India

Developing short duration mungbean genotypes suitable for rice-wheat cropping system

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Abstract

The research work was conducted at Punjab Agricultural University (PAU) in Ludhiana and AVRDC in Taiwan by PAU Scientists during summer and *Kharif* seasons 2002 and 2003 under the DFID Mungbean project "Improving Income and Nutrition by Incorporating Mungbean in Cereal-Fallows in the Indo-Gangetic Plains of South Asia." A number of trials were conducted to identify cultivars suitable for farmers and adoption in rice-wheat cropping system. New variety SML 668 was identified to be very stable in yield performance with synchronous and early maturity, bold and shining seeds. It was also tolerant to mungbean yellow mosaic virus (MYMV) disease and thrips, a very serious pest of summer season crop. Thus, based on its superior performance, this new variety was approved and recommended for cultivation not only in summer season but also in *Kharif* season. Hence it is the first ever variety approved for general cultivation in both the seasons in Punjab State. Apart from this, some other strains were also found promising. New breeding populations were generated and evaluated for the continuity of future research work on mungbean. New crosses between the local superior, MYMV-resistant lines and early maturing, bold-seeded genotypes from AVRDC were successfully made. Inheritance studies on MYMV-resistance also indicated that, depending on the genetic make up of the plant, resistance is governed by a single dominant gene and two complementary genes (YM 1 or YM 2). Hardseedness studies indicated that small-seeded genotypes possess more hardseeds compared with the bold seeded types. In the studies on effect of aging on hardseededness, it was observed that in all three seasons, i.e. spring, summer and autumn, there was a reduction in the percentage of hardseeds in some genotypes when stored in controlled conditions (Temp. 18 C $\pm$ 2 & RH 45%). It was also found out that large-seeded cultivars can be stored safely for a longer period compared with small-seeded ones. DNA fingerprinting studies by RAPD markers in 21 and 32 genotypes of diverse origin, in 2002 and 2003 respectively, showed diversity among themselves but revealed narrow genetic base.

Introduction

In the Indo-Gangetic Plains of South Asia which mainly comprises India, Pakistan, Bangladesh and Nepal, rice-wheat is the major cropping system. In India alone, this system covers over 10 million hectares mainly in the states of Punjab, Haryana, Uttar Pradesh, Bihar, parts of Rajasthan, Madhya Pradesh, Himachal Pradesh, Jammu, and Kashmir. The system of growing cereal after cereal results in multiple adverse effects on soil health, and water reservoirs. Further, it gradually increases the occurrence of diseases and insect-pests and environmental hazards. Thus, there is an urgent need to alter this cropping pattern with some short duration crops to address the said problems successfully.

Mungbean is cultivated either as summer or *Kharif* crop because of its high degree of heat tolerance that is up to 40 C plus. The short duration (55-60 days) varieties could be successfully cultivated in wheat-rice rotation without affecting this popular cropping pattern, since after wheat harvest and before the transplantation of rice, 60-65 days are available which no long duration crop could fit in.

The mungbean cultivars released for spring/summer season in the past are generally of long duration (70-75 days) and thus, did not fit well for cultivation in rice-wheat cropping system. Moreover, majority of these cultivars are susceptible to mungbean yellow mosaic virus (MYMV) disease which is the major cause of unsuccessful cultivation of mungbean. Because of these limitations, the production of mungbean is very low. Thus, available supply for consumption is both low and costly that it adversely affects the health of the poor urban and rural people.

Keeping all these constraints in view, the South Asian Vegetable Network (SAVERNET) launched a research project funded by the Department for International Development (DFID). Research was conducted for the last three years in six South Asian countries, namely Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka. This resulted in the identification of early-maturing, uniform ripening, bold, green seeded and MYMV-resistant cultivars for India and Bangladesh (Shanmugasundaram, 2002). Another project on mungbean "Improving Income and Nutrition by Incorporating Mungbean in Cereal-Fallows in the Indo-Gangetic Plains of South Asia" funded by DFID for Punjab Agricultural University, Ludhiana, India, Bangladesh and Nepal which aimed at identification and release of cultivars with stable performance, early and synchronous maturity, resistance to MYMV and other diseases, and tolerance to insect-pests, thus ultimately making mungbean available to each and every needy person, particularly the poor. Therefore, it, becomes pertinent to evaluate new mungbean lines and generate materials through various breeding approaches so that the widely adaptable cultivars could be developed for high and stable production with productivity level of 2 tons ha^{-1}. Therefore, the following studies were carried out at Punjab Agricultural University, Ludhiana, India and at AVRDC, Taiwan.

Material and Methods

1. Varietal Improvement for Summer/Spring Season

The objective is to develop cultivars/varieties possessing high-yield, early and uniform maturity (55-60 days), shining green and bold seeds, resistance to MYMV, and tolerance to thrips and *Helicoverpa*.

1.1 Experiment 1
Identification of Superior Varieties for Summer/Spring Season

Varietal trials were planted at PAU, Ludhiana, Faridkot and Gurdaspur locations in Punjab, India with promising strains including SML 668 (NM 94) and the check SML 134 during the summer/spring season of 1999 to 2001 in a Randomized Complete Block Design (RCBD). Each trial consisted of four replications with plot size of 4.0 x 2.4 sq. meters accommodating 8 rows with row- to- row spacing of 22.5 cms and plant-to-plant spacings of 5 cm. Data were recorded on grain yield (kg ha^{-1}) from each plot. Data were also recorded for days to 50% flowering, days to complete maturity, 100-seed weight (g), plant height (cm), seeds pod^{-1}, and MYMV and thrips attack. In 2001, SML 668 was also tested at the farmers' field at 12 locations in Punjab state with plot size of 4000 sq. meter during summer season. Observations were recorded on maturity, MYMV attack etc. Data were subjected to ANOVA to calculate C.D. at 5% and C.V.(%).

1.2 Experiment 2
Evaluation of Promising Strains in the Advance Varietal Trial at AVRDC, Taiwan in Summer 2002

Twelve strains/varieties of diverse origin from AVRDC, India, Thailand, and Bangladesh were planted on August 16, 2002 at AVRDC farm in RCBD with three replications. Each strain in each replication consisted of four rows with row length of 3 meters. Row-to-row spacing was kept at 50 cm and plant-to-plant at 5 cm. Data were recorded on grain yield at maturity, days to first flower, pods per plant, seed per pod, 100 seed weight (g), plant stand at harvest, lodging and powdery mildew score (1-9 scale). Data were analyzed using ANOVA.

1.3 Experiment 3
Evaluation of Breeding Strains in Grain Yield Trials

In 2002 and 2003, 56 and 57 breeding strains, respectively, including checks (SML 668 and SML 134) were evaluated in six trials. The experiments were conducted in RCBD with 3/4 replications. The plot size consisted of 6-8 rows with row length of 4 m. Distance between rows was 22.5 cm and plant-to-plant at 5 cm. Sowing of four experiments was done on March 19 and two experiments were planted on April 22 (after wheat harvest). Recommended package of practices for cultivation was adopted. Data were recorded on grain yield, 50% flowering, maturity time, 100-seed weight (g) and MYMV incidence. Data were analyzed by ANOVA to compute C.D. and C.V. for evaluation.

1.4 Experiment 4
Development of New Crosses to Generate Breeding Populations and Evaluation of the Breeding Populations in Different Segregating Generations

Crossing blocks consisting of diverse genotypes were planted in summer and *Kharif* seasons in 2002 and 2003. Two rows of each parental line were planted with row length of 4.0 meters and row-to-row spacing of 22.5 cm. Two rows were kept vacant after every parental line to facilitate crossing. Based on yield performance, maturity, MYMV resistance, pod number, seed size, seeds/pod etc., 78 crosses were made successfully. Twenty-five F_1s, along with their parents, were grown per year with wider row spacing of 45 cm and plant-to-plant spacing of 15 cm. In F_2 to F_7 crosses, the progenies were grown for evaluation in wider spacing,just like in F_1s. Each F_2 cross consisting of 1000 plants, along with 25 plants of parents, were accommodated in each line. Each F_3 progeny consisted of 75-80 plants, whereas F_4 onward progenies consisted of about 100 plants in each progeny. From F_3 onward checks were also planted alongside at regular intervals of three to four progenies.

2. Development of Varieties Suitable for *Kharif*/Rainy Season

The objectives in the development of varieties for *Kharif* season are high grain yield, medium maturity (80-85 days), and resistance to diseases and insect/pests. Major disease of this crop is MYMV, while the major pest is pod borer. Good cooking quality is another objective. The following experiments were carried out in *Kharif* 2002 and 2003 to identify superior varieties for *Kharif* season.

2.1 Experiment 1
Identification of SML 668, New Variety for Cultivation in Kharif Season

SML 668 variety was tested against ML 613 (check) in different multilocation trials at Punjab Agricultural University research stations during *kharif* 1999 to 2002. All trials were planted in the first fortnight of July in RCBD with four replications each year for each trial. Plot size consisted of 8-10 rows with row spacing of 30 cm and plant-to-plant distance of 5 cm. Forty-eight adaptive trials at farmers' fields using both varieties were conducted at different locations. Each variety at each location had 500 m^2 in 11 districts of Punjab. For all the trials, observations on disease, insect pests, and grain yield were recorded. The data were analyzed statistically using ANOVA to determine the significance of two varieties.

2.2 Experiment 2
Evaluation of Promising Strains for Identification of Superior Varieties

Six yield trials in 2002 and nine in 2003 were conducted during *Kharif* season at University farms and research stations.

The advanced yield trials consisted of 10 rows, while the initial evaluation trials were of 6-8 rows per plot per strain/progeny. RCBD was used in all trials. There were three to four replications for each trial and sowing time was on the first fortnight of July in both years. A total of 82 and 148 progenies were evaluated during *Kharif* season in 2002 and 2003, respectively. Data were recorded on grain yield. ANOVA was performed to test the significance of varietal effects. C.D. and C.V. comparing performance against the checks (ML 613, ML 818, and SML 668) were provided from the ANOVA results.

2.3 Experiment 3
Inheritance of Resistance to Mungbean Yellow Mosaic Virus in Mungbean

Six crosses involving two resistant parents (ML 613 and ML 1165), and three susceptible parents (NM 54, 92 and VC 6173-B-10), were generated. The F_2 populations of these crosses were raised during *Kharif* 2003. The natural incidence of MYMV disease was very high which enabled the screening of the F_2 populations under natural field conditions. The data were recorded 60 days after sowing on 1-9 scale (1-resistant; 3-moderately resistant; 5-moderately susceptible; 7-susceptible; 9-highly susceptible). Finally, the plants were categorized as resistant (1-3 score) and susceptible (>3 score). The data were subjected to χ^2 analysis.

3. Research on Mungbean conducted at AVRDC, Taiwan in 2002 and 2003

3.1 Experiment 1
Studies for Hardseededness in Mungbean

This experiment was conducted in the Legume Unit of AVRDC, Taiwan in 2002. Forty-four (44) diverse lines representing AVRDC, India, Pakistan, Bangladesh, Thailand, Mauritius and SriLanka were used. They had variable seed size and seed color. Hundred seeds for each variety were counted and placed in petri dishes on filter paper with covers. Sufficient quantity of distilled water was poured into the petri dishes so that all the seeds are soaked in water. The petri dishes were placed at room temperature and germination count was taken after 72 hours. The hardseeds were also counted.

3.2 Experiment 2
The Study of Variability for Hardseededness in Mungbean Cultivars and Their Association with Seed Size

Fourteen diverse cultivars from the harvest of autumn 2002 and eight cultivars from the harvest of spring 2003, available at the Legume Unit of AVRDC, were selected for this study in 2003. Three replications of 100 seeds for each cultivar were taken. Further,100-seed weight for each sample was recorded. For determination of hardseeds, standard germination test was used. Fifty seeds from each replication were kept between two moist paper towels in the incubator at 27/30^0 C per recommendation of the International Rules for Seed Testing (Anonymous, 1985). Hard seeds were counted after seven days.

3.3 Experiment 3
Effect of Ageing on Hardseededness in Mungbean

This experiment was first conducted in 2002. Seeds from four mungbean lines grown in different seasons, i.e. spring, summer and autumn, in 1998 to 2002 and stored in the Legume Unit of the AVRDC were used in this study. For each line, 100 seeds were counted and placed in petri dishes on filter paper. The seeds were soaked in sufficient quantity of distilled water. Petri dishes were covered and placed at room temperature. Germination count was taken after 72 hours. The percentage of hard seeds was also determined.

The experiment conducted in 2002 was further refined in 2003 to elicit more information on ageing effects. The seed samples of both small and large seeded cultivars grown in different seasons in 1998 to 2000 at AVRDC were taken for this study. These seed samples were taken from the cold store (temperature 18 C ± 2 and relative humidity 45%) of the Legume Unit of AVRDC. Common cultivars over different years were taken. Random sample of 100 seeds of each cultivar was taken in three replications. The standard germination test was done per International Rules for Seed Testing (Anonymous, 1985). The hardseeds were counted after seven days.

3.4 Experiment 4
Studies on Genetic Diversity in Selected Mungbean Cultivars Using RAPD Markers (2002)

Twenty-one lines consisting of released varieties and advanced stable breeding lines from different countries available at the Legume Unit of AVRDC were selected for this study. These cultivars were sown in pots in the greenhouse. The young healthy leaves pooled from three separate plants (20 days old) were collected and used for DNA extraction (Doyle and Doyle, 1987).

PCR reactions were carried out in a thermolyme cycler (Amptitron II). The amplification products were electrophoressed on 1.5% agarose gel at 100 volts for 2 hrs. Gels were stained and photographed under ultraviolet light using an Alpha Imager Program.

Photographs of gels were analyzed using NTSYS software. Presence or absence (1 or 0) of the band were considered a single trait and the binary data were used to calculate pair-wise similarity coefficients following Jaccard (1908). This matrix of similarity coefficients was subjected to unweighted pair group method analysis (UPGMA) to generate a dendrogram using linkage procedure.

3.5 Experiment 5
Studies on Genetic Diversity in Selected Mungbean Cultivars Using RAPD Markers (2003)

The study was undertaken to evaluate the genetic diversity of 32 selected mungbean cultivars chosen from different Asian countries. Each cultivar was sown in two pots in the greenhouse of the Legume Section of AVRDC on August 13, 2003. Young healthy leaves from 20-day old plants were collected in ice box for DNA extraction (Doyle and Doyle, 1987). PCR and gel electrophoresis were carried by standard procedures. Gels were photographed under ultraviolet light using an Alpha Imager Program. DNA analysis was conducted using standard procedures given by Jaccard (1908) which were used to prepare dendrogram using linkage procedure.

Results and Discussion

1. Varietal Improvement for Summer/Spring Season

1.1 Experiment 1
Identification of Superior Varieties for Summer/Spring season

The results on grain yield are presented in Table 1. The yield data indicate that SML 668 variety produced grain yield of 2,051 kg ha^{-1} against 1,441 kg ha^{-1} for the check SML 134 in the 1999 season. In the 2000 season, eight breeding trials and one agronomic trial were conducted and grain yield of SML 668 ranged from 694 kg ha^{-1} to 1754 kg ha^{-1} against 1,396 kg ha^{-1} for the check SML 134. Grain yield of SML 668 was significantly higher than the check variety in seven of the eight breeding trials. Percentage increase over the check ranged from 11.0 to 84.4. Similarly in the year 2001, SML 668 was tested against SML 134 in five breeding trials, one agronomic, and one microbiology trial. Grain yield of SML 668 varied from 833 to 1,227 kg ha^{-1} against 500 to 1,060 kg ha^{-1} for the check, SML 134 depicting that SML 668 was significantly superior to SML 134 in four of the five breeding trials and one agronomic trial with percentage superiority of 13.6 to 66.0. On the overall mean basis of 17 trials, SML 668 showed an increase of 30.53 percent over the check SML 134. Based on the overall superiority in grain yield of SML 668 over SML 134, the new variety was recommended for evaluation at the farmer's field (Table 2). The 26 adaptive trials at 12 locations in 2001 summer season SML 668 recorded an average of 1,071 kg ha^{-1} grain yield against the check SML 134 (704 kg ha^{-1}) with percentage increase of 52.1. Data on ancillary characters indicated that SML 668 matures in 60 days with plant height of 44.6 cm and an average of 16 pods $plant^{-1}$. Seeds pod^{-1} is 10.4 with 100 seed weight of 5.78 g. Thus, SML 668 matures nine days earlier than the check and 1.5 times bolder in seed size.

Data on disease and insect-pests are given in Tables 3 and 4, respectively. Over the period of three years, average MYMV scores indicated that SML 668 was resistant, whereas the check SML 134 was moderately susceptible. No other disease was observed in both of these varieties during the summer season. Data on nematode sensitivity showed that SML 668 has more tolerant than SML 134. The incidence of thrip population (Table 4) depicts that SML 668 possesses more tolerance than the check in both the years (2000 and 2001).

The cooking quality parameters were studied for SML 668 and the check SML 134 which suggested that water absorption and volume expansion are higher in SML 668 than the check. Protein percentage is also high in the new variety. There were no hard grains in both varieties.

Table 1. Performance of new mungbean variety SML 668 against the check SML 134 in the state trials during summer 1999-2001

	Trial	Location	Yield (kg ha^{-1})			% increase
			SML 668	SML 134	C.D. at 5%	Over SML 134 (check)
1999	AVRDC trial	Ludhiana	2051[1]	1441	154	42.3
2000	FYT-I	Ludhiana	1433[1]	1255	170	14.2
	FYT-II	"	1314[1]	1089	122	20.7
	FYT (summer)	"	913[1]	611	55	49.4
	AVRDC trial	"	1754[1]	1396	76	25.6
	FYT-I	Faridkot	1383[1]	750	210	84.4
	FYT-II	"	1367[1]	933	197	46.5
	FYT-I	Gurdaspur	694	625	88	11.0
	FYT-II	"	729[1]	625	101	16.6
2001	FYT (spring)	Ludhiana	1144[1]	861	112	32.8
	AYT (spring)	"	1227[1]	894	149	36.7
	SST (spring)	"	1154[1]	926	187	24.6
	FYT (spring)	Gurdaspur	833[1]	500	233	66.6
	FYT (spring)	Faridkot	1204	1060	176	13.6
	Mean		1210	927	-	30.53

[1] Significantly superior.

The proposal of variety SML 668 was presented in the Research Evaluation Committee of PAU, and subsequently in the State Seed-Sub Committee, for its release in the state. Thus this variety was approved and notified for cultivation in Punjab State in 2002.

Table 2. Performance of SML 668 against the check variety SML 134 in the adaptive trials at farmer's field during summer (sown after wheat harvest) 2001

District	No.of trials	Average grain yield (kg ha^{-1})	
		SML 668	SML 134
Amritsar	1	1,450	1,300
Hoshiarpur	2	890	855
Jalandhar	4	1,047	874
Ludhiana	1	1,220	1,040
Patiala	1	1,420	1,240
Ropar	2	1,900	1,400
Fatehgarh Sahib	1	1,650	1,240
Kapurthala	2	850	380
Gurdaspur	1	700	600
Ferozepur	1	644	No podding due to heavy attack of MYMV
Faridkot	5	884	388
Bathinda and Mansa	5	973	436
Overall Mean	**26**	**1071**	**704**

% increase over the check (SML 134) = 52.1

Table 3. Disease reaction of summer varieties SML 668 and SML 134 (check)

Disease	1999		2000		2001		Overal mean	
	SML 668	SML 134	SML 668	SML 134	SML 668	SML 134	SML 668	SML 134
Mungbean Yellow Mosaic Virus (MYMV)[1]	1.00	2.00	1.49	6.93	1.30	6.00	1.26	4.98
Root Knot Nematode[2]	-	-	1.50	3.00	1.30	3.00	1.40	3.15

[1]Based on 1-9 scale, [2]Based on 1-5 scale.

Table 4. Incidence of thrips (*M. distalis*) on mungbean variety SML 668 and check variety SML 134 tested in summer season (2000 and 2001)

Variety	Average population of thrips/10 flowers[1]		Overall Mean
	2000	2001	
SML 668	9.84(3.28)	8.08(3.00)	8.83(3.12)
SML 134	16.89(4.22)	14.00(3.83)	15.24(3.99)
Infestor	21.70(4.76)	36.68(5.28)	24.53(5.05)

[1]Figures in parentheses are the transformed √n+1 values

1.2 Experiment 2
Evaluation of Promising Strains in the Advanced Varietal Trial at AVRDC, Taiwan in Summer 2002

Data on grain yield, morphological traits, plant stand, lodging score, and powdery mildew score are given in Table 5. Grain yield data depicted that VC 3890–A, VC 6153-B-20G, KPS 1, KPS 2, SML 134, NM 92, ML 613, VC 3960-88, and VC 6369-53-97 in order of merit excelled the check NM 94 by a significant margin. Days to 50% flowering ranged from 31-35. BINAmung 2 was usually late to flower. Days taken to first pod maturity varied from 47 to 51. NM 92, NM 94, and VC 6372-45-81 were the earliest in first pod maturity. There was high variation in pod number per plant (14 to 34). SML 134 and BINAmung 2 were highest pod bearing varieties. Seeds/pod ranged from 10.5 to 13.0. VC 6369-53-97 possessed maximum number of seeds per pod. The 100-seed weight (g) ranged from 3.3 to 7.0. It clearly indicated that varieties from AVRDC and Thailand were bold seeded, whereas, varieties of Indian and Bangladesh origin were small seeded. There was no significant variation in plant stand. KPS 1, KPS 2 and VC 3890-A were non-lodging. ML 613, VC 3890-A and VC 6153-B-20G were moderately resistant to powdery mildew.

