 377231 (mungbean) X 175240 (adzuki bean). Thus, embryo abortion in the mungbean x adzuki bean cross is apparently delayed until the pod collapses, and hybrids can be secured by culturing the young embryos from some parental line combinations.

In the F_1 hybrids, all pods set from open-pollinated flowers. Controlled selfings were shed in 10 days. Backcrosses of all 4 combinations were unsuccessful.

Hybrid sterility, which is complete, is considered another absolute barrier to hybridization between these 2 species, at least the diploid level.

Chromosome pairing at metaphase I in the hybrids was extremely low. The pairing ranged from 0-6 with a mean of $2.39_{II} + 17.22_{I}$. Chromosomes in metaphase II were scattered randomly throughout the P.M.C. rather than in orderly arrangement on the 2 equatorial plates. In telophase, adjacent chromosomes congregated to form microspores at random. Examination of 54 sporads showed 36 (66.7%) were diads and 3 (5.6%) diads with 1 or 2 micronuclei. Only 4 (7.1%) were tetrads while 11 (19.6%) were monads or monads with 1 or 2 micronuclei.

Extremely low chromosome pairing due to lack of homology, followed by abnormal successive divisions, is considered responsible for hybrid sterility. Because of the sporadic arrangement of the chromosomes spores which form from diads do not seem to be restitution gametes, which would contain whole sets of chromosomes of both genomes of the 2 species.

Crosses between mungbean and rice bean

This cross had a much higher success rate when mungbean was used as the female. Pod set was 53.1% on mungbean but only 5.6% on rice bean.

When rice bean was used as the female, pod set differences between the 2 rice bean lines were not significant, but the differences effected by the 3 mungbean pollinators were significant. Pods on rice bean usually shed within 3 wks after pollination. Embryos older than 10 days were highly disorganized sponge-like bodies. Out of twenty 11-23-day old embryos cultured, none developed into a normal seedling. One seedling formed a shoot without root. Deformed primary leaves developed in 2 embryos. The extremely rare and abnormal development of embryos in culture is additional evidence of reciprocal differences in the strength of barriers to hybridization.

No differences in pod set between mungbean parental combinations was found. Pods developed normally for 3 wks, then dried prematurely. The dried pods contained 2 kinds of seeds, empty and partially-filled. The empty seeds did not germinate, but an average of two-thirds of the partially-filled seeds germinated. Viable seed production differed between combinations of parental lines.

A characteristic feature of hybrids from mungbean X rice bean was seedling weakness. Hybrid seedlings were very weak and grew very slowly at first. Abnormal seedlings with 3 or 4 primary leaves often appeared. The hybrid plants, however, passed this weak seedling stage and vigorously grew thicker stems and larger leaves than the parental species.

About 150 hybrid plants, grown in both winter and summer, flowered profusely and set a few pods. The young pods, however, dropped in a week. Pistils of opened flowers had very few or no pollen grains on them. Stainable pollen ranged from 0.8-5.8%, compared to over 90% for the parental species. Pollen grain size was highly variable. Numerous controlled self-pollinations and backcrosses to the parental species in every possible direction failed to produce seeds. Complete sterility of the hybrids operates as an absolute reproductive barrier between these 2 species at the diploid level.

Meiosis in the F_1 plants was highly irregular. In metaphase I, the mean chromosome pairing was $0.09_{IV} + 4.69_{II} +12.26$. Maximum pairing was $7_{II} + 8_{I}$ or $1_{IV} + 5_{II} + 8_{I}$ and modal pairing was $5_{II} + 12_{I}$ which is much lower than the maximum 11_{II} and modal $8_{II} + 6_{I}$ (7). The quadrivalent observed during meiosis (7) indicates that at least one reciprocal translocation has occurred during chromosmal differentiation of these 2 species.

The lack of normal congregation of the bivalents and random distribution of the univalents resulted in unequal separation of chromosomes at anaphase I. The second division was also abnormal. Chromosomes in metaphase II failed to orient properly, which resulted in random distribution of the second anaphasic chromosomes.

Polyspory was another peculiarity in microsporogenesis in these hybrids (14). The number of microspores formed from a microsporocyte was highly variable. Monads, diads, triads, and tetrads alone or together with up to 6 extra micronuclei were observed at varying frequencies.

Considering the extremely irregular chromosome associations in both meiotic divisions and the polyspory observed, the production of a gamete with a complete chromosome set of one genome would hardly be expected. Therefore, the complete sterility of the hybrids is apparently due to the lack of chromosomal homology and resultant meiotic irregularities. (7)

Thirty vigorous cuttings were taken from the completely sterile F_1 plants and treated with colchicine. Of these, 17 produced fertile branches which yielded ripe pods with crinkled but viable seeds. The C_2 plants had gigas effect of polyploidy in the vegetative and floral characters. Pollen stainability increased to as much as 75.5-83.6% and, seed number/pod averaged 4.2. Pod set was very low at first, but increased later. The seeds were crinkled like those of the colchicine-treated plants (C_1). Numerous crosses with the parental species and F_1 hybrids failed to yield any pods.

Meiosis in the amphidiploids showed 22 bivalents and orderly disjunction in both anaphases (14). Amphidiploid progenies up to C_4 generation were grown. Plants with plump seeds or increased pod set were not observed.

The complete sterility of the hybrids of mungbean X rice bean can be effectively overcome by chromosome doubling, indicating that hybrid sterility is due largely to chromosomal factors. The crinkled seeds and low pod set may mean that some adverse genic interactions exist and, thus, these amphidiploids are unlikely to become an economic crop without further extensive breeding work. However, their exceptionally vigorous vegetative growth with strong perennialism and substantial seed production may be useful for a soil-building or forage crop.

Crosses between black gram and mungbean

This cross was successful only when mungbean was used as the female parent. Pod set was 29.4% on black gram and 58.6% on mungbean.

