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AVRDC GERMPLASM: ITS UTILIZATION AND DEVELOPMENT OF IMPROVED MUNGBEAN

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Abstract

Attempts to improve mungbean have been mainly confined either to examination of varietal differences or selections from the cultivator's improved stocks. Cognizant of this situation, the Asian Regional Center of the Asian Vegetable Research and Development Center (ARC-AVRDC), Thailand and Nuclear Institute for Agriculture & Biology (NIAB), Pakistan, initiated a mungbean shuttle breeding programme to strengthening the research activities for the development of new high-yielding and disease-resistant genotypes suitable for both South and Southeast Asian countries. As a result of combined efforts, several mungbean promising lines have been developed. With this collaboration, three varieties namely NIAB Mung 51, 54, and 92 have been released as commercial varieties for general cultivation to the farmers in Pakistan. In this paper, brief history of development of improved mungbean genotypes at NIAB, Faisalabad and inter-relationships among various component traits of seed yield observed in an experiment conducted at ARC-AVRDC, Thailand are described.

Introduction

Mungbean (*Vigna radiata* (L.) Wilczek) is an ancient and well-known pulse crop in Asia and is now becoming popular in other continents. It is an excellent source of easily-digestible protein of low flatulence, which complements the cereal-based diet of the Asian people. In Pakistan, mungbean is grown mainly in summer, starting from the end of June in the northern areas with the onset of monson and continue to the first week of August in the southern regions. With the introduction of new high-yieldding and early-maturing varieties, mungbean spring cultivation has rapidly expanded in the fallows preceding cotton and rice, in the orchids with citrus for intercropping and as a catch crop in the fallows between the wheat and rice/maize (Malik *et al.*, 1989).

The low yield potential due to indeterminate excessive vegetative growth, low harvest index, defective plant type, small seed size, late and asynchronous maturity and susceptibility to insect pests (bruchid), diseases (Mungbean yellow Mosaic Virus; MYMV, Cercospora Leaf Spot; CLS and Powdery Mildew; PM) and environmental stresses are among the major drawbacks.

To improve the yield potential and seed size, a collaborative hybridization program involving local small seeded and bold seeded varieties developed at Asian Vegetable Research and Development Centec (AVRDC), Thailand having contrasting characters was initiated in 1980 and further intensified with shuttle breeding programme during 1992. In order to gauge the inter-relationship among various component traits of seed yield to devise a suitable selection criterion for mungbean improvement, an experiment comprising of sixteen genotypes was

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conducted in a randomized complete block design replicated thrice maintaining inter- and intra row distance of 0.5 m and 0.125 m and consisting of a plot of 5 x 2 m^2 of 2 beds with 2 rows/bed. at Asian Regional Center of the Asian Vegetable Research and Development Centec (ARC-AVRDC), Thailand. In this paper, a brief history of development of high yielding mungbeans with other improved plant characteristics at NIAB and observations regarding associations of some of the plant characters to yield and yield components recorded in Thailand are described.

Mungbean Production and Yield Gaps in Pakistan: Mungbean area and production in Pakistan is shown in table1. The area and production remained static upto eighties due to the scarcity of high-yielding, early-maturing and disease-resistant varieties suited to modern intensive farming practices. With the introduction of new varieties possessing improved plant characteristics during the period from 1983 to 1998, mungbean area and production in the country increased substantially from 67,000 ha producing 31,800 t in 1980-81 to 1,99,500 ha with the production of 90,500 t in 1998-99 respectively, almost 3-fold increase during the last two decades, thus can help overcome the pulse shortage in the country by the development of even high-yielding and disease-resistant varieties with desired plant type to the farmers' community.

In spite of the development of high-yielding varieties, mungbean could not make a breakthrough in Pakistan. Indications of inefficiency were observed in mungbean cultivation. Average farmers got only half the potential yield, while the yield of top 5 % progressive farmers approached the experimental potential yield. The gap between average and potential yield on the progressive farms might be due to "technical efficiency", "allocative efficiency", or both. The mean population efficiency was estimated about 65 % implying that average farmers were obtaining less than 2/3 yield of progressive farmers, both at the same levels of input use. The mean yield loss over the sample was 500 kg ha^{-1}, indicating a clear potential to improve productivity at the given level of resources. More than 1/3 of the sample of farmers were losing 100 kg ha^{-1} or more, and 1/4 of the farmers lost 400-500 kg ha^{-1}. Only 4 % of farmers were losing 100 kg ha^{-1} or less.