Table 5. Evaluation of mungbean genotypes in the Advanced Varietal Trial conducted at AVRDC, Taiwan in summer 2002

Variety	Grain yield (kg ha^{-1})	Days to 50% flowering	Days to 1st pod maturity	Pods $plant^{-1}$	Seeds pod^{-1}	100 seed wt (g)	Plant stand	Lodging Score[1/]	Mildew score[1/]
SML134	1103	32	48	34	11.8	3.3	223	4	4.3
ML 613	959	33	51	32	12.0	4.0	241	4	2.8
NM 92	1006	31	47	21	12.3	5.2	224	4	6.5
NM 94 (ch)	725	31	47	22	12.2	5.3	215	8	6.2
VC3890A	1286	33	50	16	12.2	6.5	207	2	2.8
VC3960-88	952	32	48	20	11.7	5.7	241	4	7.0
VC 6153-B-20G	1254	32	49	14	10.5	7.0	239	3	3.3
VC6369-53-97	950	31	49	17	13.0	5.3	238	4	5.7
VC6372-45-8-1	938	31	47	21	11.7	5.2	202	3	5.7
KPS 1	1244	32	50	15	11.6	6.6	243	1	3.7
KPS 2	1175	33	50	22	12.8	5.9	214	1	5.7
BINAmung 2	683	35	50	34	11.0	3.3	212	9	4.2
C.V.%	12.62	1.38	1.13	24.70	4.89	5.68	11.59	49.03	10.28

[1/]Based on 1-9 scale.

1.3 Experiment 3
Evaluation of Breeding Strains in the Grain Yield Trials

Results on grain yield trial revealed that SML 668 (1,283 kg ha^{-1}) continued to give superior performance. However, some genotypes, namely SML 745 (1,846 kg ha^{-1}), SML 750 (1,602 kg ha^{-1}), SML 732 (1,648 kg ha^{-1}), and SML 489 (1,258 kg ha^{-1}), were also found to be promising. None of the strains flowered and matured earlier than SML 668. SML 668 also possessed the boldest seed size. Incidence of MYMV also indicated that SML 668 was the most resistant type, although some other strains were also found to be resistant to the disease (PAU, 2002a and 2003).

1.4 Experiment 4
Development of New Crosses to Generate Breeding Populations and Evaluation in Different Segregating Generations

Nearly 35 to 40 crosses were made to combine higher grain yield, early and synchronous maturity, bold seed size, and resistance to MYMV. F_1s were observed for selfing and selfed plants were rougued out. In F_2, 60 crosses were evaluated and nearly 600 single plants were selected. In F_3 to F_7 segregating generations, 1,700 progenies were evaluated and 969 superior single plants were selected. Superior, uniform progenies (132) were also bulked (PAU, 2002a and 2003).

2. Development of Varieties Suitable for *Kharif*/Rainy Season

2.1 Experiment 1
Identification of SML 668, New Variety for Cultivation in Kharif Season

Grain yield of SML 668 against the check ML 613 recorded in different years at multilocations (university farm and its research stations) is given in Table 6. A total of 15 trials were conducted. The yield data of 13 trials were considered for calculating the weighted mean. It was found that in eight trials, SML 668 produced significantly higher yield than the check variety. On the basis of weighted mean of 13 trials, SML 668 gave 16 percent higher yield over the check variety ML 613. The Research Committee and Research Evaluation Committee of PAU approved it for adaptive trials in farmer's field. Data of 39 adaptive trials are presented in Table 7. Maximum grain yield of 1,460 kg ha^{-1} was recorded in the adaptive trials and on the basis of weighted mean, SML 668 exceeded the check ML 613 by 16.8 percent.

Table 6. Performance of mungbean variety SML 668 in state trials during *Kharif*

Year	Location	Name of the trial	Grain Yield (kg ha^{-1})			% increase of SML 668 over the check ML 613
			SML668	ML 613	C.D. at 5%	SML668
1999	Ludhiana	FYT	1,185	1,037	168	14.3
2000	Ludhiana	FYT	1,288*	1,067	128	20.7
	Faridkot	FYT	1,986*	1,417	239	40.1
	Bathinda	FYT	2,157	2,139	233	0.8
2001	Ludhiana	FYT	1,578*	1,257	145	25.5
	Gurdaspur	FYT	1,419	1,521	153	-7.1
	Bathinda+	FYT	583	542	-	-
	Ludhiana	AYT-1	2,000*	1,767	175	13.2
	Bathinda	AYT-1	1,288	1,468	166	-9.6
2002	Ludhiana	FYT	2,021*	1,583	175	27.7
	Ludhiana	AYT	2,118*	1,597	206	32.6
	Ludhiana	SST	1,712*	1,296	402	32.1
	Faridkot	FYT	1,333	1,333	200	0
	Gurdaspur+	FYT	275	417	69	-
	Ludhiana	FYT(S)	1,902*	1,485	297	-
	Weighted Mean	-	1,692(13)	1,459(13)		16.0
			1,734(12)	1,494(12)		16.1

* Significantly superior than ML 613. + Data not considered for calculating means due to very low yield.

Table 7. Performance of SML 668 against the check variety ML 613 in the adaptive trials conducted in farmer's field during *Kharif* 2002

District	No. of trial	Yield kg ha^{-1}	
		SML 668	ML 613(check)
Amritsar	3	1333	1083
Gurdaspur	3	1053	1151
Kapurthala	3	900	820
Ropar	3	987	830
Patiala	4	1188	835
Faridkot	4	1268	1000
Bathinda	4	1460	1240
Sangrur	5	1253	1290
Ferozepur	3	1083	1100
Ludhiana	5	1232	940
Hoshiarpur	2	1325	832
Weighted Mean		**1200**	**1027**
% Increase over ML 613=16.8			

Data on ancillary traits given in Table 8 showed that SML 668 flowered a week earlier and matured four days earlier than the check. SML 668 is short statured (55 cm) than ML 613 (78 cm). SML 668 is bold seeded (5 g 100 $seeds^{-1}$) compared with ML 613 (3.5 g 100 $seeds^{-1}$).

MYMV incidence in both the varieties were at par indicating that both the varieties are moderately resistant (Table 9). Incidence of *Cercospora* leaf spot (CLS) disease also showed that both varieties are resistant. Similarly, reaction to bacterial leaf spot (BLS) indicated that both varieties were moderately resistant. Incidence of whitefly (*Bemisia tabaci*) recorded for three years showed that both varieties were tolerant to the insect compared with the infestor (Table 10).

Data on quality traits showed that all important parameters like cooking time, water absorption after cooking, volume expansion after cooking, and solid dispersion after cooking were very favorable for preparation of good, acceptable dishes. Bold seededness has negative correlation with protein content (Singh, 2003). Based on the superiority of SML 668 over ML 613 in all aspects, the new variety was approved by the State Variety Approval Committee (SVAC) for cultivation throughout Punjab State. It is the first variety recommended for cultivation in all seasons, i.e spring, summer and rainy/*Kharif.*

Table 8. Ancillary characters of mungbean varieties in *Kharif* season

Character	Variety	
	SML 668	ML 613
50% flowering	33	40.5
Maturity (days)	75	79
Plant height (cm)	55	78
Pods plant^{-1}	24	27
Seeds pod^{-1}	11.1	10.5
100-seed weight (g)	5.0	3.4

Table 9. Incidence of diseases in *Kharif* mungbean varieties (1-9 scale)

Name of the Disease	Variety	Year				
		1999	2000	2001	2002	Mean
Mungbean Yellow Mosaic Virus (MYMV)	SML 668 ML 613	3.0 4.0	3.0 4.0	5.2 4.4	5.1 4.5	4.1 4.2
Cercospora Leaf spot (CLS)	SML 668 ML 613	2.0 2.0	2.5 1.7	3.0 2.0	2.0 2.0	2.4 1.9
Bacterial Leaf Spot (BLS)	SML 668 ML 613	- -	3.0 2.0	4.0 3.0	2.0 2.0	3.0 2.3

Table 10. Incidence of whitefly *(Bemisia tabaci)* on *Kharif* mungbean varieties

Variety	No. of whiteflies/cage[1]					Mean
	2000 (FYT 1)	2nd yr. Ent Trial	2001 (AYT)	2001 (FYT)	2002 (FYT)	
SML 668	N.T.	N.T.	1.33(1.52)	1.33(1.52)	1.33(1.52)	1.33
ML 613(ch.)	1.00(1.38)	1.33(1.48)	0.66(1.24)	1.66(1.62)	2.66(1.91)	1.66
Infestor	6.33(2.65)	7.33(2.87)	7.00(2.81)	7.66(2.94)	6.66(2.76)	7.11
C.D. at 5%	(0.47)	(0.52)	(0.42)	(0.33)	(0.40)	-

[1] Figures in the parentheses are the transformed $\sqrt{n+1}$ values. N.T. = Not tested

2.2 Experiment 2
Evaluation of Promising Breeding lines for Identification of Superior Varieties

Data of the most promising lines evaluated during 2002 and 2003 *Kharif* season in the advanced varietal trials are presented in Table 11. Based on the average of five locations, ML 1109 exceeded the best check SML 668 by a margin of 11.0 percent. ML 1109 is of medium seed size and possesses resistance to MYMV, CLS and BLS diseases prevalent in Punjab State.In addition, 15 and 42 lines in 2002 and in 2003 were found to be promising based on their higher grain yield, resistance to diseases, and other desirable morphological characters. To further broaden the genetic base and generate breeding materials, 35-45 crosses involving diverse parents are made every year. Similarly, 35-40 F_2s are evaluated. In F_3 to F_7 segregating generations 1,000 to 1,500 progenies are also evaluated each year. Single plant selections from superior progenies are carried out on the basis of disease reaction, pod number and erect, compact and uniform ripening of plants. Nearly 40-50 superior uniform disease-free progenies in F_6 to F_7 are bulked for evaluation (PAU, 2002a and 2003).

Table 11. Performance of elite strains of *Kharif* mungbean evaluated in the advanced varietal trial conducted at multilocations during *Kharif*, 2002 and 2003

Variety	No. of loca-tion	Yield (kg ha^{-1})	% increase over check	Days to matu-rity	100-seed weight (g)	MYMV Score[1]	CLS Score[1]	BLS Score[1]
ML 1109	5	1,591	16.0	80	3.3	2.5	3.0	2.0
ML 1268	5	1,481	8.0	75	3.0	2.7	2.0	2.7
ML 1299	5	1,490	8.4	77	3.2	2.5	3.0	2.5
Pusa 9971	5	1,347	-	74	4.7	4.8	3.0	4.0
SML 668 (check)	5	1,311	-	74	4.9	4.8	3.0	5.0
ML 818 (check)	5	1,371	-	80	3.1	3.2	3.0	2.8

[1]1-9 scale

2.3 Experiment 3
Inheritance of Resistance to Mungbean Yellow Mosaic Virus in Mungbean

F_2 progenies of four crosses (ML613 x NM54, ML613 x NM92, ML1165 x NM54, and ML1165 x NM92) gave a good fit for a 3:1 ratio (resistant and susceptible plants) indicating that resistance is governed by single dominant gene. Two crosses (ML613 x VC6173-B-10 and ML1165 x VC6173-B-10) gave a good fit for a 9:7 ratio for resistant and susceptible plants suggesting that the resistance is governed by two genes with complementary gene action (Table 12). The results suggested that resistance to MYMV is governed by two complementary genes, Ym_1 and Ym_2, and the resistant parents had both genes in homozygous dominant conditions. The susceptible parents, NM54 and NM92, had at least one gene (Ym_1 or Ym_2) in homozygous recessive condition, while the parent VC6173-B-10 had both genes in homozygous recessive condition (*$ym_1ym_1ym_2ym_2$*). Previous reports suggested that resistance to MYMV is conferred by a complementary recessive gene (Shukla and Pandey, 1985); a dominant gene and complementary recessive genes (Sandhu *et al.,* 1985); and by three recessive genes (Mishra and Asthana,1996).

Table 12. Inheritance of resistance to MYMV in mungbean

Cross	F_1	Number of F_2 plants			Expected ratio	χ^2	**Probability**
		Total	R	S			
ML613 x NM54	R	224	172	52	3:1	0.595	0.30-0.50
ML613 x NM92	R	180	132	48	3:1	0.740	0.30-0.50
ML613 x VC6173-B-10	R	280	164	116	9:7	0.615	0.70-0.90
ML1165 x NM54	R	158	126	32	3:1	0.898	0.30-0.50
ML1165 x NM92	R	140	102	38	3:1	0.342	0.50-0.70
ML1165 x VC6173-B-10	R	240	144	96	9:7	1.371	0.30-0.50

R: Resistant; S: Susceptible

3. Research on Mungbean Conducted at AVRDC, Taiwan in 2002 and 2003

3.1 Experiment 1
Studies on Hardseededness in Mungbean (2002)

Sufficient variability for hard seededness was found among the genotypes, which ranged from 0-53%. Seven genotypes were free from hard seeds (CN 9-5, VC 6040-A, CO 3, Mauritius Mung, Mauritius Mung-1, Mauritius Mung-4, and Mung-4). Maximum number of hard seeds were found in MUL 56 (47%) from India; VC 3960-88 (48%) from AVRDC, and BARImung 2 (53%) from Bangladesh. The hard seeds isolated from these lines when scarified gave 100% germination suggesting that the hardseedness is due to hindrance in water absorption by the seed coat. The inheritance of hardseededness is the most viable and reliable study for the development of genotypes free from hard seeds. Hardseededness is a very complex trait greatly influenced by temperature, seasonal, and weather parameters which might interfere with the physiological development of the seed.

3.2 Experiment 2
Study of Variability for Hardseededness in Mungbean Cultivars and their Association with Seed Size (2003)

Fourteen diverse cultivars from the autumn season of 2002 and eight from the spring season of 2003 were available at the Legume Unit of AVRDC were selected for this study. In autumn 2002, VC 3890A exhibited no hardseeds and SML 134 (28.66%) recorded the highest percent of hardseeds. Similarly in spring of 2003, KPS 1 gave no hard seeds, while SML 134 and NM 92 had the maximum hardseeds (5.33%). The overall mean for hardseededness for two seasons, i.e. autumn 2002 and spring 2003, showed considerable differences. The coefficient of variation was also quite high. This suggested that hardseededness is a highly variable character and is influenced by environmental conditions. The ANOVA indicated that the genotypes differed significantly for 100-seed weight in both the seasons. But for percent hardseededness the genotypes differed significantly in autumn 2002, while the differences between genotypes were non-significant in spring 2003. Negative relationship between hardseededness and seed size suggested that bold seededness genotypes have less hard seeds than small seeded genotypes.

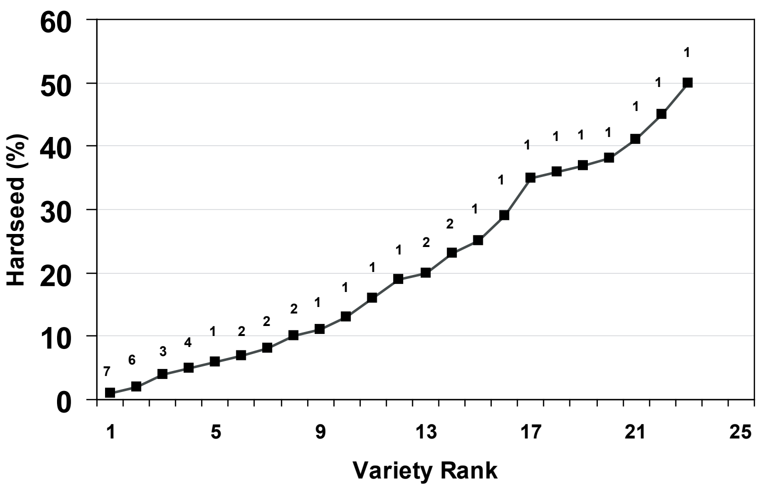

Figure 1. Variability for hard-seededness in mungbean

3.3 Experiment 3
Studies on Effect of Ageing on Hardseededness in Mungbean

In some genotypes (ML 267, VC 3960-88, BARImung 2, NM 92, KPS1, Basanti, and BINAmung 2), ageing of seeds results in reduction of hardseeds when stored in controlled conditions (temperature 18 C $\pm$ 2 and humidity 45%). But generally, reduction in percentage of hardseeds was not only caused by ageing but also of specific genotype.

In 2003, the seed weight of different cultivars in different seasons showed a wide range, suggesting that there was considerable variation for this character (Table 13). The range of percentage of hardseeds was observed to be large over the seasons as well as over the years. This indicated that hardseededness is influenced by environment. In general, the storage of seed increased the percentage of hardseeds but its effects were more pronounced in small seeded cultivars, Thus, it can be concluded that large seeded cultivars can be stored safely for a longer period compared with small seeded ones. Specifically, large seeded cultivars can be stocked. even up to five years in cold store without any adverse effect on their viability.

The correlation coefficient between the percentage of hard seeds and seed weight across all durations of ageing and seasons was found to be negative and highly significant (= - 0.683**) suggesting that there were less number of hardseeds in large seeded varieties with storage duration ranging from 33 to 64 months.

Table 13. Seed weight (g) and hardseeds (%) in mungbean cultivars in different seasons during 1998-2000

Season/year	Age in months	N. of cultivars studied	100 seed weight (g)		Hard seeds (%)	
			Mean	Range	Mean	Range
Autumn 2000	33	4	5.20	3.04-6.18	7.10	0.40-19.60
Spring 2000	40	4	5.14	2.56-6.22	8.50	0.006-28.00
Autumn 1999	46	5	4.05	2.68-6.02	3.68	0.006-12.00
Spring 1999	53	5	4.40	2.78-6.02	8.96	0.006-25.60
Summer 1998	60	8	4.07	2.50-6.20	12.98	0.006-46.66
Spring 1998	64	8	4.14	2.70-6.13	14.16	0.66-42.66
Overall			4.384	2.50-6.22	10.068	0.006-46.66

Correlation between seed weight and hardseededness= -0.683**

3.4 Experiment 4
Studies on Genetic Diversity in Selected Mungbean Cultivars Using RAPD Markers (2002)

Randomly 34 primers were used to detect RAPD markers among 21 mungbean cultivars (Figure 1). A total of 204 bands were scored with different primers of which 75% exhibited polymorphism. The primer UBC 467 was found to be the most polymorphic and it could distinguish the maximum number of cultivars. Genetic distances among 21 cultivars ranged from 0.54 to 0.85 but most were concentrated between 0.61 to 0.74. The RAPD cluster pattern showed four main clusters. Thus, considerable diversity was found in the cultivars which could be attributed to their origins. The results revealed narrow genetic base among the cultivars, which limits further improvement in yield.

3.5 Experiment 5
Studies on Genetic Diversity in Selected Mungbean Cultivars Using RAPD Markers (2003)

Fifteen randomly selected primers were used to detect RAPD markers among 32 cultivars studied. The dendrogram of these cultivars was prepared by standard procedure. Two major clusters established diversity among the cultivars. Within these major four to five sub-clusters were noted and cultivars in each sub-cluster were much close to each other. Most of the entries from India were in second major cluster. The first major cluster included cultivars of AVRDC, Pakistan, Bangladesh, India and Mauritius.

Conclusion

Research activities on mungbean breeding carried out in this project resulted in the significant achievement of the identification and release of the variety SML 668 which is the first early-maturing and high-yielding variety found most suitable for cultivation in the present rice-wheat system of Indo-Gangetic plains. In two years, the use of SML 668 has resulted in substantial increase in area and production and farmers are very much satisfied with its performance. Studies carried out for varietal improvement also suggested that there is plenty of opportunities to develop better varieties through consistent efforts. In the future, extra efforts on MYMV resistance studies are needed, since resistance is not very stable in present day cultivars. Studies on hardseededness also need much more attention than what is presently given because hardseededness adversely affects consumer

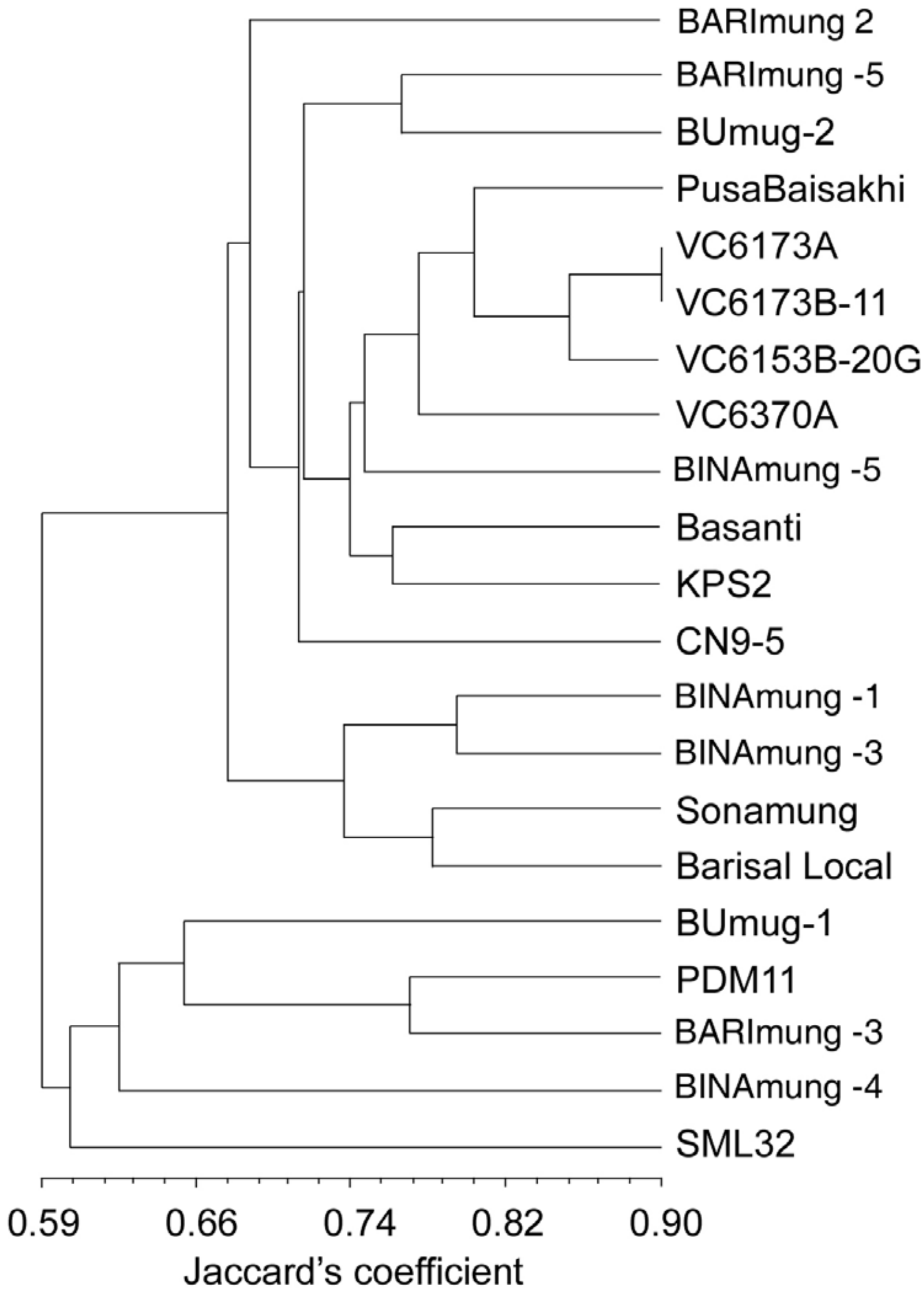

Figure 1. Dendrogram of 21 mungbean cultivars using cluster analysis of Jaccard's similarity coefficients calculated from 34 primers

preference. No inheritance work has been done so far for this very complicated trait. Biotechnological approaches need to be strengthened to identify markers for different traits of interest. The preliminary studies done through RAPD markers suggest that there is a narrow genetic base in the cultivars studied.