On black gram, pod set varied according to the combinations of parental lines used. Pods seemed to develop normally but dried prematurely. Dried pods contained 2 kinds of seeds; empty and slightly-filled seeds. Neither kind germinated. Some embryos appeared fairly normal, but the radicle and growing point were poorly developed and the cotyledons were distorted and fluffy. We cultured 14 hybrid embryos of black gram. None developed into a normal seedling. Three formed callus only, and the others did not show any sign of growth. Thus, incompatibility between the degenerating embryos and the developing endosperm does not seem to cause the failure of this cross.

Differences in mungbean pod and seed set were highly significant. No differential effect of black gram pollen on pod set was noticed. The pods developed normally up to maturity. Ripe pods contained partially-filled seeds, which appeared normal when soaked in water and germinated well.

There were differences in the vitality of hybrids from different mungbean lines. The hybrids displayed hybrid vigor in their early seedling growth. Vigorous plant growth extended throughout the growing season, except that hybrids from crosses with 377261 (mungbean) as females suddenly lost vigor upon forming flower buds and barely grew.

The hybrids were partially fertile and flowered profusely, but pod set was very low. A few ripe pods harvested from open-pollinated flowers contained usually one or rarely 2 seeds. These seeds ranged from empty to fully developed Some had burst seed coats. Pollen stainability ranged from 24.0-26.6%. The stained pollen grains were comparatively uniform, but the unstained grains were much smaller and highly variable in size. Viable seeds were produced when the hybrids were used as both male and female parents in backcrosses to the parental species.

Many kinds of irregularities were observed during microsporogenesis in the hybrids. Complete bivalent formation occurred in 28.6% of 147 cells examined. The other cells contained one quadrivalent and/or 2 or 4 univalents. The mean chromosom configuration was $0.37_{IV} + 9.59_{II} + 1.34_{I}$. Often the bivalents failed to orient poorly on the equatorial plate. Heteromorphic pairing was noticed in diakinesis. Chromosome bridges occurred in 3 cells and 1 - 5 laggards were observed in 5 out of 29 cells examined at anaphase I. Chromosome distribution at anaphase I was 11-11 in 11 cells, 10-12 in 9 cells, and 13-9 in 1 cell. Polyspory was observed in many tetrads.

The results show that these 2 species are closely related with chromosome differentiation having occurred through one major reciprocal translocation (6.8). The low pod set compared with the fairly high frequency of bivalent formation indicates that the cause of the sterility may be partly due to either chromosomal heterozygosity or genic interaction. From pachytene analysis, De and Krishnan (8) reported that a terminal deletion and an interstitial duplication are also involved.

Germination of well-developed F_2 seeds was highly irregular. Seeds germinated sporadically over an extended period. Some seeds remained hard and germinated late and others failed to germinate at all. Out of 74 F_2 seeds, 47 (64%) germinated in 10 days. Germination in 3 days was quite uniform in mungbean, black gram, and the F_1.

Seedling lethality and weakness were other characteristics found in the F_2 generation. Fifteen seedlings died during early or late seedling stages, among which 3 were complete albinos, 4 were sectorial albinos, and the rest died after forming clusters of curly leaves or when flower buds formed. The hybrid vigor shown in the F_1 was completely lost in the F_2 generation. No individual F_2 plant grew as vigorously as an F_1. Wide variability in fertility was observed in the F_2 generation. Pollen stainability ranged from 9.26-71.63%. Eighteen out of 32 plants which flowered produced pods with well-developed seeds.

Seedling lethality was much lower in the backcross progenies (BC_1) than in the F_2. Out of 38 BC_1 seeds, 27 (70%) seedlings were obtained, of which 3 died during seedling stages, 3 did not flower, and 21 flowered. All of the BC_1 plants showed a mixture of mungbean and black gram characters. Plant growth was highly diverse, from dwart to normal growth, and from bush to vine. Pollen stainability ranged from 4.0-75.1%. Three plants with less than 20% stainable pollen did not produce any mature pods. Pod set was very high in some plants. Germplasm exchange between mungbean and black gram is considered to be highly possible through backcross of the F_1 to either parent.

<u>Crosses between adzuki bean and rice bean</u>

When adzuki bean was used as the pistillate parent, 75 pods (55.6%) set out of 135 flowers pollinated. There was no significant difference in pod set between the parental combinations. Pods developed normally and reached their maximum size in 3 wks, when they suddenly discolored, lost turgidity, and collapsed. Pods older than one week contained only highly distorted, sponge-like embryos. Of 17 embryos 8-11 days old cultured, none developed into normal viable seedlings. Only one embryo developed abnormal primary leaves with callus, and 3 others callused only.

When rice bean was used as the female, significant differences were found between the parental lines of both species. Rice bean (322571) set more pods (31.3%) than 276369 (10.0%), and adzuki bean (237689) was a better pollinator (27.3%) than 175240(12.7%). The highest pod set (36.0%) was from the cross 322571 x 237689. Pods grew slowly and shed 2-3 wks after pollination. Embryos from pods 11 days old or more appeared normal and healthy. Shrivelled seeds obtained from the dried pods appeared normal when soaked in water but failed to germinate. We made cultures of 47 embryos 11-24 days old. Viable seedlings were only obtained from the cross 322571 X 237689. Twelve pale green and 12 healthy seedlings developed out of 33 embryos cultured. All the pale green seedlings and 5 of the healthy seedlings died during the seedling stages while the other 7 healthy seedlings reached maturity.

The exact cause of the seedling etiolation is uncertain, but it is evident that normal, viable hybrids can be secured in certain rice bean X adzuki bean crosses by embryo culture.

The reciprocal differences in hybrid embryo development suggests that cytoplasmic differentiation is a principal factor involved in the evolution of isolating mechanisms between these 2 species.

The hybrids produced 76% stainable pollen as compared to 94.4% in rice bean and 91.0% in adzuki bean. The number of seeds/pod was 3.2 which is 52.5% of the midparent value (6.0). Viable seeds were produced in backcrosses to both parental species in all combinations.