To help farmers to deal with disequilibrium, agronomic research should focus on developing expert management packages for various regions and environments. And farmers must be trained in how to use these packages.

Apart from this, there is a need to recognize seed industry to provide clean and pure seed. Mixing of mungbean seed has further reduced the potential yield of modern varieties. Farmers attribute 12 % of yield losses to weeds and 12% to insects and about 5 % to diseases. Study into crop protection management, and the development of insect-pest-resistant varieties could help farmers to greatly increase mungbean yield (Ali *et al.*, 1997).

Indigenous Mungbean Germplasm: Before the start of varietal research, two major types of local or Desi mung available were i) photoperiod sensitive, and ii) photoperiod insensitive. The photoperiod sensitive types were lower yielding, asynchronous, and late maturing (95-115 days). They had spreading growth, small pods and small seed size (20-25 g/1000 seed). The seeds were usually green, either shiny or dull. Strong response to daylength forced farmers delayed sowings of the following wheat crop. They were susceptible to both mungbean yellow mosaic virus (MYMV) and cercospora leaf spot (CLS) diseases. The photoperiod insensitive

Desi types gave relatively better yield possessing erect growth habit with crop duration of 90-95 days in summer and about 80 days when sown in spring. They had comparatively bigger pods, medium seed size (25-30/1000 seed), and green, but dull seed coat. They were also susceptible to MYMV and CLS diseases. The variety 6601 (land race) released by the Department of Agriculture, Punjab, in 1971, remained the only approved variety of mungbean until 1983. Long duration and asynchronized maturity created strong competition with other crops for land and labour. Low yield eventually threw mungbean out of competition (Ali *et al.*, 1997).

AVRDC Mungbean Germplasm: The improvement of mungbean at the Asian Vegetable Research and Development Center (AVRDC), Taiwan was initiated in 1971 with the objectives of high- and stable-yielding, uniform maturing, disease- and insect-resistant varieties that made an efficient use of solar energy and soil nutrients (AVRDC, 1977). The large-seeded varieties developed at AVRDC have higher yield potential, but fail to thrive in summer in Pakistan, the major crop season, largely due to MYMV disease. When grown in the spring, most suffer pod shattering at maturity, requiring two to three hand pickings, which is not economically feasible. However, some possess resistance to CLS and powdery midew (PM) diseases which are also serious diseases of mungbean. VC 1973A, possessing higher yield potential, has been grown successfully in Thailand and China, the leaders in mungbean export, and other countries in the world (Ali *et al.*, 1997; AVRDC, 1994).

Utilization of AVRDC Mungbean Germplasm: To improve the yield potential and seed size in indigenous mungbean in Pakistan, a collaborative hybridization programme involving local small-seeded and AVRDC bold-seeded varieties possessing contrasting characters (Table 2) was initiated in 1980 and got a boost in 1981 with collaboration among National Agricultural Research Center (NARC), Islamabad, NIAB, Faisalabad, Ayub Agricultural Research Institute (AARI), Faisalabad and AVRDC. NIAB benefited from the AVRDC advanced lines of VC 1482, VC 1560, VC 1628, VC 1973, VC 2719, VC 2768, VC 3726, VC 2754, VC 2771, VC 2778, and VC 3902 (Ali *et al.*, 1997).

Development of Improved Mungbean in Pakistan: With the objectives of higher yield potential, non-shattering pods with bold seeds, resistance to MYMV and other diseases, and improved plant characteristics, a local small-seeded (30 g/1000 seed) variety 6601, tolerant to MYMV but susceptible to CLS, was crossed with AVRDC large-seeded (70 g/1000 seed) variety VC 1973A, susceptible to MYMV but tolerant to CLS, following irradiation of F_1 seeds with 10 kR dose of gamma rays to enhance their variability. From this hybridization, four promising lines, namely NIAB Mung (NM) 51, 54, 18, and 36, having short plant type with erect growth habit, early (64 – 72 days) and uniform maturity, and large pods with bold seeds (46 – 53 g/1000 seed) were proposed for approval (Table 3). NM 51 and NM 54, producing 21 – 36% higher yield than standard NM 121-25, were approved by the government of the Punjab in 1990 for general cultivation (Malik, 1991).