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Agronomic management of mungbean grown under different environments

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Abstract

Field experiments were conducted in 2002 and 2003 on the agronomic management of extra-short duration mungbean (*Vigna radiata* (L.) Wilczek) at the Punjab Agricultural University in Ludhiana (India) and Asian Vegetable Research and Development Center (AVRDC) in Taiwan. In Punjab, the best time for sowing summer mungbean was from March 20 to April 10. The April 20 sowing was at par with sowings in March 30 and April 10 but was inferior to March 20 sowing. Grain yield data indicated that new variety SML 668, which takes about 60 days to mature, can be successfully grown up to April 20 after the harvest of wheat. Mungbean sown after wheat without tillage gave grain yield equivalent to tillage treatment. Also at AVRDC, mungbean sown after rice without tillage gave grain yield that is almost similar to tilled plots. Interestingly, SML 668 can also be grown in rainy (*Kharif*) season. In 2002, July 8 and 16 sowings were significantly superior to July 24 and August 10 sowings, while in 2003, July 10 and 25 sowings gave significantly higher yield than August 10 sowing. In Ludhiana, 400,000 plants ha^{-1} sown at 25 cm x 10 cm spacing gave higher grain yield than 333,000 and 500,000 plants ha^{-1} during summer season. Varieties Pusa Vishal, SML 668, and Pusa 9531 were at par in yield. The optimum seed rate for higher productivity was 37.5 kg ha^{-1} for summer crop and 30 kg ha^{-1} for rainy season crop sown at 30 cm x 10 cm spacing. At AVRDC, 200,000 plants ha^{-1} sown at 50 cm x 10 cm on raised beds gave significantly higher yield than 300,000, 400,000 and 500,000 plants ha^{-1}. At Ludhiana and AVRDC, seed priming did not show beneficial effect on the grain yield. For better germination, 4-6 cm seeding depth was adequate while 2 and 8 cm depths reduced the plant stand and yield on loamy sand soil of Ludhiana. A dose of 12.5 kg N and 40 kg P_2O_5 ha^{-1} drilled at sowing in summer mungbean sown after wheat increased the grain yield significantly over control (no fertilizer). At Ludhiana on loamy sand soil, four irrigations (25, 32, 41 and 49 days after sowing [DAS]) produced the highest grain yield in summer season. Though the termination of last irrigation at 47 DAS showed synchronous crop maturity, continuous supply of irrigation up to 75 days gave 41.6% more yield than the crop with terminated

irrigation at 47 DAS. During rainy season, missing irrigation at the pod formation stage in the absence of rainfall showed drastic reduction in yield compared with the irrigated crop. The application of pendimethalin (Stomp 30 EC) at 0.75 kg a.i. ha $^{-1}$ as pre-emergence or fluchloralin (Basalin 48 EC) at 0.625 kg a.i. ha^{-1} as pre-sowing gave effective control of weeds. Grain yield was equivalent to 2 hoeings (25 and 40 DAS). Experimental data revealed that with proper use of inputs like weed control, fertilizer application, and insect pest control, the grain yield of mungbean can be enhanced three times over the non-use of these inputs.

Introduction

Agronomic management practices help greatly in managing the soil and crops efficiently in a particular environment. Management inputs not only increase crop yields but also enhance the income of farm and ensure efficient use of farm resources, resulting in short-term as well as long-term gains. To exploit the high yield potential of improved varieties appropriate management technology is required.

Among the agronomic factors the optimum time of sowing is the most important non-monetary input to realize the yield potential of an improved variety. It ensures complete harmony between the vegetative and reproductive phases on the one hand, and the climatic rhythm on the other hand (Dhingra and Sekhon, 1988). The effect of time of sowing under field conditions is indeed a reflection of the response to photo-thermo period which has a profound influence on crop productivity.

The optimum plant population density is also a pre-requisite for obtaining higher productivity. It varies with growth rhythm of genotype, time of sowing, growing condition, and cropping system. The optimum plant population can be maintained by using adequate seed rate in a proper planting geometry. Regan *et al.* (2003) reported that the economic plant density helps in estimating the most profitable seed rate.

A good seedbed preparation with sufficient tillage helps in achieving optimum germination, proper seedling establishment, and an adequate plant population. Deep tillage, particularly under rainfed conditions, is advantageous in conserving soil moisture and eradicating weeds. The no-tillage rice stubble cultivation was popular in Taiwan before 1970 (Shanmugasundaram, 2002) and is becoming popular in Punjab for the sowing of wheat (Kaul and Singh, 2002). No-tillage sowing saves time, money, and energy.

Harris *et al*. (1999) showed the beneficial effect of on-farm seed priming (a technique in which seed is soaked in water for a given time prior to sowing) on a number of crops particularly under rainfed conditions. Similarly, depth of sowing also influences emergence, plant stand, and establishment of crop especially under rainfed conditions (Ahlawat and Rana, 2002). Other cultural practices like the application of fertilizer, weed control, and irrigation schedule are also equally important. Agronomic studies on summer mungbean are scarce particularly when sown after the harvest of wheat. In the present DFID-AVRDC project on "Improving income and nutrition by incorporating mungbean in cereal-fallows in the Indo-Gangetic Plains of South Asia" the experiments on the aforesaid areas were undertaken at the Punjab Agricultural University (PAU) in Ludhiana (India), at the Regional Stations of PAU, namely Gurdaspur and Bathinda, and at AVRDC, Taiwan with the following objectives:

1. To assess the effect of time of sowing on the growth and yield of newly-developed extra-short duration variety of mungbean SML 668;
2. To evaluate the performance of diverse mungbean genotypes under different plant densities;
3. To study the effect of no-tillage and crop residue management of summer mungbean sown after wheat;
4. To work out the influence of seed priming and seeding depth on emergence and establishment of mungbean;
5. To find out nutritional requirement of summer mungbean sown after wheat;
6. To work out the effect of irrigation schedule and termination of last irrigation on the growth and yield of mungbean;
7. To study the effect of mechanical and chemical weed control on the productivity of mungbean; and
8. To evaluate the contribution of various inputs on the productivity of mungbean.

Materials and Methods

Locations and Soil

Field experiments were conducted at the Punjab Agricultural University, Ludhiana (30°56' N, 75°52' E, altitude 247 m) India, to work out the appropriate agronomic management of extra-short duration genotypes of mungbean. The experimental site was loamy sand (coarse-textured) with pH 8.2, low in organic carbon (0.29 to 0.33%). It has 86-160 kg N ha^{-1} available N and 14.5 – 19.7 kg P ha^{-1} available

P. At AVRDC in Taiwan, the soil was sandy loam (65% sand, 20% silt, and 15% clay) with 0.85% organic carbon, 0.9-0.11% available N, 62 ppm P, and 57 ppm K. The pH was around 7.8.

Season and Climate

The average annual rainfall of Ludhiana is about 780 mm and 75% of it occurs in monsoon season (July to September). The maximum temperature ranged between 28.6 and 47.2 C and minimum 12.7 and 29.5 C during the two years of study. The relative humidity (RH) during summer season varied between 38 and 69%; and during rainy season, between 66 and 82%. The total rainfall during summer was 123.5 and 93.2 mm, and in rainy season 256.5 and 530.5 mm in two years respectively. At AVRDC in Taiwan, the average annual rainfall is about 1600 mm and most of it occurs from May to August. The maximum temperature during the crop season remained 31.9 to 33.5 C and minimum of 16.1 to 26.7 C in years 2002 and 2003. Correspondingly, RH was 78-88% in 2002 and 68-77% in 2003. The total rainfall in the crop season was 721.5 mm in 2002 and 315.0 mm in 2003.

Method of Sowing, Fertilizer Application, and Weeding

In Ludhiana, summer mungbean sowing was done on flat bed at 22.5 cm row spacing with plant-to-plant distance of about 10 cm, while at AVRDC, sowing was done on raised beds having 2 rows 50 cm apart and plant-to-plant distance of 10 cm. In both ocations, sowing was done under irrigated conditions. A basal dose of 15 kg N and 40 kg P_2O_5 ha^{-1} was applied and weeding was done mechanically, as well as chemically, using pendimethalin 30 EC as pre-emergence.

Experiments

Expt. 1
Time of Sowing x Genotypes

In Ludhiana in 2003, the experiment comprising 18 dates of sowing (March 10, 20, 30; April 10, 20, 30; May 10, 20, 30; June 10, 20, 30; July 10, 20, 30 and August 10, 20, 30) was designed in a randomized complete block design with three replications. Variety SML 668 was sown. In 2002, another experiment with four dates of sowing (July 8, 16, 24 and 1 August) and six genotypes (NM 92, ML 613, ML 818, SML 668, Pusa 9971 and Asha) was laid out in a split plot design with three replications during rainy season. However, in 2003, the dates of sowing were July 10, 25 and August 10, and the same six genotypes were tested. The dates of sowing were kept as the main-plots and the genotypes were sub-plots.

Expt. 2(a)
Plant Densities x Genotypes

In Ludhiana, during summer 2002, experiment consisting of four genotypes (Pusa Vishal, SML 668, Pusa 9531, and UPM 98-1) and three plant densities (500,000, 400,000, and 333,000 plants ha^{-1} sown at 20 cm x 10 cm, 25 cm x 10 cm, and 30 cm x 10 cm, respectively) was laid out in a split plot design with three replications. Genotypes were in the main-plots and plant densities were sub-plots. In 2003, genotype MH 96-1 was sown instead of UPM 98-1. The sowing was done on March 26, 2002 and March 28, 2003.

At AVRDC, in 2002 and 2003, the experiment comprising four genotypes of mungbean (NM 92, NM 94, SML 134, and VC 3890A) and four plant densities (200,000; 300,000; 400,000; and 500,000 plants/ha sown at 50 cm x 10 cm, 50 cm x 6 cm, 50 cm x 5 cm, and 50 cm x 4 cm, respectively) was arranged in a split plot design with genotype as main-plot factor and planting density as sub-plot factor. Each treatment was replicated thrice. The sowing was done on July 17 in both years.

Expt. 2(b)
Seed Rate Studies

Field experiments were conducted to study the optimum seed rate during summer as well as *Kharif* season. Five seed rates (25, 30, 35, 37.5 and 40 kg ha^{-1}) were tried in summer and six (20, 25, 30, 35, 37.5 and 40 kg ha^{-1}) in *Kharif* using SML 668 variety in a randomized complete block design with three replications. During summer of 2002 and 2003, sowing was done on March 26 and April 19 and during *Kharif* on July 10.

Expt. 3
No-tillage, Tillage, and Crop Residues Management in Summer Mungbean Sown After Wheat

In Ludhiana, an experiment comprising six treatment combinations, viz. no-tillage, tillage, and wheat straw incorporation as the main-plots and urea 2% spray (sprayed and unsprayed) as the sub-plots were arranged in a split plot design with four replications. In tillage and straw incorporation treatments, the field was prepared by running disc harrows twice followed by cultivator and planking two times. In no-tillage treatment, seed was sown directly by using single row cotton drill. Variety SML 668 was sown on April 23, 2002 and April 30, 2003. The spray of urea was done twice, i.e. first during flower initiation and second a week thereafter.

In 2002, the crop was harvested on June 24. However, though crop growth was very good in 2003, continuous rains at the time of maturity badly affected grain quality. In on-farm trials, tillage, and no-tillage sowing of mungbean were compared in Ludhiana and Hoshiarpur districts.

At AVRDC, a trial consisting of six treatment combinations of two genotypes (NM 92 and NM 94) and three tillage treatments (no-tillage, tillage, and tillage + mulch application of rice straw at 4 t/ha) was sown on August 2, 2002 and July 21, 2003. Treatments were replicated thrice in a split plot design. Tillage plots were prepared by running rotovators twice.

Expt. 4
Seed Depth Studies

The combinations of four genotypes (SML 668, Pusa Vishal, Pusa 9531, and MH 96-1) and four seeding depths (2, 4, 6 and 8 cm) were tested in a split plot design with genotypes in the main-plots and seeding depths in the sub-plots. The treatments were replicated thrice. Sowing was done on April 11, 2003.

Expt. 5
Seed Priming Studies

At Ludhiana, a trial was laid out on variety SML 668 with seven seed soaking periods (0, ½, 1, 2, 4, 6 and 8 h). The sowing was done on March 27, 2002. Treatments were arranged in a randomized complete block design in three replications. At AVRDC, experiment was conducted in the green house with three genotypes (NM 92, NM 94 and SML 134).

Expt. 6(a)
Irrigation x Fertilizer Studies

A study was conducted in 2002 and 2003 after the harvest of wheat with all the combinations of four irrigation levels, i.e. two irrigations (20 and 40 DAS), three irrigations (20, 30 and 40 DAS), four irrigations (15, 25, 35 and 45 DAS), and five irrigations (15, 23, 31, 39 and 47 days after sowing) and three fertilizer levels (control [no fertilizer], recommended dose of 12.5 kg N ha^{-1} + 40 kg P_2O_5 ha^{-1}, and recommended dose of N + 50% higher P_2O_5). The treatment combinations were placed in a split plot design with irrigation levels in the main-plots and fertilizer levels in the sub-plots using 3 replications. The soil of the experiment was loamy sand with organic carbon 0.32%, available N at 106 kg ha^{-1}, P at 16.8 kg ha^{-1}, and K,at 292 kg ha^{-1}. The sowing was done on April 24 and 30 in the two years.

Expt. 6(b)
Irrigation x Straw Mulch Studies

In 2002, three irrigation levels (2 irrigations – 25 and 40 DAS; 3 irrigations – 20, 40 and 50 DAS and 4 irrigations – 25, 32, 41 and 49 DAS) and two mulch treatments (wheat straw mulch at 4 t ha^{-1} 23 DAS and no mulch) were compared in a split plot design. Irrigation levels were kept in the main-plots and straw mulch treatments in the sub-plots with three replications. Variety SML 668 was sown on March 27, 2002 and March 28, 2003. In 2003, one additional treatment of straw mulch applied at sowing was also tried.

Expt. 6(c)
Studies on Termination of Irrigation

In an experiment on SML 668 in 2003, seven treatments were tried in which irrigation was terminated at 42, 49, 56, 63, 70, 77, and 84 DAS. The treatments were designed in a randomized complete block design in three replications. Experiments were also laid out at the Regional Research Stations at Gurdaspur and Bathinda. The soil of Ludhiana was loamy sand while that of Bathinda and Gurdaspur was sandy loam.

Expt. 7
Studies on Weed Control

Weed control consisting of mechanical (two hoeings) application of pendimethalin 0.75 a.i. ha^{-1} and fluchloralin 0.625 kg a.i. ha^{-1} were compared with weeding check (no control). A randomized complete block design was used with three replications. Variety SML 668 was sown on April 14, 2002 and April 1, 2003. Pendimethalin was applied as pre-emergence and fluchloralin as pre-sowing.

Expt. 8
Contribution of Various Inputs

In 2003, the effects of individual inputs of fertilizer alone, weed control alone and plant protection alone and their combined effects of all the three inputs were studied on summer mungbean variety SML 668. A RCBD with three replications was used and the trial was sown on 2 April 2003.

Results and Discussion

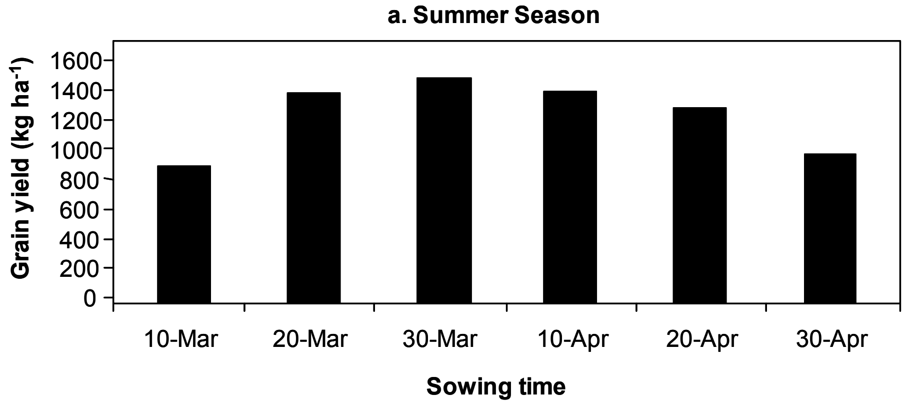
Expt. 1
Time of Sowing x Genotypes

The optimum time of sowing is very important to realize the yield potential of an improved variety since production efficiency of a variety is influenced by photothermal variations which influence the crop growth, flowering, and economic yield (Sinha, 1977).

In 2003, SML 668, an extra-short duration variety, recorded a maximum grain yield (1517 kg ha^{-1}) when sown on March 30 (Figure.1). However, there were no differences in the grain yield under March 20 and 30 and April 10 sowings. After potatoes or toria, summer mungbean can be raised successfully between March 20 to April 10. The April 20 sowing was at par with March 30 and April 10 sowings but was inferior to March 30 sowing. This indicates that SML 668 can be successfully grown after wheat up to April 20. The April 20-sown crop matures around June 20. The monsoon rains in Punjab usually start in the end of June or beginning of July. In another experiment, April 20 sowing produced grain yield of 1432 kg ha^{-1} in 2002 and 1472 kg ha^{-1} in 2003, respectively. The growth of SML 668 improved with delay in sowing after March 10. Nodulation varied significantly under different dates of sowing. The crop sown in March produced small, more number of nodules but these were lacking in leghemoglobin. On the other hand, April-sown crop produced less number of nodules which were of large size and pinkish color due to leghemoglobin. May and June sowing crop again had small nodules while remarkable nodulation was observed in July sowing.

Earlier studies conducted on summer season mungbean in Punjab showed that March 20 to April 10 sowings produce higher yields than early, as well as late, sowings; and crop matures well before the onset of monsoon rains (Dhingra and Sekhon, 1988; Jaiswal, 1995; Ram and Dixit, 2000 and Dhanjal *et al.*, 2000). Early-sown crop shows poor germination and depressed growth due to prevailing low temperature. On the other hand, under late sown conditions, the risk of crop failure increases because of rains. Under Hissar (India) conditions, March 15-30 was the optimum time to raise successful summer mungbean (Faroda *et al.*, 1983).

Interestingly, SML 668 can also be grown during rainy season. In 2002, July 8 and 16 sowings gave significantly higher grain yield than July 24 and August 1 sowings. However, in 2003 in one experiment, July 10, 20, and 30 sowings produced higher yield than August sowings. Another experiment in July 10 and 25 sowings gave more yield than August 10 sowing (Figure 1).



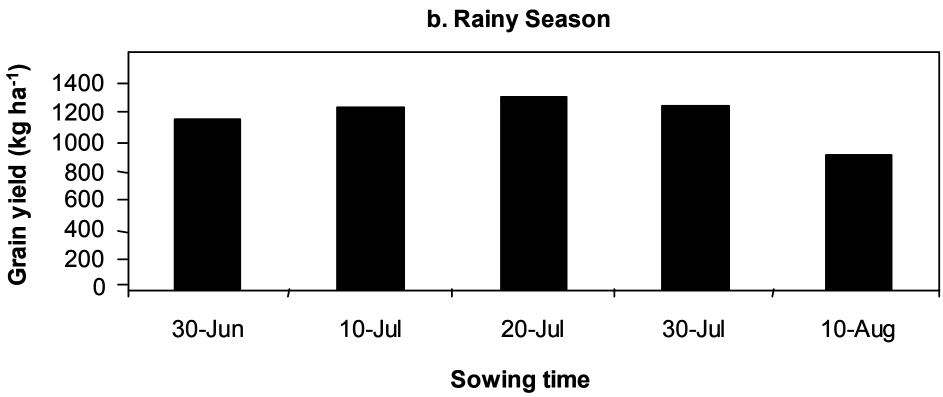


Figure 1. Effect of time of sowing on grain yield in mungbean SML 668 during (a) summer and (b) rainy season

The variation in yield under different dates of sowing was possibly due to the occurrence of variable rainfall during crop growth. In 2002, rainfall was 256.5 mm while in 2003, it was 530.5 mm during the crop growth.

In 2002, genotypes NM 92, ML 613, ML 818, and Asha were inferior to Pusa 9971 and SML 668. Genotype Asha was the tallest and it produced the highest biological yield but the lowest grain yield than all the other genotypes. Genotypes NM 92, SML 668, and Pusa 9971 were earlier in flowering (50% between 33 and 35 DAS) as well as in maturity (57-64 DAS) than the other genotypes (66-81 DAS) under different dates of sowing. In another experiment in 2003, Pusa 9971 was superior to other genotypes in yield.

Expt. 2(a)
Population Density x Genotypes

Effect of plant density

Optimum plant density varies with genotype, agronomic inputs, and agro-climatic conditions (Sinha, 1977; Dhingra and Sekhon, 1988). The optimum plant density can be maintained by using adequate seed rate in a proper planting geometry (Regan *et al.,* 2003).

In summer season, higher plant density is required, as plant height remains short due to high temperature and low humidity. Recent studies conducted at Ludhiana showed that 400,000 plants ha^{-1} (40 plants m^{-2}) at 25 cm x 10 cm spacing gave higher yield in both the years than 300,000 plants ha^{-1} (Table 1). There was no difference between 400,000 and 500,000 plants in the case of grain yield.