The hybrids regularly formed 11 bivalents at first metaphase in 26 cells examined. As in the parental species, precocious separation of a few bivalents was observed. Otherwise the separation and movement of the chromosomes in both anaphases was normal.

In 23 F_2 plants, plant growth was normal except for 2 dwarfs, and segregation for morphological characters was observed. Stainable Pollen ranged from 48.5-93.3% in 5 plants observed. Plants with a high percentage of stainable pollen also had good pod set. Backcross progenies from the 4 possible combinations were produced. Plant characters of the BC_1 were more similar to the parental species used in the backcross, but plants with all the characters of one species did not appear.

This species hybridization indicates that embryo abortion can be overcome only by culturing developing embryos from the cross with rice bean as the pistillate parent. Success also seems to depend upon the particular combination of genotypes of the 2 species.

The high fertility of the F_1, F_2, and backcross generations indicates that no barrier other than embryo abortion completely blocks the exchange of genes between these 2 species. Therefore, it appears that these 2 species are very closely related and that an isolation mechanism has evolved primarily through embryo abortion due to cytoplasmic differentiation or possibly embryo-endosperm incompatibility. Accordingly, once embryo abortion is circumvented, it would be possible to exchange germplasm between these 2 species and, thus, improve either adzuki bean or rice bean.

CONCLUSIONS

A variety of isolating mechanisms were found to operate between these 4 species. The results of the hybridizations are summarized in Table 1. Normal pod set means pod set in at least one cross was equal to that found in interspecific pollinations. After pods had set, in most cases the embryo aborted before reaching maturity. Only in the pollinations of mungbean by black gram and rice bean was there not complete embryo abortion.

In some cases, successful embryo culture was followed by loss of all seedlings in the seedling stage. Some seedlings which survived remained weak, while others grew well. Finally, some hybrids were completely sterile, while others were only partially sterile.

The variability in crossability shown by different lines of the same species suggests that the use of more than one genotype as well as intraspecific hybrids is desirable when making interspecific crosses.

Reciprocal differences in crossability were found in all interspecific crosses. The differences were observed in pod set, embryo abortion, embryo culture, and seedling lethality. No interspecific crosses were successful in both directions.

Since unidirectional success is a common phenomenon in all crosses between any 2 species, cytoplasmic differentiation is assumed to have played the primary role in speciation of these 4 species.

Cytoplasm which prevents the development of a hybrid embryo can be considered to be an evolved cytoplasm, while cytoplasm which permits the development of a hybrid embryo can be considered to be the original type. By this reasoning, mungbean would have more nearly the original cytoplasm, since this cytoplasm had by far the least inhibitory effect on hybrid embryos On the basis of this assumption and crossability relationships of these 4 species can be postulated as in Figure 1.

Mungbean and rice bean might have been derived independently from a common progenitor,

Table 1. Summary of hybridization among the 4 *Vigna* species

Crosses Female		Male	Pod set	Embryo abortion	Embryo culture	Seedling lethality	Hybrid weakness	Hybrid sterility	Hybrid meiosis
AB	x	BG	normal	complete	partial	complete			
BG	x	AB	partial	complete	partial	complete			
BG	x	RB	normal	complete	partial	partial	complete		
RB	x	BG	partial	complete	none				
AB	x	MB	normal	complete	partial	complete			
MB	x	AB	partial	complete	partial	partial	none	complete	$2.39_{II} + 17.22_{I}$
MB	x	RB	normal	partial		partial	none	complete	$0.09_{IV} + 4.69_{II} + 12.26_{I}$
RB	x	MB	partial	complete	none				
BG	x	MB	normal	complete	none				
MB	x	BG	normal	none		none	partial	partial	$0.37_{IV} + 0.59_{II} + 1.34_{I}$
AB	x	RB	normal	complete	none				
RB	x	AB	normal	complete	partial	partial	partial	partial	11_{II}

but the rice bean was likely first. Black gram and adzuki bean seem to be the later derivatives from mungbean and rice bean, respectively. Thus these 4 species can be divided into 2 subgroups, mungbean with black gram and rice bean with adzuki bean, in which the 2 species of each group still retain enough chromosomal homology to allow germplasm exchange within the group.

This postulation is supported by the grouping of these 4 species into 2 taxa by Piper and Morse (11) on the basis of morphological similarities.

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Interspecific Hybridization of Food Legumes by Unconventional Methods of Plant Breeding

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INTRODUCTION

Food legumes are essential in providing the amino-acid balance for people living on vegetarian diets. They can be helpful in alleviating the world protein-deficiency problem, especially in the developing nations. Their ability to fix atmospheric nitrogen and produce seeds with high protein and oil content are invaluable traits to mankind. However, their relatively narrow gene base has limited varietal improvement. During the past 25 years, yield increases in the food legumes have not been as dramatic as with other crops (9). Furthermore, a need exists to broaden the genetic base of food legumes because of their genetic vulnerability to pests and pathogens (15). Interspecific hybridization within the extensive gene pool represented by the *Leguminosae* family would greatly enlarge the genetic base of the individual agricultural species. A broader genetic base may permit significant increases in food legume productivity. Thus, enlarging the gene pool and enhancing recombination of desired, but divergent, genotypes would be of great economic importance.

Interest in "wide" hybridization has gained impetus as improved hybridization techniques have increased the possibilities of successful crosses. The recent advent of unconventional plant breeding methods for variety improvement (4,7) suggested "radical" plant breeding might play an important role in the improvement of economic species. These methods include genetic manipulation of the somatic cell, including hybridization, and the use of immunosuppressive chemicals to overcome crossability barriers. We have proposed to develop and use these methods to facilitate the exchange of genetic material (gene, chromosome, genome, etc) between species of food legumes.

RESEARCH PROCEDURES

Immunosuppressive chemical treatments. New techniques in the employment of immunosuppressants for interspecific hybridization are still being tested and refined. Bates (3,4) used a microsyringe to inject the chemical into the culm of the floral spike for intergeneric hybridization of cereals. Using another technique, and aqueous solution of Σ-amino-caproic-acid (EACA) was dropped into the leaf axils of the maternal plant on the cross of *Zea mays* x *Sorghum vulgare* (2). However, we found that neither of these techniques were successful with *Vigna radiata*.