To further improve the yield potential of mungbean, enhance resistance to diseases and other stresses, three small-seeded mutants, induced in local cultivars and released as commercial varieties in 1986 namely NM 13-1, 19-19, and 20-21, were crossed with four AVRDC promising accessions namely VC 1482E, 1560D, 1973A, and 2719A mainly at AVRDC and partly at NIAB and NARC. The entries 5-80 (1786 kg ha^{-1}), 10-12 (NM 88) (1789 kg ha^{-1}), 10-22 (1888 kg ha^{-1}) and 10-43 (NM 89) (2138 kg ha^{-1}) proved not only high yielding and early-maturing but also disease resistant genotypes (Table 4) (Malik, 1993). Furthermore, the lines 6-97 (a derivative of VC 1973A x NM 20-21) and 10-12 (NM 88) have been reported to be resistant to alkaline soils and used as a genetic source of tolerance for transfer of resistance genes into AVRDC cultivars in Thailand (Srinives, 1995).

The crosses, made among NM 36, 51, 54 and several AVRDC promising lines such as VC 2768A and B, 3726, 2754A, 2771A, 2778A, 1973A and 1560D, produced a large number of segregants with higher yield potential, wider adaptability, improved plant architecture and even resistant to diseases. Four derived lines- NM 92, 93, 96, and 90- showed good performance under different agroclimatic conditions, but NM 92 maintained superiority over its counterparts in yield and other agronomic characteristics. NM 92 was approved as commercial variety by the government of Punjab in 1996 (Sadiq *et al.*, 1999). This variety is performing well, not only in Pakistan, but also in other countries (AVRDC, 1994).

Shuttle Breeding for Mungbean Yellow Mosaic Virus Resistance and Other Important Plant Traits between ARC-AVRDC, Thailand and NIAB, Pakistan: To intensify the research efforts, a shuttle breeding collaborative programme between the Asian Regional Center of the Asian Vegetable Research and Development Center (ARC-AVRDC), Thailand and Nuclear Institute for Agriculture and Biology (NIAB) in Pakistan started during 1992. The hybridization and generation advancement at ARC-AVRDC, screening of the segregating populations against MYMV at NIAB under strong biotic stress, and the evaluation of new recombinants both at NIAB and ARC-AVRDC under diverse ecological and agroclimatic conditions led to the development of a large number of new improved mungbean genotypes with high level of resistance to MYMV, uniform maturity, nonshattering pods, and large seed size.

NM 89 was crossed with 15 AVRDC promising lines viz. VC 1000C, 1482C, 1482E, 2307A, 2719A, 2750A, 2754A, 2755A, 2768A, 2768B, 2771A, 3061B, 1945, 2565, amd 3726. From the F_2 populations of these crosses, more than five hundred segregants with desired plant traits were isolated at NIAB under strong biotic stress for MYMV and sent to ARC-AVRDC, Thailand for generation advancement and further evaluation. Based on out-yielded performance in the International Mungbean Nursery (IMN), NM 92 was crossed with five AVRDC large-seeded lines (VC 3902A, 1560A, 1628A, 1973A, and 2768A) at ARC-AVRDC. The F_1 and F_2 generations were raised and the F_3 populations were despatched to NIAB for MYMV screening. The MYMV resistant recombinants with desired plant traits selected at NIAB were sent to ARC-AVRDC for generation advancement. During 1994, nearly 250 lines (derivatives of crosses between NM 18, 51, 88, 92, 93, 94, 96 and several AVRDC lines) consisting of different generations (F_3 – F_7 and M_3) were sent to NIAB for their reaction against MYMV and other plant traits. Besides this, seventeen promising lines in F_7 generation were evaluated at ARC-AVRDC during dry season and the same set of lines in F_8 generation was evaluated at NIAB in the summer season. The data of some of the lines are presented in table 5. The genotype-environment interaction of the entries grown under two diverse agroclimatic conditions is clearly manifested in yield and other plant attributes. Entries such as S. No. 1, 7, and 14 giving higher yields (180