Table 1. Influence of plant density on growth and yield of mungbean at Ludhiana (India) and AVRDC (Taiwan)

Ludhiana							Taiwan				
Plant density (000 ha^{-1})	Grain yield (kg ha^{-1})			Plant height (cm)			Plant density (000 ha^{-1})	Grain yield (kg ha^{-1})			Plant ht.(cm)
	2002	2003	Mean	2002	2003	Mean		2002	2003	Mean	2003
							200	1,378	1,857	1,617	85.6
333	2,114	1,758	1,936	46.1	47.9	46.0	300	1,348	1,860	1,604	88.0
400	2,305	1,849	2,077	44.9	46.6	45.7	400	1,226	1,925	1,575	89.9
500	2,339	1,864	2,101	45.1	47.9	46.5	500	1,163	1,785	1,474	87.2
C.D.5%	178	102		NS	NS		C.D.5%	153	NS		NS
Genotype							Genotype				
Pusa Vishal	2,366	2,007	2,186	49.7	47.1	48.4	NM 94	746	1,837	1,291	76.1
Pusa 9531	2,376	2,006	2,191	50.7	47.7	47.2	NM 92	1,417	2,037	1,727	84.8
UPM 98-1	1,844	1,151*	-	37.3	58.2	47.7	VC 3890A	1,709	2,059	1,884	91.7
SML 668	2,424	2,069	2,296	41.5	36.2	38.8	SML 134	1,242	1,494	1,368	98.1
C.D. 5%	390	160		5.2	4.36		C.D. 5%	153	175		3.78

*Genotype MH 96-1, NS not significant at 5% level.

To maintain 40 plants m^{2}, 37.5 kg ha^{-1} seed rate is required for bold-seeded variety SML 668 (about 6 g 100^{-1} seeds) (Figure 2). Earlier studies conducted at the Punjab Agricultural University in Ludhiana on summer mungbean revealed that 22.5 cm x 10 cm spacings with 44 plants m^{-2} were optimum on loamy sand soil to attain higher yields (Dhingra *et al*., 1988). To maintain 44 plants m^{-2}, 25 kg ha^{-1} seed rate was recommended for medium seed size (about 4 g 100^{-1} seeds) varieties (Sekhon *et al.,* 1993).

Interestingly at AVRDC in Taiwan, plant density of 200,000 plants ha^{-1} (50 cm x 10 cm) seemed to be the optimum for achieving higher yields of mungbean (Table 1). At AVRDC, crop attains a plant height of around 88 cm, which is almost double than at Ludhiana. Due to more plant height, lodging of the crop occurs in Taiwan. The lodging was 2.5 and 2.8 (according to lodging scale 1-9) in the case of 400,000 and 500,000 plants ha^{-1}, respectively while in the case of 200,000. plants the lodging score was 1.6. Number of pods plant^{-1} decreased with lodging. The grain yield is governed by number of pods plant^{-1} (Hamid, 1996).

Performance of Genotypes

At Ludhiana in 2002, UPM 98-1 gave the lowest yield (1844 kg ha^{-1}) while the yield levels were 2366 kg ha^{-1} for Pusa Vishal, 2376 kg ha^{-1} for Pusa 9531 and 2424 kg ha^{-1} for SML 668 (Table 1). Almost similar results were observed in 2003. At AVRDC in 2002, genotype VC 3890A was superior to other genotypes. However, in 2003, VC 3890A and NM 92 were comparable (Table 1).

Expt. 2(b)
Seed Rate Studies

In 2002, a seed rate of 37.5 kg ha^{-1} was significantly better than 25 kg ha^{-1} during summer (Figure 2). The grain yield continued to increase up to 40 kg ha^{-1} seed rate. However, the differences between 35, 37.5 and 40 kg ha^{-1} seed rates were non-significant. In 2003 also, 37.5 kg ha^{-1} seed rate gave higher yields. In *Kharif* 2003, 30 kg seed rate ha^{-1} was significantly better than 20 and 25 kg ha^{-1}. A slight decline in yield was recorded with 35, 37.5, and 40 kg ha^{-1} seed rate.

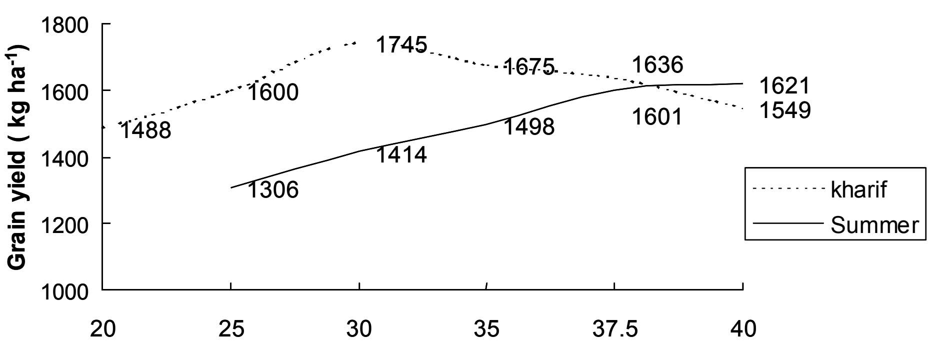


Figure 2. Grain yield of summer and *Kharif* season mungbean as influenced by seed rate at Ludhiana

Expt. 3
Tillage and Crop Residue Management

Tillage is done to physically manipulate the soil to achieve weed control; to create aeration, porosity, and friability; and obtain optimum soil moisture to facilitate subsequent sowing. However, in the age of energy crisis, no-tillage or direct seeding of seeds into soil is becoming popular (Baker *et al.,* 1996). Gautam (2000) reported that energy output and energy input ratio is higher in no-tillage compared with conventional tillage.

In 2002, mungbean variety SML 668 sown after wheat gave 1835 kg ha^{-1} yield in no-tillage and 1756 kg ha^{-1} grain yield in tillage treatment (Table 2). The grain yield in tillage + straw incorporation was 1,707 kg ha^{-1}, which was significantly inferior to no-tillage. In the case of no-tillage plots the emergence was earlier by one day than the tillage treatment. The early emergence of even one day is highly beneficial in this short duration crop. Tillage and no-tillage treatments showed better nodulation than tillage + crop residue treatment. In 2003, crop growth was very good but due to continuous rains for two days at the time of maturity, grain quality was badly affected. The sowing was late, i.e. April 30 in the second year. However at farmers' fields, no-tillage treatment produced almost similar yields as the tillage one.

At AVRDC in Taiwan no-tillage and tillage treatments gave similar yields of mungbean sown after rice (Table 2). Lodging and powdery mildew score was also less in no-tillage plots compared with tillage plots. Application of straw mulch or straw incorporation did not show any difference in the grain yield. Both the genotypes (NM 92 and NM 94) were on par in yield.

Table 2. Effect of no-tillage, tillage, and crop residues on the grain yield of mungbean sown after wheat at Ludhiana and after rice at AVRDC

<table>
<tr><th rowspan="4">Treatment</th><th colspan="6">Grain yield (kg ha^{-1})</th></tr>
<tr><th>Ludhiana</th><th colspan="3">On-farm trials</th><th colspan="2">AVRDC</th></tr>
<tr><th rowspan="2">2002</th><th colspan="3">2003[1]</th><th rowspan="2">2002</th><th rowspan="2">2003</th></tr>
<tr><th>I</th><th>II</th><th>II</th></tr>
<tr><td>No tillage</td><td>1,835</td><td>1,230</td><td>1,340</td><td>1,175</td><td>1,464</td><td>2,567</td></tr>
<tr><td>Tillage</td><td>1,756</td><td>1,250</td><td>1,300</td><td>1,200</td><td>1,410</td><td>2,487</td></tr>
<tr><td>Tillage + Straw incorporation</td><td>1,707</td><td>-</td><td>-</td><td>-</td><td>-</td><td>2,452</td></tr>
<tr><td>Straw mulch</td><td>-</td><td>-</td><td>-</td><td>-</td><td>1,444</td><td>2,466</td></tr>
<tr><td>C.D. 5%</td><td>115</td><td>-</td><td>-</td><td>-</td><td>NS</td><td>NS</td></tr>
</table>

[1]On-farm trials

Expt. 4
Depth of Sowing

Depth of sowing influences the emergence and establishment of crop especially under rainfed conditions. Various factors influencing seeding depth include soil texture, date of sowing, soil moisture in the seeding zone, climatic conditions, and seed size. Ahlawat and Rana (2002) reported that on heavier soils and in moist conditions, sowing depths at five cm are more beneficial. For smaller-seeded pulses, sowing depths of 2.5-4.0 cm are adequate under moist conditions. Studies conducted in 2003 on loamy sand soil at the Punjab Agricultural University in Ludhiana revealed that germination percentage was higher in the case of four and six cm depths than the shallow and deep sowings (Figure 3). With 8 cm sowing depth the emergence of seedlings was late by one day than four and six cm depths. The grain yield was significantly higher in four and six cm depths than two cm depth (Figure 3).

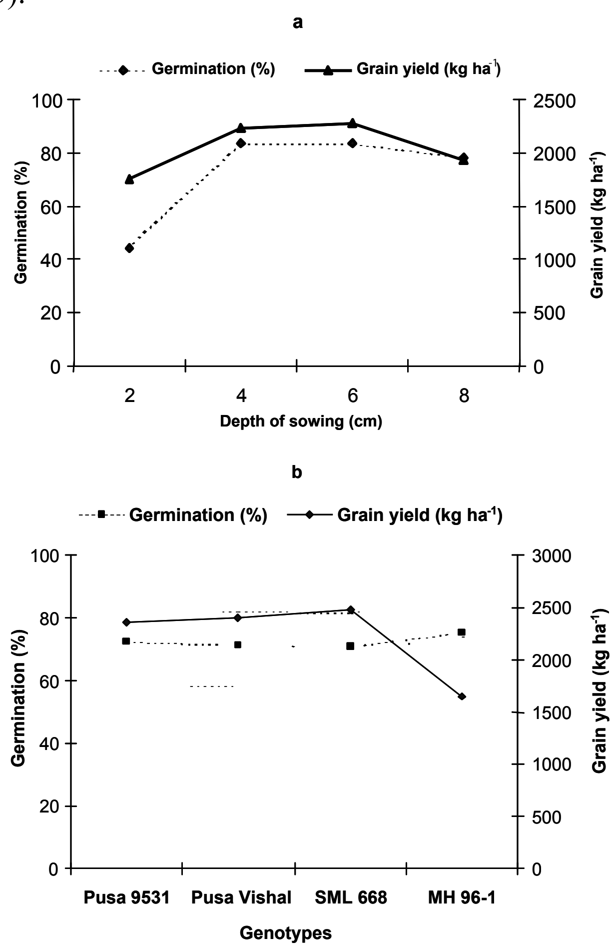


Figure 3. Effect of (a) depth of sowing and (b) genotypes on germination and grain yield of mungbean in summer 2003

Expt. 5
Seed Priming

Harris (1996) reported a low-cost simple technique termed ‘on-farm seed priming’. Studies conducted on mungbean at Ludhiana and AVRDC under irrigated conditions did not show significant effect of seed priming on mungbean yield. Data indicated that emergence was earlier by one day where the seed soaking was done for four hours. The seed priming seemed to be more beneficial in improving the rate of emergence of large-seeded variety SML 668 than the medium-seeded variety SML 134.

Expt. 6(a)
Irrigation x Fertilizer Studies

Summer mungbean cultivation is possible where irrigation facilities are available while *Kharif* season crop is primarily cultivated as a rainfed crop. Mungbean suffers considerably due to water stress compared with irrigated crop (Chokhey Singh and Yadav, 1978; Sadasivam *et al.*, 1988; PAU, 2001). Pandey *et al.* (1984) reported that mungbean is more susceptible to water stress than soybean and cowpea. Water stress at the reproductive stage is more deleterious in mungbean as it causes more flower drop and poor pod setting.

In summer, mungbean sown after wheat with four irrigations gave significantly higher grain yield than two and three irrigations. There was no difference between the grain yield of four and five irrigations (Figure 4). Previous studies showed that in summer season on sandy loam soils, mungbean responded favorably to two irrigations in Delhi and Kanpur and to three irrigations in Hissar and Sri-Ganganagar (Agarwal *et al.*, 1997). In Hissar and Delhi, summer mungbean could be irrigated either at IW/CPE of 0.4 or at 300 mm CPE for higher yields. At Ludhiana on loamy sand soil, four to six irrigations were needed (Sekhon *et al.*, 1990). The first irrigation applied 25 DAS produced higher grain yield than that which received irrigation at 20 or 30 DAS.

The grain yield of mungbean increased significantly with 12.5 kg N and 40 kg P_2O_5 ha^{-1} than no application (Figure 4). There was no further increase in yield with 12.5 kg N and 60 kg P_2O_5 ha^{-1}. Interaction between irrigation and fertilizer levels was non-significant. Singh *et al.* (2004) reported 46.1 kg P_2O_5 ha^{-1} as economic optimum dose for summer mungbean.

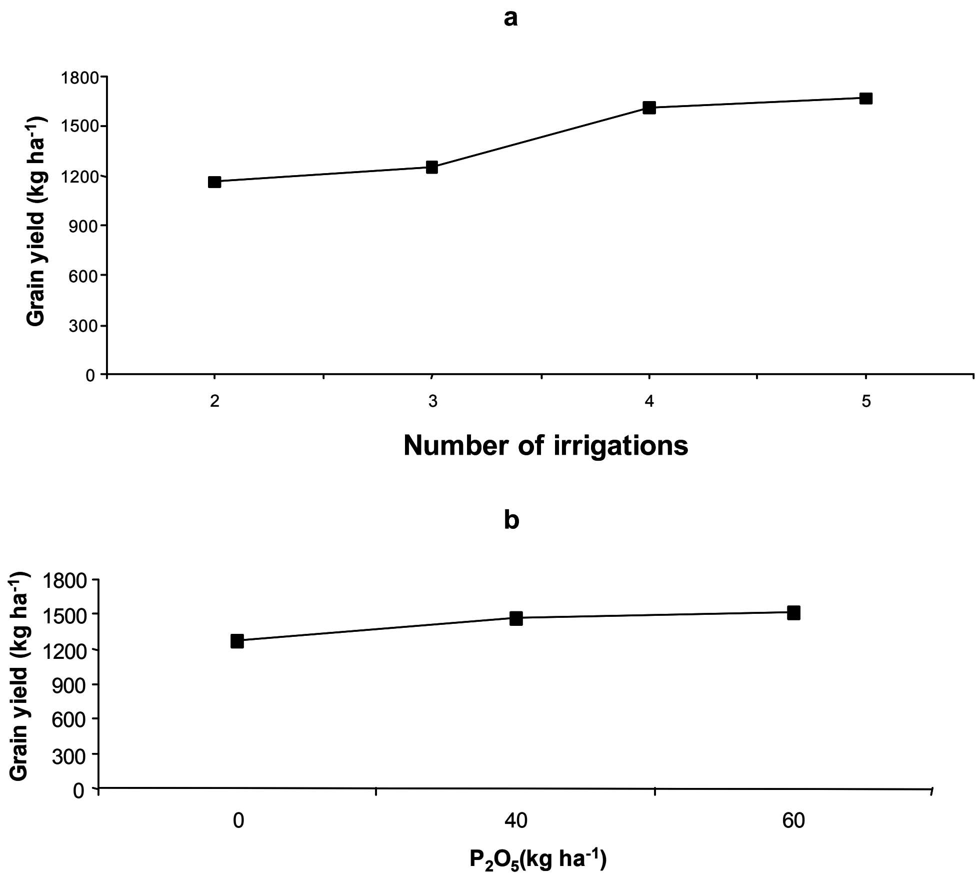


Figure 4. Effect of (a) irrigation (b) phosphorus on summer mungbean sown after wheat

Expt.6(b)
Irrigation x Mulch Studies

Experiments in 2002 and 2003 showed significant increase in yield with irrigation. The highest grain yield was recorded with four irrigations applied at 25, 32, 41, and 49 DAS (Figure 5). The application of straw mulch at 4 t ha^{-1} improved the grain yield significantly. Mulch applied 25 DAS showed better results than that applied at sowing. In the case of 25 DAS mulch application, the root system was more developed than the mulch application at sowing. Interaction between irrigation and mulch was non-significant.

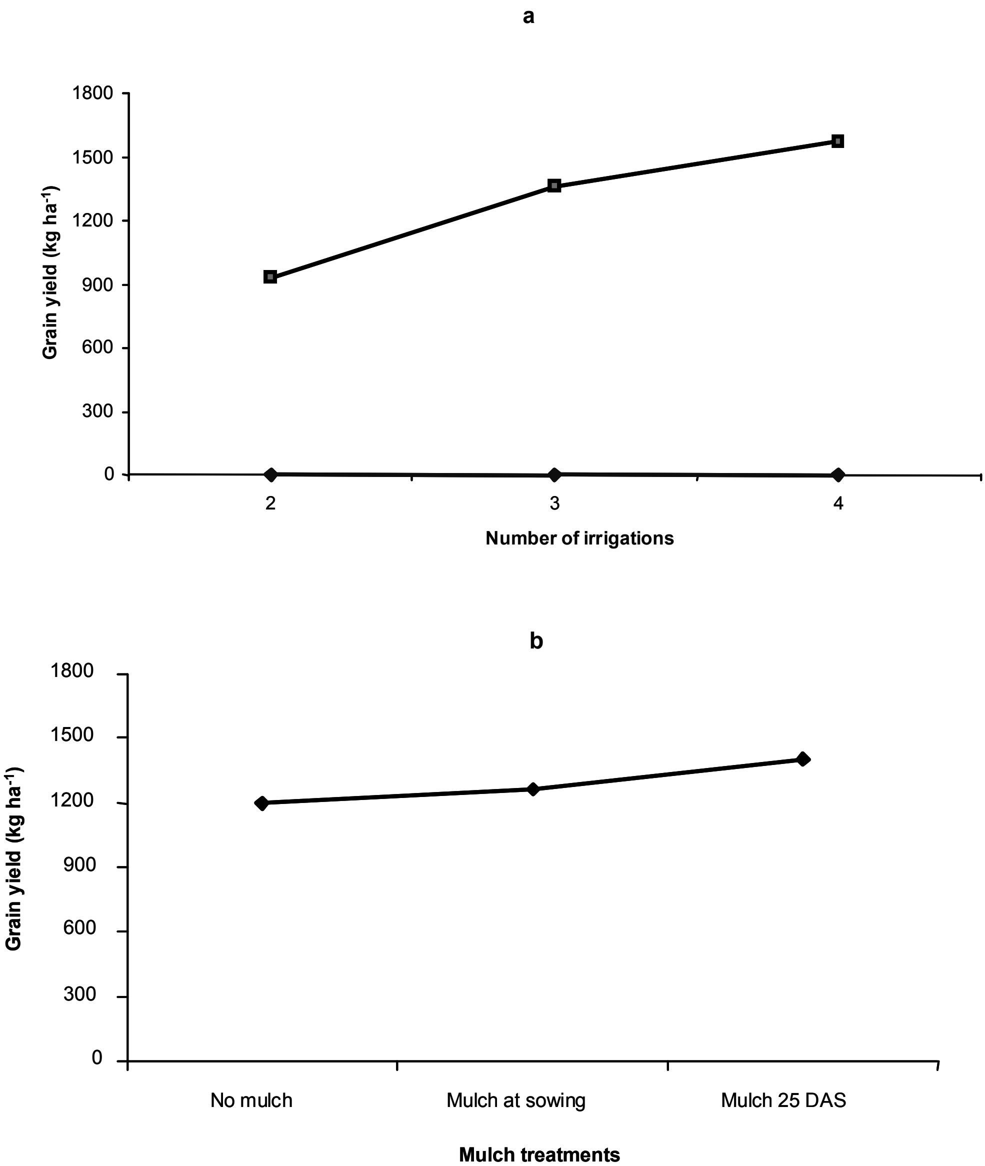


Figure 5. Effect of (a) irrigation and (b) mulch application on grain yield of summer mungbean at Ludhiana

Expt. 6(c)
Termination of Irrigation

SML 668 matured synchronously with the termination of irrigation at 47 DAS. Sekhon *et al.* (1990) reported synchronous crop maturity of summer mungbean in variety SML 134 with the termination of irrigation at 55 DAS. However, significant increase in yield was recorded with continuous irrigation to summer mungbean (Table 5). In Ludhiana, grain yield was significantly more where irrigation was terminated 75 DAS. Though yield increased up to 82 DAS termination, the differences were non-significant between 75 and 82 DAS termination of irrigation. Similar results were obtained at Bathinda and Gurdaspur stations (Figure 6).