In searching for better techniques, we applied an aqueous solution of EACA to the maternal plant as a foliar spray to the stage of run-off. Treatments were initiated at the pre-meiotic stage of floral development or earlier. For mungbean, meiosis occurs when the floral envelope of the bud is 2-3 mm in size. Daily treatments of 100-10,000 mg/ℓ EACA were made over a 14-day period before attempting interspecific hybridization. Flowers were emasculated the day before anthesis and either pollinated immediately after emasculation or the following morning (under controlled greenhouse conditions). The methods of hybridization adopted in our research were a modification of those described by Buishand (6) and Boling et al. (5). After cross-pollinating for 5-7 days, all subsequent flowers were removed to eliminate competition between hybrid and naturally self-pollinated pods. Each pod was harvested at maturity and the number of shriveled and normal seeds noted. Hybrid seeds were then germinated to confirm their hybridity. These F_1 plants were then used in attempts to advance the hybrid through natural self-pollination and/or backcrosses to both parents.

To determine the most effective plant stage for chemical treatment, we designed an experiment using various pre- and post-pollination EACA treatments and several combinations of both. Plants of the maternal parent, *V. radiata,* were subjected to daily treatments of 3 EACA concentrations (100, 500, and 100 mg/ℓ) at various stages.

Several supplemental techniques were explored to facilitate the interspecific hybridization of *V. radiata* with *V. umbellata* (rice bean):

1. White's nutrient solution was applied to *V. radiata*'s stigmatic surface with a camel hair brush prior to pollination with *V. umbellata*.
2. Pods with hybrid seeds, 10 days after pollination, were either partially broken at the pedicel or completely removed and placed in "Ziploc" plastic bags, and then cultured in the air-conditioned laboratory (25°C) for 2 weeks.
3. The plant was defoliated 4-6 days after cross-pollination.
4. Pollen of *V. umbellata* was mixed with that of a third species, *V. angularis* (adzuki bean), to pollinate *V. radiata* with the third apecies' pollen acting as "recognition" pollen to increase pod and seed set.

All treatments were split into 2 groups, one with 1000 mg/ℓ EACA and the other without any EACA treatment.

Cultural conditions. All plants were grown under existing greenhouse conditions with control of temperatures and light by means of vents and shading. As indicated in the tables, experiments were conducted at the Asian Vegetable Research and Development Center (AVRDC) in Taiwan and at Michigan State University (MSU) in East Lansing, Michigan, USA. The varieties used were: *V. radiata:* Tainan #1, PHLV 18, ML-3; and, *V. umbellata*: HK.

RESULTS AND DISCUSSION

Effect of EACA on interspecific hybridization of *V. radiata* x *V. umbellata*. Foliar treatments with a concentration series of EACA (10^0 to 10^4 mg/ℓ) were compared to the control. A relatively large number of viable F_1 seeds were obtained (Table 1). The treatment of 100 mg/ℓ EACA was superior to other treatments including the control, which did yield several seeds.

Table 1. Effect of an immunosuppressant, EACA, on the success of the interspecific cross of *Vigna radiata* x *V. umbellata*; 1975, AVRDC.[a]

EACA concentration	Overall success (pods with seed)	F_1 seeds obtained ($\bar{x}$ no.)	F_1 seeds obtained total no.	Efficiency as seeds/ day/100 attempts
--- mg/ℓ ---	---- % ----			-- no.
0	15 ± 4	6.5 ± 2.7	39	25 ± 9
10^1	9 ± 4	3.0 ± 1.4	18	10 ± 4
10^2	30 ± 7	11.3 ± 4.2	68	66 ± 19
10^3	10 ± 3	3.7 ± 1.3	22	13 ± 4
10^4	0	0	0	0

[a]Data represent the mean and its standard deviation for 6 single-plant replications. Plants were grown under greenhouse conditions in May to June, 1975. A total of 695 pollination attempts were made in this experiment.

In subsequent experiments, attempts do determine the optimal concentration were made with no consistent findings with regards to the "best" concentration of EACA. However, concentrations of EACA less than 100 mg/ℓ seemed ineffective; whereas, concentrations over 2500 mg/ℓ appeared phytotoxic. Concentrations of 100-1000 mg/ℓ seemed most effective, although the exact optimal concentration could not be determined.

There were no significant differences in the number of viable F_1 seeds/attempt among treatments with 100, 500, and 1000 mg/ℓ EACA when the chemical was applied daily at different stages of plant development and durations (Table 2).

A significant increase in embryo formation of an intergeneric cross of cereals had been reported as affected by post-pollination EACA treatment (12). The EACA treatment was effective on embryos up to 4 days after pollination, but without a significant effect of the endosperm. However, in this experiment, the pre-pollination treatments (Table 2, B, and D) were superior to that during post-pollination.

Two varieties of *V. radiata* were used to determine their crossability with *V. umbellata* and the effects of EACA on this cross. They were treated with a series of EACA concentrations (100-4000 mg/ℓ) for 14 days before anthesis. Maternal plants were crossed with the same variety (HK) of *V. umbellata*. The degree of crossability was found to be higher in Tainan #1, which yielded higher numbers of viable seeds than PHLV 18 regardless of the chemical treatment (Table 3).

Treatments with EACA were effective on both varieties as the number of viable F_1 seed was increased. However, the varieties responded differently to the EACA concentrations. The treatment of 100 mg/ℓ EACA resulted in relatively large numbers of viable F_1 seeds in Tainan #1 ; whereas, the highest number of viable seeds in PHLV 18 was obtained from the treatment of 50(mg/ℓ EACA. These data indicate that the effective concentrations of EACA to facilitate the interspecific cross of *V. radiata* x *V. umbellata* ranged from 100 mg/ℓ-1000 mg/ℓ, although variety responses of the maternal species to the chemical are not the same.