2114 kg ha^{-1}) at AVRC-AVRDC did not prove superior (1193-1373 kg ha^{-1}) at NIAB. However, entry at S. No. 9 (VC 6153-B-31-2B-1-B, a derivative of cross between VC 3902A and NM 92) gave higher yield both at ARC-AVRDC (1865 kg ha^{-1}) and at NIAB (1872 kg ha^{-1}), expressive of wider adaptability. Most of the entries showed marked improvement in their seed size. All the entries exhibited a high level of resistance to MYMV and CLS diseases at NIAB and powdery mildew (PM) and lodging at ARC-AVRDC (Ali *et al.* 1997). From the 1994 summer crop raised at NIAB, 228 lines and 73 single plant selections with desired plant traites were isolated from different populations and sent to ARC-AVRDC, Thailand in 1995 (Table 6). An advanced lines yield trial consisting of ten promising lines alongwith two standards was conducted at ARC-AVRDC (Table 7). The entry at S. No. 1 produced the highest seed yield of 2.1 t ha^{-1} followed by 2.0 t ha^{-1} obtained from entries at S. No. 2, and 3. All the entries exhibited improved seed size and other yield components (AVRDC, 1996). For development of mungbean genotypes suitable for South and North Asia, nearly 170 lines with resistance to MYMV, large seed size, high yielding ability, uniform maturity, nonshattering pod, and varied crop duration (55-85 days) were evaluated in different trials for yield and other agronomic parameters during dry season. The most promising lines from these trials were identified. In addition, nearly 200 F_3 progenies and 52 $F_5 - F_9$ families derived from several crosses between NIAB and AVRDC lines were grown for generation advancement and further selection (AVRDC, 1997).

Direct and indirect effects of different characters on seed yield in mungbean: With the crosses made between the germplasm of diverse origin (AVRDC and indigenous), a vast amount of variability has been created offering immense scope for further gain in yield and other plant traits of economic importance. Many plant characters important in breeding superior yielding mungbean cultivars are inherited in a quantitative manner. Quantitative characters are genetically controlled by several genes at different loci with varying types of gene action. Additionally, the phenotypic expression of a quantitative character may be altered by environmental stresses that affect the growth of the plant and its development. Genetic improvement in the expression of a quantitative character is dependent upon having germplasm with a range of genetically controlled variability for the trait under consideration. Inability to visually recognize small difference in a quantitative trait has led to frequent attempts to find associated traits amenable to visual selection (Poehlman, 1991). Characters with low heritability, or that not easily and precisely measurable, can be improved through indirect selection. With the objective of improved seed yield, the studies were conducted at ARC-AVRDC, Thailand to describe inter-relationship among various component traits of seed yield so as to devise a suitable selection criterion for mungbean improvement. The study of direct effects (Table 8) on seed yield for sixteen genotypes showed that pods per plant had the highest positive effect (0.622) followed by seeds per pod (0.473), pod length (0.382), days to mature (0.127), and with negligible effect of 1000-seed weight (0.087). The indirect effect of pods per plant via seeds per pod (0.32), pod length (0.19), days to flower (0.07), and 1000-seeed weight (0.02) were observed, followed by negative effects via plant height (-0.25) and days to mature (-0.05). The total correlation coefficient (0.921) was mainly due to direct effect of seeds per pod. Seeds per pod were the second most important character, which showed high positive direct effect on seed yield. In the same way, pod length also showed high positive direct effect on seed yield. Plant height showed negative effect (-0.349) on seed yield but its influence could not manifest in the total correlation (0.886) due to the high positive indirect effects via pods per plant, seeds per pod, and pod length. Days to flower had low negative direct effect while days to mature showed low positive direct effect on seed yield. The low positive direct effect of days to mature was accounted for by negative indirect effects of days to flower, pod length, seeds per pod, pods per plant, and 1000- seed weight. Several previous reports revealed that pods per plant was the major variable having direct effect on seed yield in mungbean (Malhotra *et al.*, 1974 and Satyal *et al.*, 1986). Khattak (1999) reported that seed yield per plant in mungbean depended primarily on pods per plant and 1000 seed weight, similar to the results obtained by Zubair and Srinives (1986). Many researchers reported that 1000 seed weight and pods per plant were the best selection indices for developing high-yielding mungbeans (Ghafoor *et al.*, 1990; Khan, 1991; Naidu *etal.*, 1994; Khorgade, 1995; Khattak *et al.*, 1995, 1997).