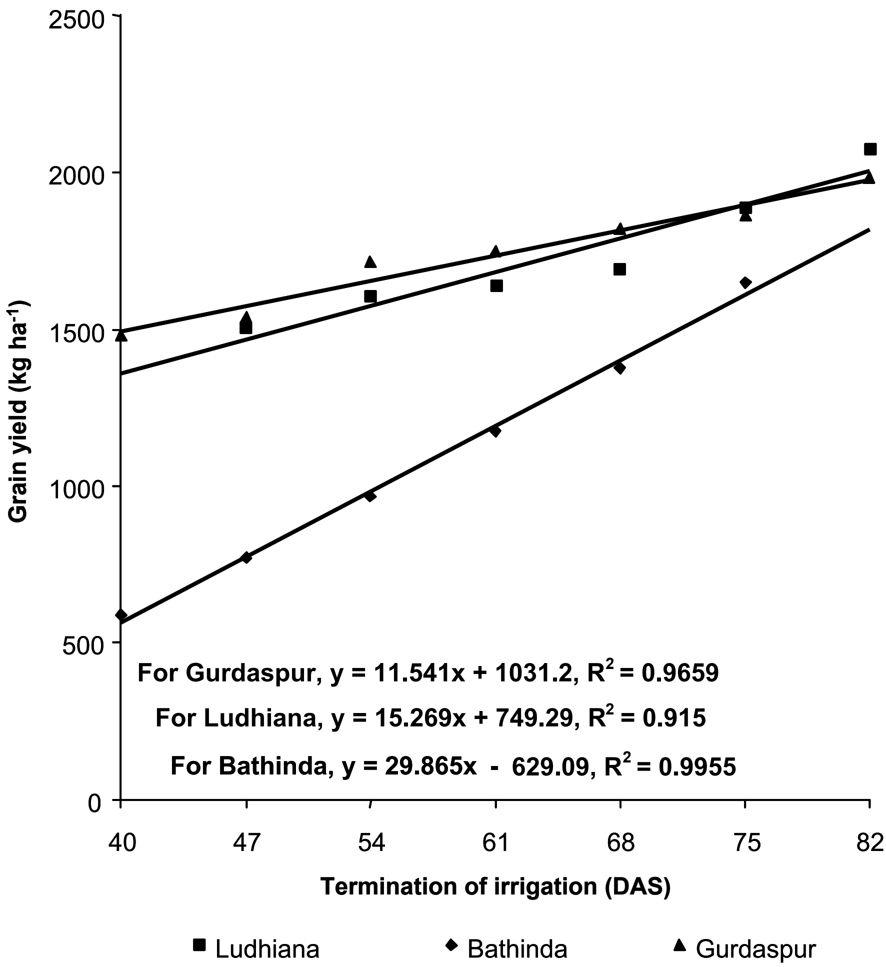


Figure 6. Effect of termination of irrigation on grain yield summer mungbean at different locations

Expt. 7
Weed Management

Weeds cause 30-50% losses in the grain yield of mungbean. However, the magnitude of loss varies with the intensity and type of weed flora. The critical period of crop-weed competition varies from 15-30 DAS (Mishra, 1997). Thus, it is imperative to eliminate weeds at proper time with suitable technique. Due to non-availability of labor and continuous rains, it is impossible to control weeds by mechanical or cultural means. Therefore, herbicides seem to be a good tool to control weeds. Experiments conducted in 2002 and 2003 showed that maximum grain yield was obtained with two hoeings done at 25 and 40 DAS. However, the application of pendimethalin as pre-emergence at 0.75 kg a.i. ha^{-1} or fluchloralin as pre-sowing at 0.625 kg a.i. ha^{-1} were at par with two hoeings in the grain yield in both years (Table 3). The crop was mainly infested with *Cyperus rotundus, Trianthema portulacastrum, Eleusine aegyptium, Digitaria sanguinalis, and Tribulus terrestris.*

Table 3. Grain yield of mungbean as influenced by weed control treatments in summer 2002 and 2003 at Ludhiana

Treatment	Grain yield(kg ha^{-1})			Dry weight of weeds (kg ha^{-1})		
	2002	2003	Mean	2002	2003	Mean
Weedy check (no weeding)	881	1,046	963	2,733	2,756	2,744
Two hoeings 25 and 40 DAS	2,680	1,510	2,095	253	507	380
Pendimethalin 0.75 kg a.i. ha^{-1}	2,430	1,447	1,938	483	463	473
Fluchloralin 0.625 kg a.i. ha^{-1}	2,412	1,437	1,924	514	1,047	830
C.D. 5%	393	255		240	395	-

Pendimethalin and fluchloralin showed good control of annual weeds while perennial weeds like *Cyperus rotundus* and *Cyperus dactylon* can only be controlled by hoeing (Saraswat and Mishra, 1993; Sekhon *et al.*, 1996).

Expt. 8
Contribution of Inputs

Full yield potential of an improved variety sown at the optimum time can be realized if its management is done properly. In crop management, the most important inputs may be fertilizer application, weed management, insect pest control, irrigation, etc.

Field experiments were conducted to study the relative contribution of three inputs, i.e. fertilizer, weed control, and insect pest control, on the productivity of summer mungbean. Data revealed that maximum grain yield (1761 kg ha^{-1}) was recorded when all the aforesaid techniques were applied (Figure 7). In the absence of these practices (control plot), grain yield was 460 kg ha^{-1}. The contribution towards grain yield was the highest by weed control, followed by fertilizer and insect pest control. Similar results were observed by Singh and Sekhon (2002) in summer mungbean.

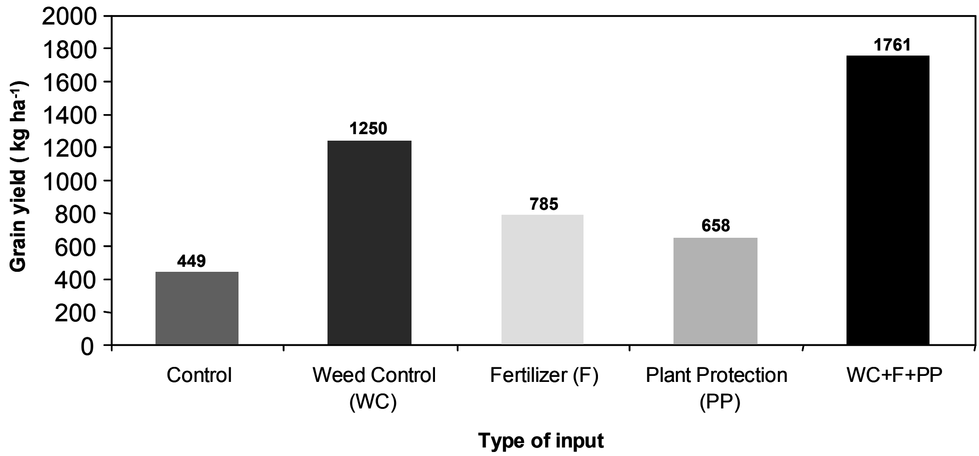


Figure 7. Effect of input contributions on the grain yield of summer mungbean

Conclusion

Agronomic management inputs are very important to realize the yield potential of improved varieties. Efficiency of high-tech-inputs also cannot be obtained without the support of matching agro-techniques. Data revealed that new variety SML 668 can be successfully grown in summer mungbean-wheat-rice cropping system. The system will not only increase the cropping intensity but also improve soil health. Interestingly, the new variety can also be grown during *Kharif* (rainy season). In this project, effort was made to work out the technology package of some agronomic practices, but due to short period (two years) only a few were tried. There is a great need to work out full cultural practices of mungbean for different agro-climatic conditions and various cropping systems in Punjab and adjoining states to achieve the maximum benefit and enhance the income of the farmers of the Indo-Gangetic plain zone. Farmer-participatory research is valuable in transfering the technology for rapid adoption.

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Status of production and distribution of mungbean seed in different cropping seasons

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Abstract

Mungbean (*Vigna radiata* L. Wilczek.) is the third important pulse crop in India. Rice-wheat cropping system is predominant and is continuously practiced by the farmers in the North-West Plain Zone of India (Punjab, Haryana, Western Uttar Pradesh, and Rajasthan). There is a big opportunity to have large area under summer mungbean and to replace rice with *Kharif* mungbean where water is scarce. But the availability of seed of improved cultivars is a major constraint. Therefore, the availability of quality seeds of improved varieties to the farmers at an affordable price, or seed production at the farmer's own field under the supervision of scientific/technical staff is considered crucial in enhancing and sustaining mungbean productivity. The Punjab Agricultural University (PAU) launched a seed production campaign for different varieties of mungbean, especially the new variety SML 668 which was released in 2001. PAU produced about 15 t of seeds of SML 668 in summer and *Kharif* season 2001. It was distributed to different seed producing agencies/organizations and progressive farmers in summer and *Kharif* 2002. Said seed producing agencies were the Punjab State Seed Corporation (PUNSEED), National Seed Corporation (NSC), and Private Seed Producing Companies. Seeds were also produced during the conduct of adaptive trials under the direct supervision of the Directorate of Extension Education, PAU, and front line demonstrations at farmer's fields. Progressive farmers also played a vital role in seed production by planting larger area for mungbean. During the Farmers' Fairs at PAU in March 2002, seed kits of 2 kg each were sold to 3,500 farmers. The Department of Agriculture in Punjab also distributed 875 minikits of Pusa Vishal to the farmers in 2002. Its most important component of seed production and distribution was the Seed Village Programme (SVP), which was very successful and helped tremendously in the distribution of quality seed from farmer to farmer. The Seed Village Programme concept consists of seed production by the farmers in compact areas in selected villages. The farmers in SVP are provided free seeds and technical know-how on production of seeds of improved mungbean varieties. In summer 2003, a total of 30 villages were selected in six clusters in Punjab. Each farmer was given seeds for one acre and a total of 270 farmers were selected

as participants. PAU is also producing basic, foundation, certified, and T.L. Seed. As a result of all these efforts, area under mungbean in Punjab increased from 23,000 ha in 2000-01 to more than 75,000 ha in 2002-03.

Introduction

Mungbean (*Vigna radiata* L. Wilczek) is an important pulse crop in India, Pakistan, Bangladesh, the Philippines, China, and Indonesia, as well as in East and Central Africa, West Indies, the USA, and Australia (Jaiwal and Gulati, 1995). It is an excellent source of dietary protein. Among the pulses in India, mungbean ranks third in area and production. Area under mungbean in India in 1988-89 was 3.29 million ha and production was 1.42 million t. However, in 2000-01, both area and production of mungbean decreased to 1.5 million ha and 0.41 million t respectively. The yield per ha during this period also declined from 432 kg ha^{-1} to 273 kg ha^{-1} (Grover, 2002). In Punjab, area and production was 52,600 ha in 1995-96 with a production of 43,800 t. But it came down to 23,000 ha in 2000-01 with a production of 13,400 t. Yield also decreased from 834 kg ha^{-1} in 1995-96 to 480 kg ha^{-1} in 2000-01 (Anonymous, 2002).

In the north west plain zone (NWPZ) especially Punjab, Haryana, Western UP and Rajasthan, rice-wheat cropping system is continuously practiced by the farmers. This has resulted in many problems such as deterioration in soil health, depletion of water table and soil nutrients, infestation of diseases and insect pests, and aggravating environmental problems. Government and farmers are keen on putting maximum area under pulses, particularly under mungbean. There is a big opportunity to increase area under summer mungbean and to diversify the cropping system by replacing rice with *Kharif* mungbean. But the availability of seed of improved cultivars is a major constraint.

Quality seed is essential in realizing the potential of a high yielding variety. In the absence of quality seed, investments on fertilizer, water, pesticides and other inputs will not pay the desired dividends. Therefore, availability of quality seed of improved varieties to the farmers at an affordable price or seed production at the farmer's own field under the supervision of scientific/technical staff is crucial in enhancing and sustaining crop productivity.

PAU has wholeheartedly directed its efforts for seed production of different mungbean varieties, especially the new variety SML 668.

Seed Production and Distribution of SML 668

Punjab Agricultural University (PAU) produced about 15 t of SML 668 seeds in summer and *Kharif* 2001. These were allocated to different seed producing agencies such as Punjab State Seed Corporation (PUNSEED), National Seed Corporation (NSC), private seed producing companies, and progressive farmers (Brar *et al.*, 2002).

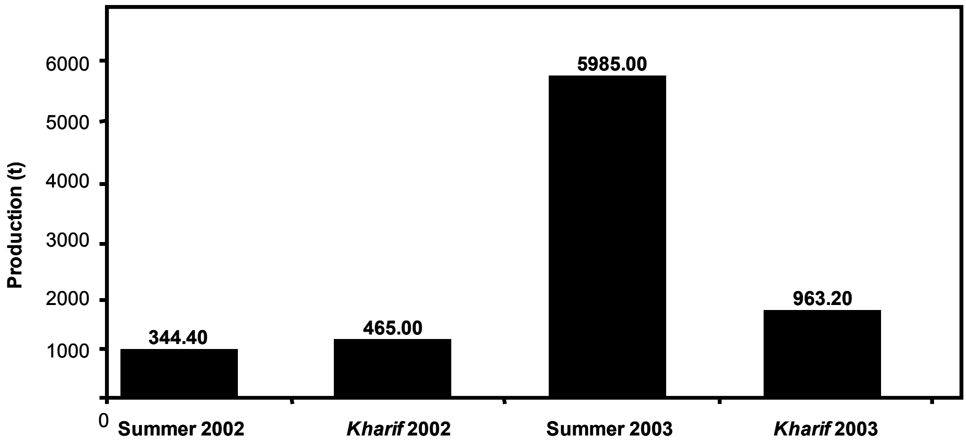

Figure 1. Seed Production of SML 668 in 2002 and 2003

Table 1. Seed Production of SML 668 in Summer 2002

Agency	Quantity (t)
PAU Seed Farms	20.0
PUNSEED	50.4
NSC	6.0
Private agencies	20.0
FLD's conducted by Pulses Section, PAU	8.0
FLD's conducted by DEE, PAU	10.0
Progressive farmers	40.0
Seed kits distributed to 3500 farms by PAU in Kisan Melas	190.0
Total	**344.4**

Source: PAU (2002a).

Table 2. Seed Production of SML 668 in *Kharif* 2002

Agency	Quantity (t)
PAU seed farms	60.0
Private agencies	50.0
FLD's conducted by Pulses Section, PAU	5.0
Progressive farmers	50.0
Seed kitsdDistributed to 3500 farms by PAU	300.0
Total	**465.0**

Source: PAU (2002b).

Table 3. Seed Production of SML 668 in Summer 2003

Agency	Quantity (t)
Seed production by different agencies	3000.0
Seed production by Seed Village Programme	2700.0
PAU Seed Farms	15.0
FLD's conducted by Pulses Section, PAU	20.0
Progressive farmers	130.0
Private agencies	120.0
Total	**5985.0**

Source: PAU (2003a).

Table 4. Seed Production of SML 668 in *Kharif* 2003

Agency	Quantity (t)
PAU Seed Farms	45.0
PUNSEED	58.2
Private agencies	500.0
Progressive farmers	300.0
FLD's conducted by Pulses Section, PAU	20.0
NSC	40.0
Total	**963.2**

Source: PAU (2003b).

A. Various Seed Producing Agencies

1. PAU Seed Farms

PAU has 19 research stations/seed farms located in different parts of Punjab. Seeds of different crops are produced in these research stations/seed farms. Since 2001 when SML 668 was released, special efforts have been made to produce a large quantity of seed of this variety. In *Kharif* and summer of 2001, 15 t of seeds were produced. Subsequently in succeeding years an efforts was made to plant maximum area under this variety in various PAU farms (Tables 1-5).

Table 5. Area of SML 668 planted at PAU Farms in Summer 2004

Name of the farm	**Area planted (ha)**
USF, Naraingarh	12.00
RRS, Gurdaspur	0.8
USF, Ladhowal	16.00
USF, Faridkot	12.00
Total	**40.8**

2. Punjab State Seed Corporation (PUNSEED)

The Corporation has its head office at Chandigarh. It has two regional offices at Kartarpur and Kotkapura where there is a facility for good grading, cleaning, packaging, and storage. There are two branch offices in Abohar and Ludhiana. The Corporation also has sales centers in Bathinda, Mansa, Sangrur, Patiala, and Amritsar. The PUNSEED is providing great help in multiplying and distributing SML 668 seeds. In 2003 when rice crop was badly affected in Majha (Amritsar and adjoining area), the corporation distributed about 50 t of SML 668 seeds to farmers. It also has the provision to buy back the seeds from farmers. The rate fixed for buying back was Rs28.5 kg^{-1}. It produced 50.4, and 58.2 t of SML 668 seed in 2002 and 2003 respectively and is expected to produce about 100 t in 2004.

3. National Seed Corporation (NSC)

It is a national government organization engaged in seed production of all crops. It received 0.2 t of seeds of SML 668 from PAU in 2001 and produced 6 t of seeds in 2002 and 40 t in 2003.

4. Private Agencies

Private seed producing agencies are actively involved in the seed production of different crops in Punjab. Together they procured 0.75 t of SML 668 seeds from PAU in 2001. They produced about 20 t of seeds in 2002 summer season and about 50 t in 2002 *Kharif* season. In summer 2003, these agencies produced about 120 t of seeds of SML 668, while in *Kharif* 2003, the total production was about 500 t.

5. Adaptive Trials (at farmer's fields)

Adaptive trials (76) of SML 668 were conducted at farmer's fields under the direct supervision of the Directorate of Extension Education, PAU and Department of Agriculture in Punjab in 16 districts of Punjab in summer 2001. This yielded about 35 t of seed. In *Kharif* 2002, 47 adaptive trials were again conducted at farmer's fields.

6. Front Line Demonstrations

Frontline demonstrations (40) of SML 668, each of 0.2 ha area were conducted at farmer's fields in the state in summer 2002. These were supervised by the scientists of the Pulses Section, PAU and a recommended package of practices were strictly followed. About 8 t of seeds were produced. Another set of 50 demonstrations were conducted by Directorate of Extension Education, PAU in summer 2002 where about 10 t of seeds were produced. In *Kharif* 2002, the Pulses Section again conducted frontline demonstrations and five t of seeds were produced. In summer and *Kharif* 2003, about 20 t of seeds were produced out of these demonstrations.

7. Progressive Farmers

Progressive farmers are also a big help in seed production because they plant a lager area (up to 15-20 ha) area for seed production.

8. Seed Sold by PAU at Kisan Melas

A large quantity of seeds is sold every year at PAU Kisan Melas (Farmers' Fairs) held twice a year at different places in the state. For example during the Kisan Melas of March 2002, seed kits of SML 668 at two kg each were sold to 3,500 farmers. Through these fairs, about 190 ha area came under cultivation of SML 668 and about 190 t of seeds were produced.

9. Seed Village Programme

Several agencies helped in producing SML 668 seeds but the Seed Village Program (SVP) was the most successful in the rapid production and distribution of a large quantity of seeds. This program, initiated in summer 2003, involves seed production done by farmers in a compact area of selected villages under the supervision of pulse scientists of PAU and officers of Department of Agriculture in Punjab. The farmers were provided free seeds for 0.4 ha each. SVP was undertaken at six places in the state and, in one place, three to four villages were selected to form a cluster. Each cluster has 45 farmers, bringing a total of 270 participating farmers in the state. For 0.4 ha each farmer produced an average of 0.4 t of seeds. These seeds were again planted in *Kharif* 2003 season. Thus a total of 2,700 t of seeds were produced through SVP (Table 6). The main advantage of SVP is that the seeds are pure, of good quality, and can quickly distribute or spread the seeds from farmer to farmer.

Table 6. Seed Production Through Seed Village Program in 2003

Name	**Quantity (t)**
No. of villages in each SVP	6
No. of farmers in each SVP	45
Each farmer given seed for planting	0.4 ha
Seed production from 0.4 ha	0.4 t
Area planted with 0.4 t. in *Kharif* 2003	10 ha
Seed produced by each farmer in *Kharif* 2003	10 t
Total seed production in one SVP 10 x 45	450 t
Total seed produced by 6 SVP 6 x 450	**2700 t**

Source: PAU (2003a).

B. Seed Production of Different Mungbean Varieties by PAU

With the release of SML 668 in 2001, the old varieties grown in summer season, i.e. SML 32 and SML 134, were subsequently withdrawn as they became susceptible to MYMV. The seed production of SML 668 was taken up on a large scale by PAU on a priority basis (Table 7). Seed production of other mungbean varieties was also undertaken (Figure 2).

Table 7. Seed Production of Different Mungbean Varieties by PAU Quantity (t)

Season	SML 32	SML 134	ML 131	ML 267	ML 613	PBM 1	SML 668	ML 818
***Kharif* 2000**	11.1	1.2	0.27	5.6	48.0	2.5	1.2	-
Summer 2001	11.6	5.0	-	-	-	-	15.0	-
***Kharif* 2001**	5.36	2.7	-	3.0	4.8	0.6	8.8	-
Summer 2002	-	3.2	-	-	-	-	20.0	-
***Kharif* 2002**	3.6	2.16	-	0.8	58.8	1.0	60.0	-
Summer 2003	-	-	-	-	-	-	15.0	-
***Kharif* 2003**	-	-	-	1.75	13.10	-	45.0	103.1
Summer 2004	Area planted	-	-	-	-	-	40.8 ha	-

All of these efforts resulted in an increase in area under mungbean in Punjab from 23,000 ha in 2001 to more than 65,000 ha in 2003 in *Kharif* season. In summer season, the estimated area under mungbean was about 25,000 ha in 2003, which was expected to increase to about 40,000 ha in 2004 (Table 8). SML 668 seeds have also started spreading to neighbouring states such as Rajasthan, Haryana, and Western UP.

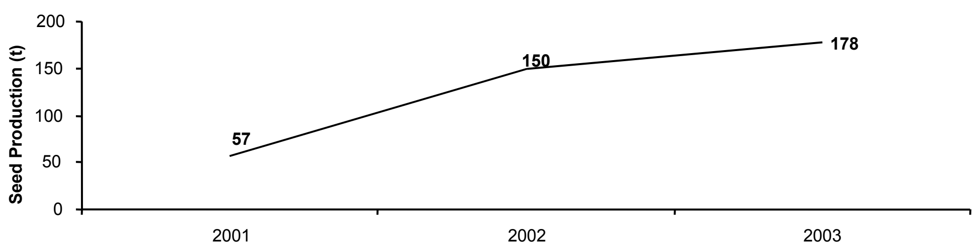

Figure 2. Total Seed Production of Different Mungbean Varieties by PAU

Table 8. Area under Mungbean in Punjab

Year	Area (ha)	
	Kharif	**Summer**
1996	***52600***	NA
2001	***23000***	NA
2003	***65000***	25000
2004	***NA***	40000

NA: not available

C. Nucleus/Basic Seed Production of SML 668 at PAU

Nucleus seed production of SML 668 was carried out in summer 2000. Seed purity was maintained by selecting true to type single plant progenies and rejecting off types. The details of nucleus seed production over the year in PAU are given in Table 9.

Table 9. Nucleus/Basic Seed Production of SML 668 at PAU

Year/Session	No. of progenies grown	No. of progenies selected	Seed produced (kg)
Summer 2000	350	260	80
Kharif **2001**	352	310	40
Summer 2002	310	233	100
Kharif **2002**	260	212	68
Summer 2003	504	456	102
Kharif **2003**	481	425	150
Summer 2004	552	-	-

D. Marketing

The marketing aspect of SML 668 for the year 2003 was studied by the socio-economists. It was found that farmers got an average price of Rs 20 kg^{-1}, with a range of Rs 13 to Rs 26 kg^{-1}. In some places, the price was found to be as low as Rs 7.6 kg^{-1} for the *Kharif* crop. This was due to poor quality of seed resulting from excessive rainfall at the time of maturity (PAU, 2003a).

E. Price of Seed

The PAU price for the seed of SML 668 was Rs 36/- kg^{-1}. A farmer had to spend about Rs 1,450 on seed for 1 ha, whereas the average net returns were calculated to be Rs 14,652 ha^{-1}. It was reported that some farmers even sold the seed of SML 668 at a price as high as Rs 60 kg^{-1}.