<u>Verification of hybridity and the characteristics of the hybrid</u>. The interspecific F_1 seedlings from the cross of *V. radiata* x *V. umbellata* can be verified by a genetic marker for cotyledon position (epigeal vs. hypogeal). Cotyledons of the F_1 seedlings were in an intermediate position, which indicate that they were, in fact, hybrid (Table 4).

A second genetic marker for petiole length of the primary leaf served to substantiate this.

Table 2. Effect of EACA treatments on the number of viable seeds/attempt and total viable seeds obtained from the interspecific cross of *V. radiata* x *V. umbellata*; 1976, MSU.[a]

Treatment[b]	EACA concentration			Mean
	100 mg/ℓ	500 mg/ℓ	1000 mg/ℓ	
A	0 (0)[c]	0.023 (2)	0.091 (8)	0.038 (3.3)
B	0.023 (2)	0.044 (4)	0.148 (14)	0.072 (6.7)
C	0.033 (3)	0 012 (1)	0.054 (5)	0.033 (3.0)
D	0.046 (4)	0.023 (2)	0.088 (8)	0.052 (4.7)
E	0 (0)	0 (0)	0.012 (1)	0.004 (0.3)
Control				0.011 (1.0)
Mean	0.021 (1.8)	0.021 (1.8)	0.079 (7.2)	

[a]Data represent the mean of 4 replications. Plants were grown in April-July, 1976. A total of 80-96 pollination attempts were made in each treatment. [b]Plants were treated with EACA: (A) from 2-leaf stage to mature; (B) from 2-leaf stage to prior to cross-pollination; (C) from pre-meiotic stage to mature; (D) from premeiotic stage to prior to cross-pollination; (E) from after cross-pollination to mature. [c]Data are number of viable seeds/attempt. Numbers in parentheses represent total number of viable seeds obtained.

Table 3. Response of 2 varieties of *V. radiata* to the immunosuppressant, EACA, in interspecific hybridication with *V. umbellata*; 1977, MSU.[a]

EACA concentration	Variety			
	Tainan #1		PHLV 18	
	viable seeds obtained	viable seeds/ attempt	viable seeds obtained	viable seeds/ attempt
0	34	0.405	22	0.262
100	133	1.583	43	0.512
500	46	0.548	63	0.750
1000	52	0.619	46	0.512
4000	43	0.512	19	0.226
L.S.D. .05		0.544		0.293
.01		0.742		0.399

[a]Data represent the total viable F_1 seeds obtained and the mean number of viable seeds per attempt; 6 replications. Experiments were conducted May-July, 1977 under greenhouse conditions. A total of 84 pollination attempts per treatment were made.

Table 4. Germination habit, hypocotyl and petiole lengths of *Vigna radiata, V. umbellata* and its interspecific hybrid; 1975, AVRDC.[a]

Pedigree	Germination	Germination habit	Hypocotyl length (mm)	Petiole lenth
V. radiata	P_1	epigeal	71.8 ± 1.8	short
V. umbellata	P_2	hypogeal	-	long
$P_1 \times P_2$	F_1	intermediate	24.1 ± 6.7[b]	short

[a]A total of 43 F_1 and 5 P_1 seedlings were measured in the same experiment. [b]Range: 10-44 mm.

The short petiole for the *V. radiata* parent was dominant to the long petiole of *V. umbellata*.

Growth of the interspecific hybrid, *V. radiata* x *V. umbellata*, was vigorous once the seedling stage was past. The hybrid plant was intermediate between the 2 parental species in most morphological characteristics. Flowering was profuse, but the hybrid was both female and male sterile. All attempts to backcross the hybrid to both parents failed. As expected, pollen stainability of the hybrid was nil.

Overcoming crossability barriers of interspecific hybridization. Several mechanisms developed during speciation which act as crossability barriers at different steps in the sexual hybridization process. These crossability barriers may be generally termed as gametic incompatibility, hybrid breakdown (or embryo abortion), and sterility of the F_1 hybrid.

Generally, pod set from the interspecific cross of *V. radiata* x *V. umbellata* was observed to be relatively high but with embryo abortion some 10-16 days after pollination.

Supplemental techniques were studied to prevent embryo abortion in the interspecific cross of *V. radiata* x *V. umbellata*. Application of white's solution to *P. coccineus* prior to pollination with *P. vuglaris* resulted in pollen germina-

Table 5. Effects of EACA treatment with supplemental techniques on the success of the interspecific cross of *Vigna radiata* x *V. umbellata*; 1976, MSU.[a]

Treatment	With 1000 mg/ℓ EACA pod set (%)	viable seeds obtained	viable seeds/ attempt	Without EACA pod set (%)	viable seeds obtained	viable seeds attempt
White's solution	48.8	7	0.088	41.3	1	0.013
Partial broken pedicels[b]	70.0	9	0.113	67.5	6	0.075
Detached pods[b]	71.3	2	0.025	58.8	1	0.013
Defoliation[c]	73.8	15	0.188	71.3	38	0.475
Mixed pollen[d]	62.5	17	0.213	62.5	8	0.100
Control	72.5	6	0.075	55.0	1	0.013
L.S.D. .05			0.050			0.050
.01			0.067			0.067

[a]Split plot design was employed with 4 replications. Plants were grown in June-August, 1976. Total 80 pollination attempts per treatment were made. [b]Partial broken pedicels and detached pods in Ziploc plastic bags were done at 10 days after cross-pollination. [c]Leaves were removed completely from the plants 4-6 days after cross-pollination. [d]A mixed pollen of *V. umbellata* with a third species, *V. angularis* (adzuki bean) was used.

tion and fertilization, but it did not prevent embryo abortion (8). We found that this technique did not increase the pod and seed set in the wide cross of *V. radiata* x *V. umbellata* (Table 5). This indicated that the crossability barriers of the interspecific cross of *V. radiata* x *V. umbellata* were not likely nutritional, as was the cause of embryo abortion in other bean-wide crosses (10,13). Ibrahim and Coyne (8) reported that viable mature seeds from the cross of *P. coccineus* x *P. vulgaris* were obtained by partially detaching the pod pedicels and by keeping detached pods in Ziploc plastic bags. These techniques were applied to overcome embryo abortion based on the assumption that inhibiting substances translocated from the leaves of the maternal plant to the pods may have caused late embryo abortion. Using these techniques with the interspecific cross of *V. radiata* x *V. umbellata*, we found that the treatment of partially broken pedicels increased markedly the number of viable F_1 seeds compared to the control (Table 5). The relatively poor results obtained from the treatment was mainly due to poor pod sterilization before placing into Ziploc plastic bags. Most pods rotted before attaining maturity.