Detailed information on the effectiveness of different quantitative traits and their contribution toward final seed yield was estimated by processing the data to multiple correlation and partial regression (Table 9 and 10). Multiple correlations of all the characters with seed yield per plant were highly significant (0.997**) and slightly higher than that of primary yield components (0.995**). Malik and Singh (1983) also reported the same results in mungbean. The significance of partial regression coefficients was tested through t-test which revealed that pods per plant, 1000 seed weight, and seeds per pod contributed highly significantly while pod length contributed significantly towards seed yield per plant thus reflecting the importance of these characters in seed yield determination. Plant height, days to-flower and mature did not contribute significantly towards seed yield. The same trend of these characters was also confirmed by path coefficient analysis. The estimates of coefficient of determination (R^2) in multiple correlation indicated that 99.1 % of the total variation accounted for seeds per pod, pods per plant, and 1000 seed weight as compared to 99.5 % of total variation for all the characters together under study. Khattak (1999) also observed that 86.6 % of the total variation for yield per plant was based only on pod length, pods per plant and 1000 seed weight against 87.1 % of the total variation by all the characters studied.

The present studies as well as several other reports indicated that pods per plant, seeds per pod, pod length, and, in some cases, seed weight might prove to be the principal yield components that should receive due cosideration while selecting mungbean genotypes for higher seed yield. Since fewer seeds per pod and small seeds may accompany high pod number, emphasis needs to be given to the latter, and particularly to seed size so that it does not decline below a norm acceptable for maintaining market quality.

Table 1: Mungbean Area and production in Pakistan, 1981 – 1999.

Year	Area ('000 ha)	Production (000 t)	Yield (kg ha^{-1})	Year	Area (000 ha)	Production (000 t)	Yield (kg ha^{-1})
1980-81	67.0	31.8	475	1990-91	141.6	56.5	399
1981-82	65.6	31.6	482	1991-92	125.8	50.9	405
1982-83	79.0	39.6	502	1992-93	146.8	62.1	423
1983-84	91.0	41.8	459	1993-94	167.9	69.3	413
1984-85	93.6	44.6	476	1994-95	179.7	80.0	445
1985-86	104.2	48.8	468	1995-96	199.1	90.6	455
1986-87	114.2	55.3	484	1996-97	192.4	89.5	465
1987-88	94.1	43.3	461	1997-98	195.4	88.9	455
1988-89	96.6	41.1	426	1998-99	199.5	90.5	453
1989-90	143.8	57.0	396				

Table 2. Morphological characteristics of indigenous and AVRDC mungbean genotypes.

Plant Character	Indigenous mungbean	AVRDC mungbean
Maturity	Late	Early
Pod shattering	Non-shattering	Shattering
Seed size	Small (30-35 g/1000 seed)	Large (50-70 g/1000 seed)
Yield potential	Low	High
Cultivation	Summer and spring	Only in spring, (fail to thrive in summer due to MYMV disease)
Reaction to diseases		
MYMV	Resistant	Susceptible
CLS	Susceptible	Resistant

Table 3: Performance of large-seeded mungbean elite lines for seed yield and other important plant characteristics (4 years average).

Variety	Days to mature	Plant height (cm)	Pods per plant	Seedsper pod	1000-Seed wt. (g)	Harvest index	Seed protein	Seed yield (kg ha^{-1})[a] Summer	Spring	Reaction to [d] MYMV	CLS
NM51	67	72	34.7	12.0	46.0	30.6	24:1	1536	1714	HR	MT
NM54	65	68	30.4	12.3	56.1	25.9	24.2	1517	1482	T	T
NM18	72	72	31.4	12.2	53.2	28.9	24.7	1544	1727	HR	T
NM36	64	57	32.1	12.2	52.7	31.4	24.4	1488	1651	HR	T
VC1973A	78	52	18.5	10.7	72.1	36.1	23.5	-	1690	HS	T
[b]	90	94	23.2	11.2	30.4	17.6	24.0	990	1049	T	S
6601 [c]	67	59	31.5	11.7	33.3	27.6	24.5	1232	1262	MR	S
NM121-25 (Check)											

a The number of locations in summer and spring experiments were 91 and 69, respectively. In 150, out of 160 locations the yield among the entries was significantly different.