F. Seed Storage

Special emphasis was given by various agencies and farmers in the proper storage of seed. Various seed producing agencies such as PAU, PUNSEED, NSC, etc have excellent seed storage facilities. After grading, the seed is stored in godowns.

Many insect-pests infest stored mungbean which cause heavy losses and affect the seed quality if proper precautions are not taken. These insects include mainly Dhora (*Callosobruchus analis*, *C. chinensis*, and *C. phaseoli*) and Spotted Bean Weevil (*C. maculatus*). Before storage the following preventive measures are taken:

- Drying grains properly
- Plugging all the cracks and holes in the godowns properly
- Disinfecting old gunny bags with fenvalerate/cypermethrin and then drying them in shade
- Disinfecting empty godowns by spraying malathion emulsion or fumigating them with aluminium phosphide (celphos) tablets
- Mixing malathion dust at 250 g 100 kg^{-1} of grains

The farmers store the seed generally in metal bins of 200-1,000 kgs capacity. These bins are placed under the sun two to three days before storage. In case the grains are infested in godowns or metal bins, fumigation is done with celphos at one tablet of 3 g t^{-1} of grains or 25 tablets 100 m^{-3} space (Kooner *et al.*, 2004).

G. Seed Purity

Special efforts were made to maintain the purity and quality of seed. Utmost care was taken from the very beginning, i.e. from the nucleus/basic seed production stage. At PAU, the nucleus seed plots were monitored by a committee. If found satisfactory, then seeds were cleared . After this, plots for breeder seeds, foundation seeds, and certified seeds are again monitored by a committee. This committee includes a representative each from the Punjab State Seed Certification Authority (PSSCA), National Seed Corporation (NSC), and Office of the Director of Seeds in PAU, including the concerned breeder. If a farmer or a private agency wants to produce seeds, breeder seeds have to be bought from PAU and seed production plots have to be monitored by PSSCA. The percentage of germination of seeds is also checked by the Punjab Government Laboratory at its grow out test farm.

H. Seed Production and Distribution of Pusa Vishal

Pusa Vishal was developed by the Indian Agricultural Research Institute (IARI) in New Delhi from AVRDC material and released for general cultivation in North West Plain Zone (NWPZ) of India in 2000 for spring/summer season. One hundred kg seeds of Pusa Vishal was procured by PAU in summer 2001. From these seeds 13 front line demonstrations (FLD) of 0.2 ha each were conducted in

Punjab. These FLDs gave encouraging results. Thus, Pusa Vishal seeds reached the farmers.

The Department of Agriculture also procured seeds of Pusa Vishal from IARI in New Delhi. The department conducted 875 minikit trials of 0.10 ha each at farmer fields in summer 2002 in seven districts of Punjab (Table 10), and about 90 t seeds were produced.

Table 10. Minikit of summer mungbean variety Pusa Vishal in Punjab[1]

District	No. of minikit	Area sown under each minikit (ha)	Expected seed production (ton)
Bathinda	150	0.10	15.0
Mansa	100	0.10	10.0
Sangrur	125	0.10	12.5
Ferozepur	150	0.10	15.0
Mukatsar	125	0.10	12.5
Faridkot	100	0.10	10.0
Moga	125	0.10	12.5
Total	**875**	**87.5**	**87.5**

[1]Conducted by Department of Agriculture, Punjab

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Role of Punjab State Seeds Corporation Ltd (PSSC) in production and distribution of mungbean seed

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Abstract

Seed is a key input in improving agricultural output. The Indian Seed Act was passed in 1966. and in 1976, the National Seeds Corporation Ltd. and 13 State Seeds Corporations (SSCS) were established by virtue of the said seed act. In Punjab (India), the Punjab State Seeds Corporation (PSSC) was also established in 1976. The head office of the Corporation is located at Chandigarh (capital of Punjab) and its two regional offices are situated in Kartarpur (district Jalandhar) and Kotkapura (district Mukatsar). The Corporation also has sales centers in Bathinda, Mansa, Sangrur, Patiala and Amritsar. The Corporation multiplies certified seed of high-yielding varieties of different crops recommended by the Punjab Agricultural University in Ludhiana. Processing and packing of the seed is done under the supervision of Punjab State Seed Certification Authority (PSSCA). Samples of the processed seeds are tested in the Government Seed Testing Laboratory in Ludhiana. In 2003, the Corporation, due to the failure of rice crop, produced 50 tons of seeds of SML 668 mungbean variety, and distributed these to farmers who lost their rice crop due to lack of rainfall. The PSSC took keen interest in producing the seed of new mungbean variety SML668. In 2002 and 2003, about 50.4 and 58.2 tons of SML668 seeds were produced respectively, while in 2004, the expected production is 100 tons.

Introduction

Agriculture is the backbone of the Indian economy. Since the country's independence, there has been earnest efforts by the Government of India to increase the agricultural output to eradicate hunger in the country. Many steps were taken to increase the agricultural production until it was found out that it can be increased in a manifold way through use of improved and certified seed. Therefore, in 1966, Indian Seed Act was passed by Government of India. In 1976, the National Seed Corporation Ltd. and 13 state seed corporations (SSCs) were established under the aforesaid Seed Act so that improved and certified seed may be provided to the farmers. The Punjab Government established the Punjab State Seed Corporation in 1976. The National Seeds Corporation, Punjab Government, and Seed Growers of Punjab participated in the capital outlay of the company.

Functioning of Punjab State Seed Corporation

The head office of the corporation is situated in Chandigarh. It has two regional offices at Kartarpur (district of Jalandhar) and Kotkapura (district of Mukatsar). There are two branch offices at Abohar and Ludhiana and sales centres at Bathinda, Mansa, Sangrur, Patiala and Amritsar.

Administrative Set Up

The head of the corporation is the Managing Director. The Head Office houses the production, marketing, engineering and processing, finance, administration and personnel divisions, which are headed by their respective managers. These managers work under the direct supervision of the managing director. Similarly, the regional offices are headed by the regional managers who supervise the production, marketing, engineering and processing, and accounts divisions.

Seed Production

The corporation mainly produces seeds of *Rabi* (winter season) and *Kharif* (rainy season) crops. It produces only the seeds recommended by the Punjab Agricultural University (PAU) in Ludhiana to be grown in the state of Punjab. The corporation multiplies certified seeds of high-yielding varieties of different crops through registered seed growers and share holders of the corporation. PAU provides foundation and breeder seeds to the corporation, while the corporation identifies the progressive farmers who will grow these seeds. Only registered growers can multiply the pure seed. The farmers' fields are inspected regularly by the officials and technical staff of PSSCA, as recommended by the Seed Act. During harvest when raw seed is found to be fit in all aspects, it is brought to the processing plants of the corporation for grading using modern seed processing machinery. Processing and packing of the seed is done under the supervision of PSSCA. Samples of the processed and graded seed are sent to the government-owned Seed Testing Laboratory (STL) situated at Ludhiana. The PSSCA acquires the seed only after the clearance from the Seed Testing Laboratory (STL). The seed is then packed in bags alongwith labels of certified seed giving information on germination, purity percentage of the seed supplied to the farmers. The amount of certified seed produced by the corporation during the last three years is given in Table 1.

Table 1. Seed production of different crops by PSSC (t)

Crop	2001-02	2002-03	2003-04
Wheat	808.5	8500	10,000
Durum wheat			150
Paddy	9350	1336.1	2175
Cotton	13.6	137.2	300
Oilseeds			20
Pulses	8	21	350
Vegetables	0.6	-	25

Production of Oilseed, Vegetable and Hybrid Seeds

The corporation is now giving emphasis to the production of seed of pulses and vegetables of different crops for diversification purposes, which is the need of the hour. The Government of India and the Punjab Government have been stressing for diversification under various schemes. So far, the corporation has produced seeds of many crops including mungbean SML 668.

Seed Processing

The corporation has installed three imported modern seed processing plants in Kartarpur, Ludhiana, and Kotkapura. The processing plant has also been installed at Abohar for processing of cotton seed. The seed is processed and packed by running the plant in three shifts so that seed is made available for marketing in time. The corporation also has modern seed stores.

Marketing

Seed is supplied to the farmers through different agencies, including the State Department of Agriculture, village level cooperative societies, registered dealers, sales centers of IFFCO and Kribcho, and the Corporation's own sales centers. The Corporation has made earnest efforts to supply seeds to the farmers at their door step. For this purpose, special emphasis is given in supplying seeds at the offices of the State Agriculture Department situated in focal points and to village-level cooperative societies. The corporation supplies certified seed of different crops/ varieties (Table 2).

Table 2. Seed supplied by PSSCA (t)

Crop	2001-02	2002-03	2003-04
Wheat	8885.5	8889	8486.2
Paddy	2273.2	928.5	1044.8
Cotton	323.3	231.6	96.4
Oilseed			12.8
Pulses			21.3
Vegetables			4
Sesbania			305
Durum wheat			150

The corporation has also come forward to help the farmers in special circumstances. For example, the untimely rains in the state in 2001 brought an acute shortage of certified wheat seeds. The corporation assessed the situation and distributed 5500 t certified seed of wheat to different government organizations. Similarly, in *Kharif* 2002, because it did not rain during the supposed rainy season, large number of farmers ploughed their rice crop. The PSSCA distributed about 50 tons of mungbean SML 668 seed. These efforts were greatly appreciated by the state government and the Board of Directors of the Corporation.

Financial Position

The Corporation has improved its financial position considerably during the last two years. All the loans obtained from nationalized banks have been repaid. Now the Corporation is debt-free as far as the banks are concerned. The Corporation has also earned considerable profit during the year 2002-03.

Crop Diversification

The Punjab Government has set a target of one million hectares to be sown with Basmati rice, pulses, oilseed, and Durum wheat in the next five years. The Corporation is seen to play a vital role so that targets set by the State Government are achieved, and the financial position of the farmers of the State and the Corporation may improve (Figure1).

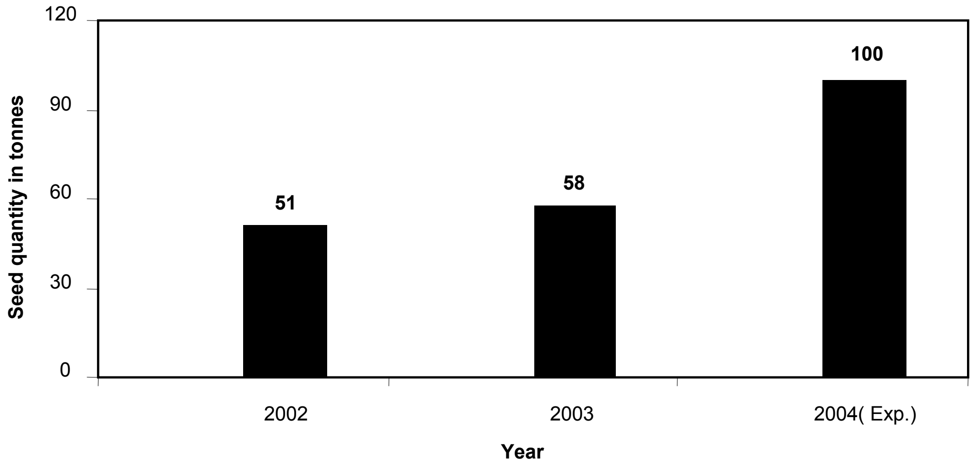

Figure 1. Seed production of SML668 by PSSC

Socio-Economic Impact of New Short Duration Mungbean Varieties in Punjab

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Abstract

A socio-economic survey of farmers cultivating short duration mungbean cultivars in summer as well as *Kharif* seasons was undertaken. Three hundred farmers participating in the seed village program from six locations in Punjab were identified as respondents for the study in summer 2003 and *Kharif* 2004. The results of the 2002 survey were used as base line for comparison. The objectives of the study were: 1) to study the socio-economic profile of the selected farmers; 2) to estimate the benefits accrued to the adopters of improved short-duration mungbean cultivars in summer and *Kharif* seasons; 3) to determine the biotic and abiotic constraints faced by the adopters in both the seasons; and 4) to suggest measures for the promotion of mungbean cultivation in Punjab. The results showed that mungbean area and production declined from 1999-2000 to 2001-2002. It remains to be seen whether this trend will be reversed in 2002-03 and 2003-04. The profile of the improved technology adopters indicate that they are educated, middle-aged, and well-to-do. The short growth duration and MYMV-resistance and high yield were the major reasons for adoption of improved mungbean cultivar. In general, the mungbean yields in the summer varied from 250 kg ha^{-1} to 1875 kg ha^{-1}. However, most of the farmers obtained yields of 500 kg to 1200 kg ha^{-1}. In *Kharif* the yield varied from 125 kg ha^{-1} to 2,375 kg ha^{-1}. Such wide variability was due to variation in management practices, irrigation, and rain at harvest time in some fields. The coefficient of variation for yield was lowest for summer mungbean after potato (25%) compared to after wheat (41%) and *Kharif* season (66%). Therefore, it is essential to recommend and demonstrate to the farmers good agricultural practices to improve the yield. The net returns for summer mungbean after wheat and potato varied from Rs 5,258 to 26,305 ha^{-1} and Rs 880 to 26,950 ha^{-1}, respectively. For *Kharif* season, the net returns were from Rs 1,743 to Rs 24,300 ha^{-1}. In general, most of the farmers benefited from

summer mungbean. However, summer mungbean after potato is less risky than other cropping systems. If rice were to be replaced with mungbean in *Kharif* season, mungbean yields should be stable in summer and *Kharif*, and the farmer should take both summer and *Kharif* season crop. In addition, there should be market demand and price support from the government to successfully diversify the rice-wheat system with mungbean.

Introduction

Pulses occupy a very important position in Indian agriculture and human diet. Pulses are legumes, so they help restore the fertility of the soil. Since they are the cheapest source of protein, they fulfill 20-30 per cent protein requirement of Indians. Among the pulses, mungbean ranks third in production after Bengal gram (33% share) and red gram (21% share) in India. Mungbean has 24% easily digestible protein and its iron content is about 6 mg 100 g^{-1} dry seed. The area under mungbean has declined in India from 3.49 million hectares in 1991-92 to only 1.50 million hectares in 2000-01. In Punjab, the decline was from about 45,000 hectares in 1991-92 to 23,000, hectares in 2001-02.

The major reasons for such decline were Mungbean Yellow Mosaic Virus (MYMV) which causes severe yield losses, and ineffective price support by the government. Chatha and Singh (1983) suggested strong price incentives and technology breakthrough in pulses. Sankhayan and Sood (1984) showed that the only pulse that showed some increase in production was mungbean (2.8% per annum) in 1960-61 to 1980-81. Singh (1989) studied the production and marketing of pulses, with mungbean as a separate pulse in Punjab, and proposed state policies for strengthening pulse production in general and that of mungbean in particular. Grover (2002) showed that in the past mungbean crop could not be stabilized in the state mainly because of its lower profitability compared with major competing crops. Grover *et al.* (2003) found huge possibility of increasing the production of mungbean in the state by adopting short duration summer mungbean cultivars in the fallows of rice-wheat cropping system.

Another major hindrance to increasing the area under mungbean in Punjab was the long growth duration of the traditional local cultivars. For want of short duration mungbean cultivars, about two million hectares in Punjab under the rice-wheat cropping system (RWCS) remained fallow after the wheat harvest and before the rice planting. This fallow period is about 60-70 days (from mid-April to end of June). However, the traditional mungbean cultivars mature in 80-90 days. Short duration mungbean is the only pulse crop that has potential to fit into this slot. To overcome the above constraints, PAU and Asian Vegetable Research and Development Center – World Vegetable Center , Taiwan have jointly developed a new mungbean cultivar, SML 668, which is high-yielding, MYMV-resistant, and has short growth duration.

Similarly the Indian Agricultural Research Institute (IARI) in New Delhi has released NM-92 as Pusa Vishal with similar traits as SML-668, which is suitable for adoption in Punjab. This improved mungbean cultivar (SML-668) has been released to the farmers by the Punjab Agricultural University for its cultivation. The Seed Village Programme (SVP) has been launched in six different locations in the state to produce enough seed for a particular area.

The farmers participating in the programme were provided with free foundation seed and seed production training. The farmers have experienced SML-668 as an improved cultivar for the last two years. However, summer mungbean (SML-668) cultivar can be grown in a variety of cropping systems, wheat – summer mungbean – paddy and potato – summer mungbean – paddy were the two dominant cropping rotations on irrigated land. The MYMV resistant, short duration mungbean cultivar (SML-668) is also well adapted to *Kharif* season showing a ray of hope for diversification and sustainability of the cereal-based cropping system. The very purpose of this study is to make impact assessment of this improved summer mungbean cultivar in terms of improved income of the adopters and associated constraints in these two rotations/ seasons.

The specific objectives of the present study are:

1. To study the socio-economic profile of the farmers cultivating short-duration mungbean cultivars in summer as well as *Kharif* season;
2. To estimate the benefits accrued to the adopters of short-duration mungbean cultivars in summer and *Kharif* season;
3. To investigate the major biotic and abiotic constraints faced by mungbean growers both in summer and *Kharif* seasons; and
4. To suggest measures for the promotion of mungbean cultivation in the Punjab.

Methodology

The Sampling

A list of 300 participating farmers in the SVP coming from six locations in the state was prepared by the Department of Plant Breeding, Punjab Agricultural University, Ludhiana, the Managing Director of Pun Seed, and the Department of Agriculture in Punjab. These farmers were segregated based on their respective rotation practices, such as summer mungbean after wheat and summer mungbean after potato. Of the 300 such farmers (150 growing summer mungbean after wheat and the other 150 growing summer mungbean after potato), 50 farmers from each rotation were randomly chosen. Similarly, 50 farmers growing mungbean in *Kharif* season were also studied for their experiences.

Data Collection and Analysis

For collection of primary data, a well-structured questionnaire was prepared. The relevant data from the 150 sample farmers (100 summer mungbean growers and 50 *Kharif* mungbean growers) were collected through personal interview method. The survey was conducted during August-September 2003 for summer mungbean cultivators and during December-January 2004 for *Kharif* mungbean cultivators. The results of earlier survey conducted in the year 2002 were used as base line/ early impact survey to study the impact of short duration cultivars on the key performance indicators such as yield, price and returns, etc. The interpretations of the data were based on simple tabular analysis and graphical presentation. Compound growth rates and coefficient of variations were also calculated. Ordinary least square (OLS) method was used to study the input-use-efficiency of mungbean in Punjab. Since there are variations in the agronomic practices, benefits, and constraints in the cultivation of summer mungbean in two rotations, i.e. after wheat and after potato, and in mungbean cultivation in *Kharif* season, the impact has been analyzed separately for these three situations.

Results and Discussion

Recent Production Trends of Mungbean in Punjab

The area, yield, and production of mungbean showed a consistently declining trend in five succeeding years. The area and production of mungbean witnessed a sharp decline from 49,300 ha and 31,800 tons in 1997-98 to 23,100 ha and 11,100 tons in 2001-02 (Table1). The annual compound growth rates in area, production, and yield of mungbean in Punjab during this period have been found as –8.3, -18.1 and –10.7, respectively. These figures are all statistically significant at 1 per cent level. This decline may be attributed to both the yield and price risks involved in mungbean cultivation resulting into the higher risk for lower profitability compared with other competing crops in the state.

Table 1. Area, yield and production of mungbean in Punjab over the period 1997-98 to 2001-02

Particulars	Year					CV(%)	CGR
	97-98	98-99	99-00	00-01	01-02		
Area (000'ha)	49.3	42.5	38.6	29.5	23.1	12.25	- 8.3[1]
Prod. (000'tons)	31.8	25.4	23.0	18.4	11.1	27.04	-18.1[1]
Yield (kg ha^{-1})	645	598	596	624	481	16.09	-10.7[1]

Source: Statistical Abstract of Punjab.
[1]Indicates the level of significance at 1 percent.
CV- Coefficient of variation, CGR- Compound growth rate.

Socio-Economic Profile of Sample Adopters

Most of the sample adopters of short duration cultivars of mungbean were found to be middle-aged, experienced farmers with relatively better schooling. Majority of the adopters were in the age group of 40-60 years with more than five years of schooling.

Land Details and Machinery Ownership of Sample Adopters

Being innovative with better risk bearing capacity, relatively larger-sized farms were adopting new short duration cultivars both in summer as well as in *Kharif* season. The average size of operational holding of adopters in summer and *Kharif* seasons was found to be eight to nine hectares, all irrigated (Table 2).

Table 2. Land details of the sample adopters, Punjab, 2003-04

Category	Area (in hectares)					
	Own	Leased in	Leased out	Operational	Irrigated	Mungbean (SML 668)
Summer mungbean after wheat	6.69	1.50	0.36	8.19	8.19	1.02(12.45)
Summer mungbean after potato	6.51	2.26	0	8.77	8.77	1.19(13.57)
Kharif mungbean	5.71	2.41	0	8.12	8.12	1.69(20.81)

Note: Figures in the bracket indicate percentage to the total.
Source: Field survey, 2003-04.

The area planted to mungbean constituted about 12-13% of total operational holding in summer season and 21% in *Kharif* season. The assured tube well irrigation facilities were available to all the adopters of short duration cultivars of mungbean both in summer as well as *Kharif* season. Besides, tube well irrigation was supplemented by canal water in case of 30% summer mungbean growers and 10% *Kharif* mungbean growers (Table 3).

Table 3. Sources of irrigation on the sample farms, Punjab, 2003-04

Category	Canal	Tube well	Sample size
Summer mungbean after wheat	15	50	50
Summer mungbean after potato	16	50	50
Kharif mungbean	5	50	50

Source: Field survey, 2003-04.

The tractor-trailer, the basic important farm machinery, was owned by almost all the adopters of new short-duration cultivars of mungbean in summer season. In *Kharif* season too, majority of the adopters (about 78%) had this useful and costly machinery. The adopters were well-equipped with other need-based farm machinery such as drills, cultivators, and potato planter/digger etc.

Farmer's Preference Towards Short Duration Cultivars

The reason for the summer mungbean growers' preference for the short-duration cultivar (SML-668) was its rapid period of maturity, as reported by all the adopters (Table 4).

Table 4. Sample respondents' reasons for preference for SML 668 over other mungbean cultivars, Punjab, 2003-04

Reason for preference	Summer mungbean after wheat and potato	*Kharif* mungbean
Short-duration variety	100	-
Bold seed size	100	42
Higher yield potential	79	15
Resistant to MYMV	80	35
Adaptation in both seasons	15	32
Synchronous maturity	14	-
Overall	100	50

Source: Field survey, 2003-04.