Defoliation at 4 to 6 days after pollination was the most effective treatment to prevent embryo abortion (Table 5). We have speculated that an active principle may be synthesized in the leaves which causes or controls hybrid embryo abortion. This incompatibility reaction may be analogous to an "immune-response". Treatment with immunosuppressive chemicals would suppress this reaction and thereby overcome this crossability barrier of hybrid embryo breakdown. Removing all the leaves from the plant eliminated the synthesis and translocation of such possible substance(s) from the leaves to the pods and seeds. Furthermore, defoliation altered the relationship between the "sink and source" that also changes many physiological processes in the plant. Whether or not these supplemental techniques facilitated the development of wide cross hybrid embryos requires more study. Further experiments on the effect of defoliation on the success of interspecific and intergeneric hybridication of food legumes are in progress.

Use of mixed pollen and pollen mixes combining a compatible "mentor" pollen with a foreign species pollen to facilitiate interspecific hybridization have been reported (11,14). A mixed pollen of a third species, *V. angularis*, which was partially compatible with *V. radiata* (1), and with *V. umbellata* was explored. The *V. angularis* pollen served as "recognition pollen", but significantly increased the number of viable F_1 seeds as compared to the control (Table 5). These hybrid seeds will be verified as to their source of hybridity, although the "control" cross of *V. radiata* x *V. angularis* yielded no viable mature F_1 seed (1).

Moreover, all treatments with 1000 mg/ℓ EACA supplemented with these techniques were superior to those without EACA treatment, except defoliation. This suggests that the use of EACA with appropriate supplemental techniques would greatly increase the success of the interspecific cross of *V. radiata* x *V. umbellata*.

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Mutation Breeding in Mungbean

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The food legumes or pulses, constitute an integral part of Indian agriculture because of their contribution to the human diet and soil fertility. They become more important for their relatively low requirements of water and costly inputs compared to cereals. The recent advances in the production of cereals in India has resulted in a reduction of total acreage under pulses. The per day productivity of pulses is very low compared to the high yielding varieties of wheat, rice, and maize, partly due to the limited genetic variability of important yield components. Pulses have always grown on marginal lands which resulted in natural selection of genotypes for vegetative growth and long growing season, but poor grain yields. Genetic variability forms the primary basis of a successful plant breeding program and mutation provides a source of this variability.

The implications of mutations in plant breeding have been reviewed extensively by Gaul (10). The successful production of various morphological and economic mutants in mungbean has been reported by Bahtt et al (1). After Y-irradiation a mutant was produced which bred true in several successive generations and was superior to parental cultivars in earliness, dwarfness, and yield and its components. Pokle (15) observed a spontaneous mutation which was under the control of a single dominate gene and produced trifoliate leaves with incised leaflets. Dahiya (6) indicated that in mungbean, mutation breeding resulted in an increase in variation of all quantitatively inherited characters. Similar observations were also recorded by Rajput (16).

The study reported here was conducted to assess the effectiveness of mutation breeding for creating more genetic variability for a number of economic traits which are important in improving mungbean production.

MATERIALS AND METHODS

Two commerical varieties of mungbean, Pusa Baisakhi and Hybrid-45, were treated with 30 and 70 kilorads of gamma rays. The radiation treatment was given to 1000 seeds of each variety. The mutation analysis was mainly done in the M_2 generation and for this purpose 30 seeds from each of the M_1 plants were grown in single row plots. The plants in the different M_2 progenies were scored for chlorophyll mutations at the seedling stage. An equal number of randomly selected plants in the M_2 progenies were studied for grain yield/plant in grams, days to flower, number of days from seeding to first open flower, number of pods/plant, and protein content.

The protein content was determined by the rapid colorimetric method (19). The plants which appeared promising in view of their protein content and other seed characters were further analyzed for tryptophan and methionine (12, 18). The significane of the increase in genetic variation attributable to irradication was determined by:

$$F = \frac{V_1}{V_2}$$

V_1 = Variation between treatments

V_2 = Variation within treatments

RESULTS

The different radiation treatments reduced germination of the treated seeds. In general, it was clear that mungbean is relatively resistant to radiation treatments and a dose as high as 70 kilorads can be given without drastic effects on seed viability. Hybrid-45 was found to be more radio-resistant than Pusa Baisakhi.

Protein content in seeds set on M_1 plants

Seeds of randomly selected M_1 plants were analyzed for their protein content. We observed that the treatments induced significant variation in respect to protein content only in Pusa Baisakhi (Table 1).

Induced variability for yield and its components

We noticed that moderate exposure (30 kr) has a stimulative effect on plant growth which was associated with some decrease in seed yield because of increased vegetative growth and poor seed setting. The analysis of variance for various yield and yield component quantitative characters are presented in Tables 2 and 3. Radiation treatments have been quite effective in inducing variability for yield/plant. The 70 kr. dose of radiation induced more significant variation over controls than a moderate dose of 30 kr.

The number of pods/plant in the irradiated material was generally higher but pod size was reduced. Treatments were found to be effective as indicated by highly significant "F" values. The variation between treatments was also of a higher magnitude, and 70 kr. was found to be more effective in inducing variability. The general mean of the treated population was higher than that of the control population. This does not confirm the findings of Brock (5) that radiation leads to a reduction in the general mean.