b AVRDC parent failed to thrive in summer.

c Indigenous parent

d MYMV: mungbean yellow mosaic virus, HR = highly resistant, MR, = moderately resistant, T = tolerant, HS = highly susceptible CLS : cercospora leaf spot, T = tolerant, MT = moderately tolerant, S = susceptible

Source: Malik, 1991.

Table 4: Performance of mungbean advanced lines (AVRDC lines x Induced mutants) for seed yield and other plant traits.

Entry	Pedigree[a]	Days to		1000-seed wt. (g)	Harvest index	Seed yield (kg ha^{-1})	Reaction to [b]	
		Flower	Mature				MYMV	CLS
5-80	VC1973A x NM19-	38	65	46	30	1786	R	R
7-114	VC2719A x NM13-	38	64	46	23	1573	MR	R
7-134	"	36	60	44	27	1656	MR	R
8-151	VC2719A x NM19-	39	68	38	26	1538	MR	R
9-180	VC2719A x NM20-:	40	73	43	24	1670	MR	R
10-12	VC1482E x NM20-:	35	58	53	36	1789	HR	R
10-22	"	40	63	42	28	1888	R	R
10-43	"	35	61	40	30	2138	R	R
1-13	VC1560D x NM13-	40	68	48	23	1413	MR	R
NM13-1	Parent	38	62	34	25	1216	MR	S
NM19-19	"	37	65	32	28	1344	R	MS
NM20-21	"	37	62	31	26	1395	R	MS

AVRDC lines VC1482E, 1560D, 1973A, and 2719A failed to thrive due to MYMV attack.

a) Induced mutants NM13-1, 19-19, and 20-21

b) MYMV: mungbean yellow mosaic virus CLS: cercospora leaf spot

Source: Malik, 1993.

Table 5: Performance of mungbean advanced lines at ARC-AVRDC, Thailand and at NIAB, Pakistan.

		ARC-AVRDC, Thailand (Spring)				NIAB, Pakistan (Summer).			
S. N(	Entry	Days to maturity	Plant height (cm)	1000-seed wt. (g)	Yield (kg ha^{-1})	Days to maturity	Plant height (cm)	1000-seed wt. (g)	Yield (kg ha^{-1})
1	VC6158-B-5-B-3-1-B	52	58	74.3	1803	66	67	67.3	1345
4	VC6158-B-31-B-3-1-B	52	58	59.8	1565	67	62	56.0	1463
5	VC6158-B-15-B-2-1-B	59	63	59.4	1313	72	57	54.6	1248
7	VC6158-B-22-B-2-1-B	53	53	75.5	1811	69	51	73.3	1373
9	VC6153-B-31-2B-1-B	54	63	70.1	1865	68	57	67.0	1872
10	VC6153-B-32-2B-1-B	55	61	64.7	1526	65	55	63.0	1290
14	VC6168-B-19-2B-1-B	50	55	71.8	2113	72	50	66.8	1193
16	VC6173-B-22-2B-3-B	54	59	78.2	1836	70	67	73.4	1387
18	NM 92	54	50	50.2	1416	67	51	53.0	1650
1(	KPS 1 (VC 1973A)	58	58	70.2	1322	Failed to thrive due to MYMV Attack			
20	NM 51 (Standard)	Not studied				74	72	43.0	1532
2:	NM 54 (Standard)	Not studied				67	57	57.0	1414

Source: Ali *et al.*, 1997.

Table 6: Mungbean material shuttled between ARC-AVRDC, Thailand and NIAB, Pakistan.