Besides MYMV resistance, bold seed size and higher yield potential were also the attractions for adopting this new cultivar. The majority of adopters in *Kharif* season were influenced by MYMV-resistance and adaptability to both seasons (summer and *Kharif*).

Agronomic Practices

The mungbean growers in the study area used broadcasting and drilling methods of sowing. Most of the growers used drilling for sowing mungbean in the state. In summer season, the drilling method of mungbean sowing was more common (78%) among summer mungbean growers after potato, compared with summer mungbean growers after wheat (54%). In *Kharif* mungbean, 66% of the farmers used drilling and 34% used broadcasting as the methods for mungbean sowing. Harvesting through picking and combination is not very common among the mungbean growers. The mungbean crop was mainly harvested with sickles, and all the *Kharif* mungbean growers followed this practice. In the case of summer mungbean after potato, 88% farmers used sickles and 2 per cent used combine for harvesting. Majority of the farmers growing mungbean after wheat also practiced sickle harvest. Threshing with mechanical thresher was very common among the mungbean grower both in summer and *Kharif* seasons, yet a small number of growers in summer season followed traditional, manual harvesting practices. A few farmers (10%) in *Kharif* season used the modern combination technology for harvesting and threshing in the state.

Variability in Yields and Price Realized

Though the new short duration cultivar (SML-668) is considered high-yielding and MYMV-resistant, many variations have been observed in the yield produced by different growers in the state as demonstrated in Table 5.

Table 5. Percentage of farmers realizing different yield and price levels in mungbean, Punjab, 2003-04

Particular	Category		
	Summer mungbean after wheat	Summer mungbean after potato	*Kharif* mungbean
Yield (Tons ha^{-1})	**No. of farmers**		
< 0.5	5	1	9
0.5 –1.2	25	27	21
> 1.2	20	22	20
Sample size	50	50	50
Price (Rs ton^{-1})	**No. of farmers**		
< 15000	10	2	22
15000-22000	34	41	28
> 22000	6	7	-
Sample size	50	50	50

Source: Field survey, 2003-04

Most of the summer mungbean growers realized a yield in the range of 0.5 to 1.2 t ha^{-1}. The range of yield variation was found to be quite varied between a low of 0.25 t ha^{-1} and a high of 1.875 t ha^{-1} in the summer season. The gap between minimum and maximum yield was even more pronounced among the mungbean growers in *Kharif* season, i.e. minimum of 0.125 t ha^{-1} and maximum of 2.375 t ha^{-1} (Table 6).

Table 6. Range in different performance indicators among sample respondents, Punjab, 2003-04

Particular	Category		
	Summer mungbean after wheat	Summer mungbean after potato	*Kharif* mungbean
Yield (tons ha^{-1})			
Maximum	1.750	1.875	2.375
Minimum	0.25	0.25	0.125
Price (Rs ton^{-1})			
Maximum	26000	26000	27000
Minimum	7550	13000	10000
Net returns (Rs ha^{-1})			
Maximum	26305.00	26950.00	24300
Minimum	-5257.50	-880.00	-1743.20
Sample size	50	50	50

Source: Field survey, 2003-04

These variations may be mainly attributed to management practices in addition to soil quality and environmental factors especially occurrence of excessive rainfall at the time of harvest. The intensity of yield variation, as calculated through coefficient of variation was found as 40.81% for mungbean sown after wheat, 25.13% for mungbean after potato and 65.55% for the mungbean grown in *Kharif* season (Table 7).

Table 7. Coefficient of variation in different profitability indicators among sample respondents, Punjab, 2003-04

Particular	**Category** (Percent)		
	Summer mungbean after wheat	Summer mungbean after potato	*Kharif* mungbean
Yield	40.81	25.13	65.55
Price	22.13	13.16	24.89
Net returns	90.27	38.58	128.20
Sample size	50	50	50

Source: Field survey, 2003-04

Impact on Key Performance Indicators

Yield

The yield ha^{-1} of mungbean in all the rotations/ seasons, i.e. summer mungbean after wheat, summer mungbean after potato, and *Kharif* mungbean, have shown significant improvement in the current year (2003) compared with the previous year (2002) (Figure 1). The yield improvement in different rotations/seasons varied between 44% and 72%.

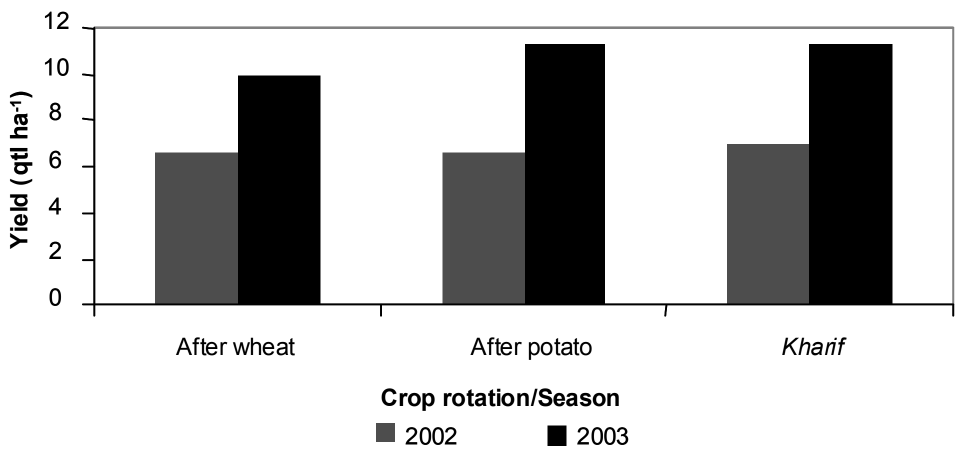

Figure 1. Change in yield of mungbean

This improvement in yields may be attributed to the improved understanding of the farmers on adopting new cultivar in terms of good agricultural practices (GAP), such as the use of recommended seed and fertilizer rate, doses of insecticides/ pesticides and herbicides, etc.

Price

The price of mungbean received by the farmers remained quite volatile partly due to the absence of effective government support for minimum price, and partly due to the product quality deterioration caused by the excessive rains at the time of harvest, especially in *Kharif* season. Most of the farmers sold their produce at the price that ranged between Rs 1,500 to Rs 2,200 100 kg^{-1} (Table 5). The price realized by the mungbean growers ranged between a low of Rs 775-1,300 to a high of Rs 2,600-2,700 100 kg^{-1} (Table 6). The coefficient of variation in price of mungbean realized by the growers was 13-22% in the summer season and 24.89% in the *Kharif* season (Table 7). The price analysis of mungbean brought out a significant decline (23%) in the price of mungbean in *Kharif* season of 2003 in relation to the prevailing price in the previous year (2002). In summer season, the price of mungbean grown after wheat showed marginal decline of about 5% (Figure 2).

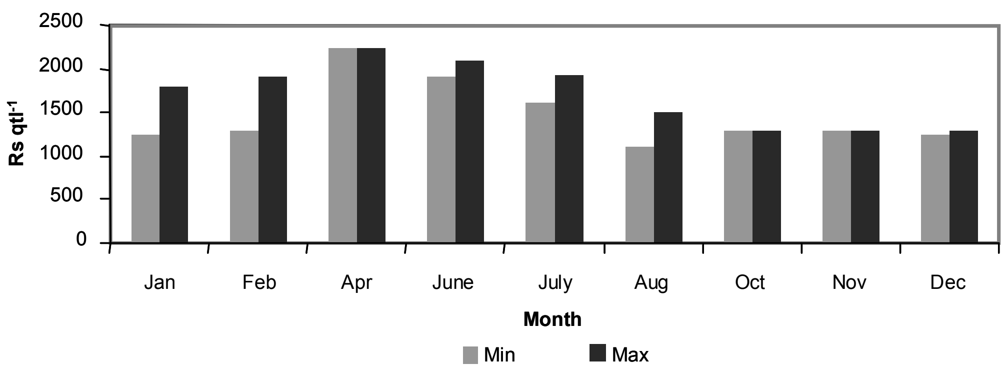

Figure 2. Change in price of mungbean

The seasonal (month-wise) price of mungbean in the two markets studied varied between Rs 1,100 100 kg^{-1} (lowest) in August 2003 and Rs 2,250 100 kg^{-1} (highest) in April 2003. The prices were found inversely related with the supply of product. The highest price level of mungbean prevailed in April, when only a minimum amount of mungbean arrived in the market. The new crop of summer season starts arriving in the market from June –July resulting in the decline of mungbean prices. Thereafter the production of mungbean grown in *Kharif* season begins arriving in the markets, causing the further decline in prices, touching floor limits in the months of October –December. Even within a given month, different mungbean growers realized different prices for their produce. The price varied between Rs 1,250-1,800 100 kg^{-1} in January and between Rs 1,100-1,500 in August. This price variation may be due to differences in quality and demand for the product. The maximum and minimum prices of mungbean that prevailed in a particular market in a particular month has also been demonstrated in Figure 3.

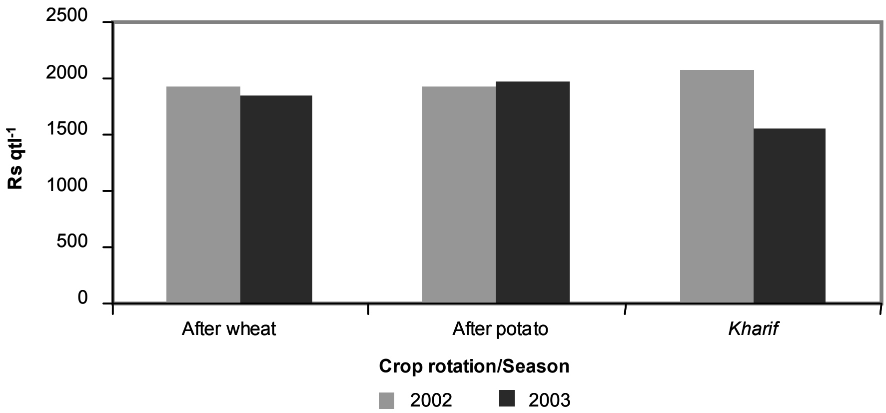

Figure 3. Seasonal price variation in mungbean in Punjab

Returns

The coefficient of variation in the returns over variable cost (ROVC) was 90.27% from crop sown after wheat, 38.58% from crop sown after potato, and a high of 128.20% from the crop sown in *Kharif* season (Table 7). The range of ROVC/ha produced from the crop sown after wheat, the maximum and minimum returns were Rs 26,305 ha^{-1} and Rs 5,257.50 ha^{-1}, respectively (Table 6). Similar variation has been observed in the crop sown after potato in summer season and in *Kharif* season as well. The negative figures of return over variable cost highlighted that some of the farmers incurred losses in mungbean cultivation in various rotations/ seasons. The practices of such mungbean growers need to be studied separately at micro level to pinpoint the problems and possible solutions. Even at a lower price, the significant yield enhancement promised encouraging improvement in the ROVC. The ROVC/ha has increased by about 54 –100% in different rotations in summer season and by about 30% in *Kharif* season in 2003 compared with the returns estimated for year 2002 (Figure 4).

Economics of Mungbean Cultivation

In order to estimate the cost of production of mungbean, various inputs purchased from the market were valued at the actual price paid by the farmers, and the home-produced inputs such as seed and farmyard manure, etc. were estimated at the prevailing market prices in the local market in a particular area. The family labor and machines they owned that were used at the farm were assessed at the prevailing wage rate for hiring casual labor and hiring charges for such machines during the survey period. The interest on the total variable cost was pegged at the rate of 14% per annum for half of the crop period. The total variable cost included human labor (family + hired) for all the farm operations, machine labor

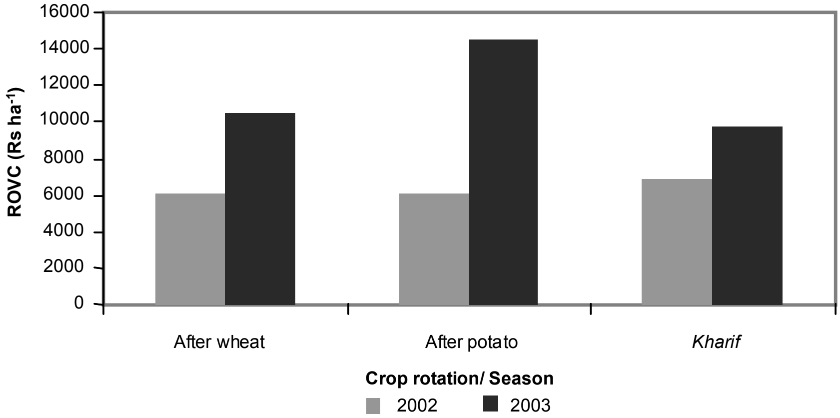

Figure 4. Change in return over variable cost of mungbean

(owned + hired) for all the farm operations, seed (farm-produced + purchased), fertilizers, farm manures, irrigation charges, plant protection material (insecticides/ pesticides + herbicides), petrol/diesel, and interest on the variable cost at the rate of 14% per annum for half of the crop period. The total output was evaluated at market prices actually realized by the farmers. The gross income per hectare of mungbean cultivation has been estimated by multiplying per hectare production of main product with their respective post harvest period prices. The ROVC was calculated by deducting variable cost per hectare from the gross income.

The gross income per hectare production of summer mungbean after wheat, summer mungbean after potato, and *Kharif* mungbean was Rs 18,289, Rs 22,021 and Rs 20,811, respectively (Table 8a and 8b). The total variable costs of cultivation were Rs 7,791, 7,451 and 8,348, respectively, which leaves a ROVC ha^{-1} of Rs 10,498 from summer mungbean after wheat, Rs 14,570 from summer mungbean after potato, and Rs 12,463 from *Kharif* mungbean, respectively in 2003 (Table 8a).

Table 8a. Returns (per ha) of summer mungbean on sample farms, 2002 and 2003

Particular	Summer mungbean after wheat			Summer mungbean after potato		
	2002	2003	Change	2002	2003	Change
Variable cost of cultivation (Rs)	6577.46	7791.13	1213.67	6577.46	7450.94	873.48
Yield (Rs qtl.$^{-1}$)	6.93	9.95	3.02	6.54	11.22	4.68
Price (Rs/qtl.$^{-1}$)	1930.00	1837.32	-92.68	1930.00	1962.62	32.62
Gross return (Rs)	13374.90	18289.05	4914.15	12622.2	22020.6	19398.40
Return of variable cost (Rs ha^{-1})	6797.40	10497.92	3700.48	6044.74	14569.66	8524.92

Table 8b. Returns (per ha) of summer mungbean on sample farms, 2002 and 2003

Particular	Mungbean		Paddy	
	2002	2003	2002	2003
Variable cost of cultivation (Rs)	7518.80	8347.87	11903.00	13281.00
Yield (Rs qtl.$^{-1}$)	8.09	13.06	57.41	58.72
Price (Rs qtl.$^{-1}$)	2064.00	1593.75	552.00	580.00
Gross return (Rs)	16697.76	20811.24	31690.00	34058.00
Return of variable cost (Rs ha^{-1})	9178.96	12463.37	19787.00	20777.00

Source: Field survey, 2003-04; 10 quintal = 1 t.

Comparative Economics of *Kharif* Mungbean and Paddy

The decline in area under mungbean in the state may be mainly caused by the lower comparative economics of this crop than its major competing crop (paddy) on irrigated lands in *Kharif* season. Table 8(b) shows that the paddy crop promised returns over variable costs of Rs 20,777 ha^{-1}, which was much higher than mungbean (Rs 12,463) in *Kharif* season. If farmers are convinced to take two mungbean crops instead of a single paddy crop (as the practice before the advent of short duration mungbean cultivars in the cereal-based cropping system) and coupled with effective price support, this may put a ray of hope for diversifying Punjab agriculture. This can be accomplished by replacing some area from paddy to these two crops. Summer and *Kharif* mungbean taken together yielded returns over variable costs of Rs 22,961 per hectare in 2003, which was more than that of paddy (Rs 20,777). It would be worth mentioning that, as observed on the yield levels of mungbean in the previous year (2002), even these two mungbean crops taken together were not able to bring to the farmers as much returns as they could have produced from paddy alone. The gap between the ROVC between the two-mungbean crops (summer + *Kharif*) and the competing crop, paddy, was observed at Rs 6,590 per hectare in 2002. Hence, higher, stable yield levels of mungbean both in summer as well as *Kharif* season, assured by effective price support, can be factors worth considering in replacing some areas from paddy crop to these two mungbean crops.

The realized yield of mungbean by farmers was found to be about 50-60% of the potential yield in the adaptive research trials compared with a high of about 85% in case of paddy. This big gap between the potential and realized yields of mungbean shows that there is an urgent need to strengthen further the agricultural extension wing of the state to disseminate effectively the available farm technology of mungbean production to farmers, the ultimate users.

Resource-Use-Efficiency in Mungbean Cultivation

In order to study the yield response (resource –use- efficiency) of summer and *Kharif* mungbean, Cobb-Douglas production function (power function) and linear production function were tried taking the dependent variable (yield of mungbean/ha) and various independent variables like human labor, machine use, seed, fertilizer (urea and diammonium phosphate (DAP)), insecticides/pesticides and herbicides both in terms of quantity (kgs, litres or hours/ hectare), as well as value (Rs ha^{-1}) separately for summer and *Kharif* mungbean. The following linear regression model was found better fit in terms of the value of coefficient of multiple determination and level of significance of different independent variables for summer as well as *Kharif* mungbean crops:

$$Y = a0+a1x1+a2x2+a3x3+a4x4+a5x5+a6x6+a7x7+u$$

Where

Y = Yield of mungbean grain (kg ha^{-1})
x1 = Human labor (hrs ha^{-1})
x2 = Machine labor (hrs ha^{-1})
x3= Seed(kg ha^{-1})
x4 =Urea (kg ha^{-1})
x5 = DAP (kg ha^{-1})
x6 = Insecticide/pesticides (Rs ha^{-1})
x7 = Herbicides (Rs ha^{-1})
a0 = Intercept
ai's = Regression coefficients of respective independent variable
u = Error term

The function was estimated using the Ordinary Least Square Method and the results have been presented in Table 9. The results brought out that in case of summer mungbean, the regression coefficient of seed was negative and significant under both the rotations, i.e. summer mungbean after wheat and summer mungbean after potato, implying that the application of excessive seed rate affected the mungbean yield adversely. The use of additional quantities of herbicides enhanced the mungbean yield under these rotations in summer season. In case of mungbean crop in *Kharif* season, the coefficient of human labor and machine labor were found to be positive and statistically significant, showing the need for additional units of these inputs to enhance the yield level of mungbean. Similar regression analysis fitted to the data of previous year (2002) had highlighted the need to increase seed rate, machine labor, insecticides/pesticides, and fertilizers to improve the yield of mungbean per hectare in both summer and *Kharif* seasons in Punjab. The comparative regression analysis of the years 2002 and 2003 brought out that in the later crop year, the mungbean growers used desired/increased level of different inputs, especially the seed and plant protection material, which contributed to the significant enhancement of the mungbean yields in 2003 compared to the 2002 levels.

Table 9. Resource use efficiency of mungbean cultivation on the sample farms in Punjab, 2003-04

Variable	Symbol	Unit	Regression coefficient		
			Summer Mungbean after wheat	Summer Mungbean after potato	*Kharif* mungbean
Intercept	.a0		31.48*	45.82**	-8.78*
Human Labor	X1	Hours	0.02	0.005	0.058*
Machine Labor	X2	Hours	0.08	-0.10	0.99**
Seed	X3	Kg	-0.65*	-0.91**	0.20
Urea	X4	Kg	-0.001	-0.007	-0.006
DAP	X5	Kg	-0.01	0.02	0.03
Insecticides/ Pesticides	X6	Rs	-0.003	0.0002	-0.003
Herbicides	X7	Rs	0.006*	0.004*	-0.005
RSQ			0.19	0.27*	0.28*

** significant at 1% level, * significant at 5% level.

Disposal Pattern of Mungbean Production

The disposal pattern of mungbean presented in Table 10 brought out that in case of summer mungbean after wheat, 73% of mungbean production was sold for consumption purpose and only 3% for seed purpose to fellow farmers. Summer mungbean growers after potato sold about 14% as seeds (12% to government agencies and 2% to fellow farmers) and 70% for consumption purpose. The corresponding figures for *Kharif* mungbean were about 1% for seed purposes and 78% for consumption. The important place for selling mungbean for consumption purpose was in the local market through private traders. It was observed that no processing of mungbean was done at the farmers' level. Mungbean sold for consumption purpose was wholly unprocessed. The growers sold most of the marketable mungbean surplus immediately after harvesting the crop both in summer and *Kharif* seasons.

Table 10. Disposal pattern of mungbean production on an average sample respondent farm in Punjab, 2003-04

Disposal	Category		
	Summer mungbean after wheat	Summer mungbean after potato	*Kharif* mungbean
Total production (kgs)	609.5(100.00)	1275.60(100.00)	1560.30(100.00)
1. Sold as seeds to			
(i) Government agencies (kgs)	-	173.60 (13.61)	9.00 (0.58)
(ii) Fellow farmers (kgs)	21(3.44)	21.9 (1.71)	4.00 (0.26)
2. Sold for consumption	445.1(73.01)	898.50(70.44)	1209.40(77.51)
3. Kept for self consumption (kgs)	49.20(8.1)	152.6(11.96)	62.30(3.99)
(i) For seed	31.4	110.50	20.80
(ii) For home consumption	17.80	42.10	41.50
4. Not sold	94.2(15.45)	29.00(2.28)	275.60(17.66)

Note: Figures in the bracket indicate percentage to the total.
Source: Field survey, 2003-04.

Constraint Analysis

Various technological (diseases, insects and weeds), environmental (rains and temperature), and marketing constraints perceived by mungbean growers in both seasons were analyzed. The constraint intensity was determined based on parameters such as mean score, number of farmers affected, percentage of yield losses, and percentage of maximum yield losses. This is presented in Table 11.