The protein content of the seeds was more significantly changed by 70 kr. radiation treatments. Changes induced for earliness (days to flower) in the M_2 progenies of both varieties were significant with a 30 kr. treatment (Table 3). The objective of selective analysis of early maturing mutants was to indicate that to obtain early mutants, late maturing varieties should be

Table 1. Analysis of variance for protein content (%) in M_1 generation.

	Source	d.f.	M.S.	F	Range 30 kr	70 kr	control
Pusa Baisakhi	V_1	2	.0907	4.50*	19.5-29.7	20.5-31.8	27.6-28.5
						Mean	
	V_2	298	.0199		23.91	25.7	27.9
					C.D. (.05) = .15		
Hybrid-45	V_1	2	.0014	0.49	18.9-30.8	18.1-28.8	23.6-24.2
						Mean	
	V_2	298	.0032		23.7	23.2	24.3
						C.D. (.05) = .02	

Table 2. Analysis of variance for quantitative characters in M_2 progenies (Pusa Baisakhi).

	Source	d.f.	M.S.	F	Range 30 kr	Range 70 kr	Range control
Yield/plant	V_1	2	.4651	6.79*	2.0-25.1	3.8-35.1	3.4-16.1
						Mean	
	V_2	1057	.0684		7.5	10.2	8.6
					C.D. (.05) = .54		
Pods/plant	V_1	2	1.3394	53.79**	7-91	6-153	9-40
						Mean	
	V_2	1057	0.0498		23	29	21
					C.D. (.05) = .39		
Percent protein	V_1	2	0.2007	5.90**	19.8-27.5	18.5-27.8	22.0-24.5
						Mean	
	V_2	688	0.0340		23.1	22.6	23.3
					C.D. (.05) = .23		

Table 3. Analysis of variance for number of days to flower in M_2 progenies.

	Source	d.f.	M.S.	F	Range 30 kr	Range 70 kr	Range control
Pusa Baisakhi	V_1	2	.01655	22.06**	31-42	31-42	43-46
						Mean	
	V_2	415	.00075		41	41	45
					C.D. (.05) = .124		
Hybrid-45	V_1	2	.1341	33.52**	33-65	48-65	66-70
						Mean	
	V_2	240	.0040		48	59	68
					C.D. (.05) = .031		

subjected to irradiation treatments. Results indicate that the difference in treated and control populations was of a higher magnitude in Hybrid-45.

Amino Acid analysis

The more promising M_2 plants were analyzed for 2 essential amino acids, methionine and tryptophan (Table 4).

The radiation treatments were not effective in inducing significant variability for protein quality. This can be seen from the variation in the range of methionine and tryptophan in the control and in the irradiated plants. Mutants with bold seeds are poor in protein content as compared to the control and to the other mutants. However, some of the mutant plants seemed superior in their protein quality.

DISCUSSION

In the present investigation 2 types of induced variations have been observed and both have practical significance. We noticed that a 30 kr. exposure has a stimulative effect on plant grow which was associated with some decrease in seed yield because of increased vegetative growth an poor seed-setting. Although the occurance of stimulation due to irradiation has been observe in a wide variety of higher plants, the mechani involved in such a reaction is not understood (Sparrow and Gunkel (17) observed an increase in plant height and stem and leaf thickness in *Ant rhinum majus*; they also noticed similar increas in plant height and early blooming in *Nicotiana* species.

The increase in the average number of pods/ plant in mungbean in the present studies at the exposure of 30 and 70 kr. was obviously due to an increase in the number of flowers. The numbe of pods varied from 6-153 in one of the treated populations, while the range was 9-40 in the con trols. Similar observations have been recorded in mungbean by Bahtt et al. (1) and, Rajput (16) in *Phaseolus vulgaris* by Mujeeb and Graig (13), in cowpeas by Ojomo and Chheda (14), and in flax by Bari (2). Gunkel and Sparrow (11) noticed a decreasing trend in the total number of seeds/po with a simultaneous increase in the number of po

Table 4. Observations on protein quality and content of M_2 mutants (Pusa Baisakhi).

Treatment	M_2 mutant plant number	Mutant characters	Yield/ plant	Protein	Methionine	Tryptophan
			- gm -	(%)	----- on protein basis	----
30 kr	55-7	Bold seeds	17.20	23.25	1.30	0.48
	120-9	Mosaic grain color	14.50	24.60	1.60	0.37
	139-1	Uniform maturity & high protein content	11.6	27.25	1.11	0.44
	168-3	Dullest green grain color	11.70	24.20	1.35	0.67
	170-3	High yield	25.10	25.25	1.24	0.45
	54-2	Shining grain color	22.75	21.50	1.54	0.54
	102-1	Bold seeds	15.30	21.50	1.27	0.52
	102-4	Bold and shining seeds	16.00	22.50	1.27	0.44
70 kr	104-18	High yield	30.50	25.00	1.25	0.38
	117-9	Highest yield	35.10	24.30	1.14	0.46
Control	1		12.70	24.00	1.36	0.46
	2		16.10	23.62	1.35	0.46
	3		13.00	23.75	1.37	0.41
	4		11.80	23.80	1.36	0.46

because of the variation in seed-setting. In this study, some of the irradiated plants producing a very large number of pods were found to give lower yield than the controls with fewer pods because of poor seed-setting. This observation is contrary to Bari (2) in flax where he observed an increase in the total number of seeds/plant.

The results also show that random mutation results in an increase in variation for all quantitatively inherited characters; however, there was decrease in the general mean of the irradiated populations with some exceptions. Thus, the results confirm studies by Rajput (16) who found that in the M_2 generation of mungbean, positive or negative shifts occurred in the mean values for all the polygenic traits except mean pod length. Also the coefficient of variability increased in all treatments for all the traits. Similar results were reported by Brock (4) on *Arabidopsis thaliana*, Gardner (9) on maize, and Bartlett et al. (3) on Tribolium which also showed that mutation increased the variation for quantitative traits but smaller selection responses were achieved than with the unmutated control population.