Population designation	No. entries received from ARC-AVRDC	Generation	No. of selections
F_7 Bulk populations	59	F_8	29
(NM 92 x AVRDC lines derivatives)			
F_5 bulk populations	13	F_6	13
(NM 92 x AVRDC lines derivatives)	34		
F_4 bulk populations	07	F_5	21
(NIAB x AVRDC)lines derivatives	53		
F_3 bulk populations	33	-	-
(NM 92, 51 x AVRDC lines) derivatives			
Backcrossed populations	6 crosses	B_4/F_2	33
F_1 populations			
(NM 92 x 15 AVRDC lines)	15 crosses	F_2	687
(M 89 x 15 AVRDC lines)	15 crosses	F_2	548
M_3 populations			
(NM 92)	09	M_4	07
(NM 94)	21	M_4	03

Source: AVRDC, 1996.

Table 7: Performance of mungbean advanced lines for yield and other plant characteristics at ARC-AVRDC, Thailand.

S. No.	AVRDC designation	Plant height (cm)	Seeds per pod	Pods per plant	1000-seed wt. (g)	Field (t ha^{-1})
1	VC 5908-B-2-2B-3	82.4	11.2	14.3	59.1	2.1
2	VC 5960-2B-2-B-2	74.2	10.8	13.9	64.4	2.0
3	VC 5960-2B-2-B-3	80.9	11.3	14.0	63.5	2.0
4	VC 5916-2B-3-B-3	89.9	11.6	14.7	60.7	1.9
5	VC 5926-2B-1-B-1	90.9	11.8	14.9	61.5	1.9
6	VC 5910-2B-3-B-1	81.1	10.7	16.2	63.5	1.9
7	VC 5911-2B-1-B-1	85.1	11.0	15.0	55.8	1.9
8	VC 5895-2B-1-B-1	83.4	11.9	13.1	58.7	1.9
9	KPS 2	85.1	12.3	15.3	54.8	1.8
10	KPS 1	85.1	10.7	14.8	61.2	1.8
11	VC 5933-2B-1-B-1	98.4	12.0	15.5	58.7	1.8
12	VC 5925-2B-1-B-1	93.1	11.2	13.4	60.9	1.7
Mean		85.8	11.4	14.6	60.2	1.9
CV	(5%)	5.29	4.72	9.53	2.08	8.99
LSD		4.54	0.54	1.39	1.26	172.60

Source: AVRDC, 1996

Table 8: Direct and indirect effect of seven characters on seed yield in mungbean Indirect effect.

Character	Direct effect	Days To Flower	Days to mature	Plant height	Pod length	Seeds per pod	Pods per plant	1000-seed weight	Correlation With seed yield
Days to Flower	-0.159	1	0.08	0.11	-0.09	0.02	-0.26	-0.02	-0.313
Days to mature	0.127	-0.10	1	0.11	-0.17	-0.03	-0.23	-0.01	-0.306
Plant height	-0.349	0.05	-0.04	1	0.31	0.42	0.45	0.05	0.886
Pod length	0.382	0.04	-0.06	-0.28	1	0.29	0.31	0.07	0.753
Seeds per pod	0.473	-0.01	-0.01	-0.31	0.23	1	0.42	0.03	0.838
Pods per plant	0.622	0.07	-0.05	-0.25	0.19	0.32	1	0.02	0.921
1000-seed weight	0.087	0.04	-0.01	-0.21	0.31	0.18	0.15	1	0.537

Table 9: Multiple correlation analysis of yield on the basis of all characters under study and of primary yield components.

Parameter	Multiple correlation (R)	R^2	Adjusted R^2	Std. Error
All characters	0.997**	0.995	0.990	0.163
Primary yield components	0.995**	0.991	0.989	0.176

** Significant at 0.01 * Significant at 0.05

Table 10: Partial regression coefficients of seed yield in mungbean.

Parameter	Partial regression coefficient (b)	S. E $_{(b)}$	t value
Days to Flower	– 1.1816	2.4691	– 0.479
Days to mature	1.4528	2.0152	0.721
Plant height	– 3.2231	2.4108	– 1.337
Pod length	3.3970*	1.5524	2.188
Seeds per pod	7.6161**	1.4051	5.420
Pods per plant	6.0198**	3.7749	15.947
1000-seed weight	7.4649**	1.7400	4.290

** Significant at 0.01 * Significant at 0.05

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