The irradiation treatments also induced variability with regard to protein content and quality. Plants with high protein content in the M_1 generation did not maintain this increase in the M_2. This is partly due to low heritability and environmental effects. This may be only an effect of irradiation, the result of lower yield, etc, and not a genetic change. The observations on protein content in M_2 pregenies did not confirm those of Mujeeb and Greig (13), who found that in *Phaseolus vulgaris* (L.), the protein content of all the mutants was similar to that of the control. Some of the M_2 progenies showed a small range of variation in methionine and trytophan. The maximum tryptophan content in the control was 0.46 (on protein basis), whereas some M_2 progenies showed a content of 0.67.

We conclude that the variability in most of the characters studied in the progenies of the irradiated material was higher than that in the control plants. Thus, we suggest that mutation breeding can be an effective tool in bringing about an improvement in the production potentials of mungbean.

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Discussion

Dolores: What should be the genetic basis of producing smaller seeds in mungbean hybrids?

Ramanujam: The genetic basis appears to be the negative correlation between seed size the seed number per pod. Path analysis indicates that the appreciable direct positive contribution of seed size to seed yield is often cancelled out by the negative contribution through the indirect paths such as seed number/pod and pods/plant.

Quebral: You mentioned socioeconomic constraints that limit mungbean production, Dr. Park. Specifically, what are these?

Park: The first problem is marketing. The farmers do not get enough profit from their produce. Perhaps, the middle-men earn profits but not the farmers. Secondly, the price of mungbean is cheap.

Dolores: Mr. Ballon, you indicated that one of your breeding objectives is to build a diverse gene pool. You also mentioned that you want to attain homozygosity. How do you intend to do this?

Ballon: We intend to produce improved varieties with a wide genetic base in pest and disease resistance and nutritional quality. As soon as these genetic sources are wrapped up in one variety, we intend to advance generations to attain homozygosity to facilitate the release of approved varieties to the farmers.

Cowell: Dr. Konno, you indicate inputs of 30-40 kg/ha of MgO for adzuki bean production. This seems quite high. Do you have a magnesium deficiency in many areas used for adzuki bean production, or does the bean require unusually large amounts of magnesium for growth?

Konno: We apply magnesium as recommended by previous research findings. We have observed Mg deficiency in some areas. And, we also know that Mg is important for pod formation and root nodule formation.

Cagampang: In your various interspecific crosses, Dr. Ahn, you failed to mention which desirable properties you wish to transfer to the progeny. What do you wish to attain in your interspecific hybridization work?

Ahn: To widen the scope of genetic resources mobilization, and to clarify the evolutionary relationships of these four species.

Cagampang: Have you done cytogenetic and biochemical studies to support you hybridization?

Ahn: Only the observation of chromosomal association at meiosis in both parents and their hybrids.

Arwooth: Has the name *Phaseolus aureus* been changed to *Vigna radiata* only on the basis of floral morphology?

Ahn: Not only on floral morphology but also sereological reaction, isozyme banding pattern, and reticulation pattern of pollen grains.

Arwooth: Could the botanical name of mungbean be changed back to *Phaseolus* spp?

Ahn: Absolutely not.

Dolores: Which of the parents in that cross where complete sterile progenies were obtained are resposible for the transfer of sterile genes to the offspring? Is there anything you can do to make them fertile?

Ahn: The sterility of the interspecific hybrids are not due to sterile genes or to plasmic factors that are found within a species. The hybrid sterility is due largely to chromosomal heterology and/or adverse genic interactions of different species.

Dolores: If mungbean, blackgram, rice bean, and adzuki bean are closely related, do they come from the same species?

Ahn: No. The barriers were broken down artificially; they are still reproductively isolated under natural conditions.

Dolores: How did you apply colchicine to double the number of chromosomes in the hybrid mungbean?

Ahn: I applied colchicine by dipping the cut branches into a 0.01% agueous solution for six hours in the shade which is patterned after the technique used by Smart and Black, and then rooting them under a mist propagator.

Laing: In varieties which show increased LAI after flowering, does the new leaf area occur on new branches on new nodes?

Kuo: The increase of LAI after the first flowering is mainly due to the increase of new nodes with leaves; however, there is also a slight increase of new branches at lower population densities - about 100,000 to 200,000 plants/ha.

Palis: Did you observe any mungbean leaf photorespiration in your gas exchange studies?

Kuo: No. But we would like to pursue this area of study in the future.

Ballon: Results obtained from the growth regulator are very encouraging. Would these chemicals have the same effect in the Philippines? What is the name of the chemical company distributing kinetin and BNOA?

Kuo: With the suitable choice of variety, stage of plant growth, and method of application, these chemicals should produce the same effect in the Philippines. Both kinetin and BNOA can be obtained from Sigma Chemical Company.

Wang: Do you think that sucrose synthase in seed results primarily from screening high yielding varieties? It seems from Figure 7 that high sucrose is found in the seed of high yielding varieties,

Kuo: Soluble sugar content in the seed shown in Figure 7 was obtained from the total seeds harvested at the specifc sampling date. On the other hand, unpublished results of studies with sucrose synthese activity at specific stages of individual seed development from varieties with contrasting yield potential showed no major differences in this enzyme activity although there was a difference in pod number.

Laing: The new leaf area is probably more efficient at photosynthetic fixation, why do you seem to have large competitive effects between seeds and leaves since the new leaf area should increase your source of photosynthate?

Kuo: Ideally, new leaf area should be already produced when the photosynthate is most needed for seed development but not at the stage when seed development is initiated and plant still has to provide photosynthate for making new leaves.

Dolores: Mr. Chen, how does defoliation affect pod setting and seed viability?

Chen: We have speculated that an active componen in the leaves may be synthesized which causes embryo abortion. Immunusuppressive chemicals could suppress this reaction. We still don't know the function of defoliation on pod and seed set.

Dolores: Which scientific name is more acceptable for mungbean, *Phaseolus aureus* or *Vigna radiata*?

Chen: *Vigna radiata*.

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