Table 11. Constraints intensity in mungbean production on sample farms, Punjab, 2003-04

Category	Constraint					
	Disease		Insect/ Pest		Weed	Environment
	MYMV	BLS	Pod borer	White fly	Itsit	Rain
Summer mungbean after wheat						
(i) Mean	0.12	0.04	0.42	0.10	0.32	0.68
(ii) % Farmers affected	6	1	20	5	13	19
(iii) % Yield losses	0.58	0.80	3.52	0.54	3.88	16.2
(iv) Max. % losses	10	40	30	10	50	70
Summer mungbean after potato						
(i) Mean	0.10	0.00	0.48	0.12	0.36	0.20
(ii) % Farmers affected	5	0	20	6	17	6
(iii) % Yield losses	1.30	0.00	7.70	0.84	1.56	4.40
(iv) Max. %Losses	20	0	50	20	30	75
***Kharif* mungbean**						
(i) Mean	0	0	0.46	0	0	0.14
(ii) % Farmers affected	0	0	23	0	0	7
(iii) %Yield losses	0	0	13.60	0	0	0.69
(iv) Max. % losses	0	0	50.00	0	0	50.00

Source: Field survey, 2003-04.
BLS- Bacterial leaf blight, Itsit- *Trianthema portulacastrum*

Disease was not reported as a serious problem, as the loss due to MYMV and BLS was only about 1% of the total production. Some summer mungbean growers reported that yield loss was actually lower than the expected based on the appearance of the disease on the crop. In the case of insects/ pest, pod borer (*Helicoverpa armigera*) was the major enemy of mungbean crop, causing losses of 3.52% in summer mungbean after wheat, 7.70% in summer mungbean after potato, and 13.80% in *Kharif* mungbean. Pod borer appeared on 20-23% mungbean growers in summer and *Kharif* season. The maximum yield losses caused by pod borer varied from 30-50% in different rotations. The major weed that caused yield loss in summer mungbean was itsit (*Trianthema portulacastrum*), which registered yield losses in mungbean after wheat (3.88%) and mungbean after potato (1.56%) as perceived by sample farmers. The farmers did not face any drought problem in any stage of the crop. It was found out that 38% of mungbean growers after wheat were seriously affected with rains that caused about 16 % loss in the yield of summer mungbean during its maturity stage. The maximum losses experienced by some summer mungbean growers were 70-75% due to excessive rains at this crucial stage of production. In *Kharif* season, most of the farmers did not experience any significant yield losses at any stage of the crop because of the rains.

Summer mungbean growers wanted scientist to develop moisture tolerant varieties for enhancing the yield levels of mungbean especially in the summer season. Among market-related constraints mungbean growers in both seasons identified elements such as price variability, lack of price information, and low market demand . Sample farmers unanimously felt that proper/effective price support can go a long way in strengthening the mungbean production base in the state. Hence, in order to effectively improve the income of farmers, diversify the state agriculture, and produce improved cultivars with desired traits, policy makers need to introduce an efficient marketing system and ensure proper price support.

Concluding Remarks/Policy Suggestions

Summer mungbean cultivation is an economically viable enterprise as shown in the length of the two-year study. There seems to be a big possibility for its further expansion as an additional crop during the fallow period between wheat/potato harvest and paddy transplantation in the cereal- fallows cropping system of the state. Regarding the possibility of replacing some paddy areas with mungbean during *Kharif* season, there seems to be a little prospect at the existing level of yield and price of mungbean. Paddy promised much higher returns than mungbean crops. Enable Mungbean (summer and *Kharif* taken together) yielded less returns over variable costs than that of paddy in 2002. But because of significant yield enhancement of mungbean both in summer and *Kharif* season in 2003, the combined returns from these two mungbean crops were better than single paddy crop. Therefore, higher, more stable yield levels of mungbean in both summer and *Kharif*, backed with effective price support, can make possible the replacement of some paddy areas with the two mungbean crops.

It is worth mentioning here that the realized yield of mungbean at the farmers' field was at about 50-60% of the potential yield in the experimental trials against a high of about 85% in paddy. This big gap, which existed between the potential and realized yields of mungbean, demonstrates that there is an urgent need to strengthen further the agricultural extension wing of the state to disseminate effectively the available farm technology of mungbean production to farmers. Yield loss due to pod borer was the major problem in mungbean cultivation in both the seasons.

The major weed Itsit (*Trianthema portulacastrum)* caused yield loss in mungbean. Significant yield losses due to rains at the time of maturity were reported. The mungbean growers wanted scientists to develop excess- moisture tolerant varieties to enhance yield levels of mungbean especially for summer season. Aside from price variability, lack of price information and low market demand were crucial marketing constraints identified by mungbean growers. In order to accomplish the basic objective of effectively improving the income of farmers, diversifying state agriculture, and developing improved cultivars with desired traits, policy makers need to ensure proper support for effective price schemes.

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Development and impact of iron-rich mungbean recipes

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Abstract

A survey of food and nutrient intake of 200 farm families from three agro-climatic zones of Punjab, viz. central plain zone, sub-mountainous zone, and western plain zone, revealed that the consumption of all food groups was adequate except pulses and legumes and green leafy vegetables. The daily per capita intake of energy, protein, fat, iron, folic acid, and ascorbic acid was also adequate. Though the intake of iron was nearly adequate, the blood hemoglobin levels of women indicated that 47% were anemic with an average hemoglobin level of 10.76 ± 0.08 g dl^{-1}. The average Body Mass Index (BMI) of women was 22.5 kg m^{-2} which is in normal range. However, 14% of the women had low body weights. Further, 36% of children below 5 years of age were smaller than the normal height for their age, while 27% were moderately undernourished, and 6 % were severely malnourished. The sensory evaluation of ten iron-rich mungbean recipes prepared from four mungbean varieties, viz. ML 613, Pusa Vishal, SML 668 and ML 818, revealed that ML 613 had maximum overall acceptability score. The total iron content of recipes varied between 3.03 to 9.04 mg $100g^{-1}$ dry matter with the highest iron content in mung spinach *saag*. The percentages of bioavailability of iron, along with the percentage of increase over raw mungbean values, were also determined in recipes namely Dhuli mung *dhal* (10.20% bioavailability, 39.53% increase), *Sabut* mung *dhal* (8.14% bioavailability, 11.35% increase), *Parantha* (11.32% bioavailability, 54.86% increase), Mung *dhal khichri* (9.16% bioavailability, 25.31% increase), Mung spinach *saag* (11.31% bioavailability, 54.71% increase), Mung sprout salad (10.66% bioavailability, 45.83% increase), Sprouted mungbean *pulao* (8.82,% bioavailability, 20.66% increase), *Dahi bhalla* (9.55% bioavailability, 30.64% increase), Mung spinach *pakodas* (9.73% bioavailability, 33.10% increase), and Mung *namkeen* (12.62% bioavailability, 72.64 % increase). The assessed impact of demonstration of iron-rich mungbean recipes as well as distribution of recipe books to the rural women revealed that 54% of the women tried two out of four recipes at home, while 16% prepared all the four recipes. The demonstration of recipes had greater impact on rural women than the distribution of recipe books alone. The change in food consumption was

not significant. However, a significant gain ($p \leq 0.01$) in knowledge, attitude, and practices score was observed at 77.7%. Therefore, imparting knowledge about iron-rich mungbean recipes can be an important measure to prevent iron deficiency anemia. However, a longer interaction time with the subjects is needed to bring about the desirable changes in their dietary pattern.

Introduction

The importance of optimal nutrition for health and human development is well recognized. The green revolution in India ensured that the increase in food production is faster than the increase in population. The country has moved from the age of chronic shortages to an era of surplus. In spite of the huge buffer stocks, every third child born in India is underweight. Despite the mortality rate decreasing by 50% and the fertility rate by 40%, the decrease in underweight incidence is only 20%. Half the pre-school children suffer from undernutrition. Micronutrient deficiencies are widespread. More than 320 million people in India suffer from iron deficiency anemia, with the highest prevalence among women and children. Nearly 40 to 80% pregnant women, 60 to 70% children, and 50% adolescent girls suffer from iron deficiency anemia (WHO, 2000). Iron deficiency anemia is the most prevalent nutritional disorder among urban and rural women of Punjab (Mann *et al.*, 1997 and Bains and Mann, 2000).

Though the country has achieved self sufficiency in food grains, there has been a progressive decline in pulse consumption especially among the poorer section in the last two decades. Mungbean is one of the major food legumes grown in India. Aside from being an excellent source of protein, it is a fair source of iron but its contribution to the iron nutrition of the consumer is limited due to phytates and other anti-nutritional factors. Many of these anti-nutritional factors can be eliminated or inactivated to a large extent by appropriate cooking during preparation of the dishes. Dehusking, soaking, ordinary cooking, sprouting, and fermentation improve the bioavailability of iron by wholly or partly removing some of the anti-nutritional factors and toxic constituents (Rosaiah *et al.*, 1993). Another way to improve iron bioavailability is through supplementation of mungbean products with ascorbic acid rich foods.

The dietary approach to alleviate iron deficiency anemia is the most sustainable but it is more complicated and involves a number of institutional and socio-economic factors. There is likewise the need to educate women on how to prepare dishes that are culturally acceptable to the family.

The objective of this research is to prepare mungbean recipes using inexpensive and easily accessible food ingredients for rural and urban poor families, and popularize said recipes to improve the iron status of the target group.

Materials and Methods

Nutritional Status of Farm Families

A sample of 200 farm families composed of 100 mungbean growers and equal number of non-growers from two districts in each of three agro-climatic zones of Punjab, viz. central plain zone, sub-mountainous zone, and western plain zone, was selected to provide information on their respective food intake by recall method through a questionnaire. The daily per capita nutrient intake was calculated using the MSU nutriguide computer program (Song *et al.*, 1992). The height and weight of all the children (1-5 years) and women (15-45 years) were taken using standard methods (Jelliffe, 1966). The Z-score classification system (WHO, 1997) was used to display the growth retardation prevalence for under-five-year-olds as measured by the proportion of weight for age and height for age below -2 and -3 standard deviations or Z-scores. The body mass index (BMI) of women was calculated using equation by Garrow (1981). Blood hemoglobin level of women (15-45 years) was determined using cyanomethemoglobin method (Dacie and Lewis, 1975).

Recipe Development

Ten mungbean recipes using simple processing techniques such as dehusking, soaking, pressure cooking, frying, sprouting and fermentation as well as use of ascorbic acid rich foods were developed and standardized in the laboratory using four mungbean varieties viz ML 613, Pusa Vishal, SML 668 and ML 818. The sensory evaluation of recipes was carried out by 10 panelists using 9-point hedonic scale to determine the suitability of these varieties for various recipes. The recipes prepared from the best variety were chemically analyzed for proximate composition (AOAC, 1980). The total iron content of the recipes using atomic absorption spectrophotometer after wet digestion (Piper, 1950) and *in vitro* available iron (Miller *et al.,* 1981) was also determined.

Iron-Rich Mungbean Recipe Intervention

A recipe book and a pamphlet containing information on the methods of preparation and the nutritional importance of iron rich mungbean recipes were prepared and published. Six recipe-demonstration camps in selected villages belonging to three agro-climatic zones of Punjab were conducted. The rural women were given demonstration of four recipes in each camp. A lecture on the nutritional problems identified in the area and the ways to cure them using mungbean was also delivered. All in all, 500 recipe books and pamphlets were distributed to rural households.

To study the impact of intervention given to the rural families, feedback was obtained from 100 households after a gap of two (2) months using a questionnaire. Knowledge, attitude and practice (KAP) scores were studied prior and after the intervention. Change in food intake was also observed. From the data obtained, the mean value and standard errors were calculated. One way analysis of variance was used to determine the significant difference between the acceptability score of four varieties, and student's t-test was used to study the impact of intervention on gain in KAP score and change in food intake.

Results and Discussion

Food and Nutrient Intake of Farm Families

The daily per capita intake of cereals was nearly adequate whereas the daily intake of pulses and legumes was inadequate compared with recommended dietary intakes (RDI) for Indians (ICMR, 1984) i.e. 23 g vs 30 g (Table 1). Consumption of fats and oils, sugar and jaggery, milk and milk products and other vegetables was above the recommended intakes, while leafy vegetable consumption was inadequate. The daily per capita energy and protein consumption was more than the recommended dietary allowances (RDA) prescribed by ICMR (1990). The consumption of dietary fat, folic acid and ascorbic acid was above the RDA while iron consumption was nearly adequate. The higher consumption of iron, folic acid and ascorbic acid by the farm families was due to higher availability of vegetables especially leafy vegetables during winter season when the survey was conducted. However, in summer season, the iron, folic acid and ascorbic acid intake was reduced drastically due to non-availability of most of the leafy vegetables. The dietary intake of farm families differed in winter and summer especially with respect to green leafy vegetables, the intake was significantly higher in winter as reported by Kaur (1985).

Nutritional Status of Women and Children

The blood hemoglobin levels of the women revealed that 47% were anemic, 11% mild degree of anemia, and 36% were moderately anemic (Table 2). The mean hemoglobin level of women was 10.76g dl^{-1}. Many survey studies in Punjab reported that 50 to 80% of adult women were suffering from different degrees of anemia. The hemoglobin level of rural Punjabi women was found to be 10.30g

Table 1. Per capita food and nutrient intake by the farm families

N=200

Food group/Nutrient	Mean ± SE	RDA (ICMR, 1990)
Food group, g		
Cereals	390 ± 5.30	400
Pulses	23.13 ± 0.67	30
Leafy vegetables	85.6 ± 2.40	100
Other vegetables	70.2 ± 1.63	50
Roots and tubers	149.7 ± 2.4	60
Milk and milk products	630.0 ± 10.0	250
Fats and oils	39.3 ± 0.60	20
Sugar and jaggery	73.6 ± 1.32	30
Nutrient		
Energy, Kcal	2887 ± 30	2400
Protein, g	89.3 ± 1.0	60
Fats, g	99.9 ± 1.53	20
Iron, mg	31.53 ± 0.53	30
Folic acid, µg	178.6 ± 2.9	100
Ascorbic acid, mg	115.9 ± 2.2	40

Table 2. Distribution of women on the basis of hemoglobin levels and body mass index

Classification	**No. of subjects** (N=310)
Anemia[a]	
Normal (11.0-14.0g dl^{-1})	165 (53)
Mild (10.0-10.9g dl^{-1})	35 (11)
Moderate (7.0-9.9g dl^{-1})	110 (36)
Body mass index[b]	
Low weight (18.5)	48 (14)
Normal (18.6-25.0)	184 (63)
Obese (>25.0)	78 (23)

Values in parenthesis are percentages

[a] WHO (1989)

[b] Garrow (1981)

dl^{-1} as reported by Mann *et al.*, (1997). The low hemoglobin values observed were caused by the farm families' dependency on vegetarian sources of iron with poor iron bioavailability. Though their diet had good amount of iron absorption enhancers such as ascorbic acid, it was also rich in inhibitors such as phytates from cereals and oxalates from vegetables. The high consumption of tea that is rich in tannins was also reported by these families. Average BMI of the subjects was 22.5 kg m^{-2} which is in the normal range. About 23% of women were obese and 14% had low body weights. The national data showed that 47% of women were underweight and 3.5-8.55 % were obese (WHO, 2000). The data showed that Punjabi rural women had higher energy status compared with average national values but the prevalence of anemia among them was close to the national values. Figure 1 and 2 indicate that 36% of children below 5 years old were smaller than the normal height for their age while the national data is 68%. Among children below five years old, 27% were moderately undernourished while 6% were severely malnourished against the national average of 47 and 18%.

Development of Iron Rich Mungbean Recipes

Sensory evaluation based on appearance, taste, texture and flavour of ten iron-rich mungbean recipes showed that recipes prepared from mungbean variety ML 613 had the maximum acceptability score for *Dhuli* mung *dhal*, *Sabut* mung *dhal, Parantha,* Mung *dhal khichri,* and Mung sprout salad. ML 818 had the maximum score for Mung spinach *saag*, *Dahi bhalla*, Mung spinach *pakodas* and Mung *namkeen* but this variety is not suitable for sprout making since the germination was very poor (Table 3). There was a non-significant difference for overall acceptability of recipes prepared from four varieties of mungbean.

Table 3. Overall acceptability of recipes developed from four mungbean varieties

Recipe	Variety			
	ML 613	Pusa Vishal	SML668	ML818
Dhuli mung *dhal*	8.1 ± 0.17	7.6 ± 0.21	7.2 ± 0.24	7.4 ± 0.26
Sabut mung *dhal*	8.0 ± 0.18	7.58 ± 0.34	7.67 ± 0.22	7.92 ± 0.28
Parantha	7.7 ± 0.34	7.5 ± 0.38	7.18 ± 0.27	7.18 ± 0.42
Mung *dhal khichri*	8.5 ± 0.16	8.2 ± 0.19	8.0 ± 0.14	8.2 ± 0.19
Mung spinach *saag*	7.36 ± 0.21	7.47 ± 0.32	7.0 ± 0.45	7.72 ± 0.29
Mungbean sprout salad	7.7 ± 0.29	7.4 ± 0.26	7.4 ± 0.21	-
Sprouted mungbean *pulao*	7.25 ± 0.52	8.16 ± 0.30	7.67 ± 0.28	-
Dahi bhalla	7.4 ± 0.21	7.9 ± 0.17	7.9 ± 0.17	8.2 ± 0.19
Mung spinach *pakodas*	7.58 ± 0.23	7.34 ± 0.25	8.08 ± 0.25	8.08 ± 0.25
Mung *namkeen*	7.90 ± 0.39	8.0 ± 0.83	7.90 ± 0.36	8.18 ± 0.19

Values are mean ± SE

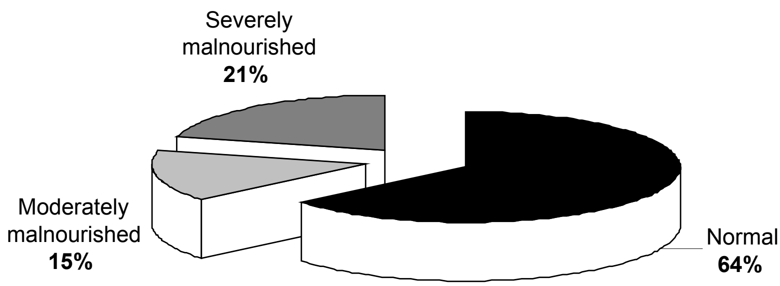

Figure 1. Percent distribution of children on the basis of Z-scores for height for age

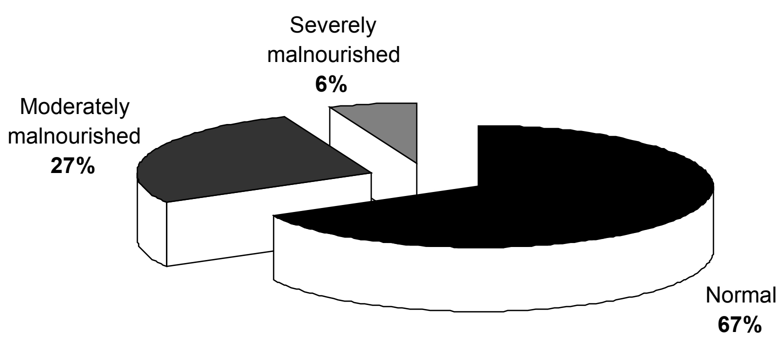

Figure 2. Percent distribution of children on the basis of Z-scores for weight for age

Proximate composition of the recipes on dry matter (DM) basis is shown in Table 4. The crude protein content of the recipes varied between 12.64 to 19.42%, where the maximum content was in *Sabut* mung *dhal*. The highest ash content was in Mung spinach *pakodas* (10.10%) followed by Mung spinach *saag* (9.30%) which was due to the inclusion of greens in the recipes. The wide variation in the ether extract i.e. 1.22 to 24.87 % was observed. The lowest ether extract value was in sprouted mung salad as no additional fat was added while high ether extract values were observed in *Dahi bhalla* (21.21%) and Mungbean *namkeen* (24.87%) as these recipes involved deep frying during cooking. The highest crude fibre content was in *Parantha* closely followed by *Sabut* mung *dhal*. The available carbohydrate content calculated from proximate principles ranged between 42.86 to 80.01 %, the minimum and maximum values were found in *Dahi bhalla* and Mungbean *khichri* respectively. The energy content of the recipes varied between 352.7 to 472.5 Kcal, the minimum energy content was in Sprouted mung *pulao* followed by mungbean sprout salad while the highest energy content was in Mung *namkeen* followed by *Dahi bhalla*. The wide difference in energy density of mungbean recipes is mainly due to varied amount of added fat in the recipes.

Table 4. Proximate composition, energy and iron content of the recipes per 100g dry matter

Recipe	Moisture%	Crude Protein%	Total ash%	Ether extract%	Crude Fibre%	Available CHO%	Energy Kcal	Iron mg
Mungbean raw	0.50	21.21	5.87	0.92	5.16	66.34	358.5	6.19
Mungbean, dehusked	3.85	19.85	1.78	1.02	1.74	71.76	375.6	4.74
Dhuli mung *dhal*	2.58	18.33	1.79	5.23	1.94	70.13	400.9	4.84
Sabut mung *dal*	3.21	19.42	8.38	4.85	5.60	58.54	355.5	6.78
Parantha	3.20	12.77	3.84	6.37	5.96	67.86	379.8	3.71
Mung *dhal khichri*	3.55	12.64	1.05	1.35	1.40	80.01	382.7	3.03
Mung spinach *saag*	6.22	13.34	9.30	6.98	4.52	59.64	354.7	9.04
Sprouted mung salad	6.47	19.20	2.50	1.22	2.68	68.43	361.5	2.96
Mung sprout *pulao*	5.68	14.70	5.40	1.25	2.30	70.67	352.7	6.34
Dahi bhalla	4.87	18.98	7.58	21.21	4.50	42.86	438.2	6.26
Mung spinach *pakodas*	2.76	17.45	10.10	6.67	5.25	57.77	360.9	5.78
Mung *namkeen*	2.73	15.70	8.38	24.87	1.86	46.46	472.5	4.16

The total iron content of the recipes varied between 2.96 to 9.04 mg $100g^{-1}$ DM. The lowest iron content was in sprouted mung salad while the highest iron content was in Mung spinach *saag* (9.04mg $100g^{-1}$ DM), followed by *Sabut* mung *dhal* (6.78mg $100g^{-1}$ DM). Sathya *et al.* (2002) standardized ten mungbean products for enhancing the iron bioavailability and reported that the total iron content of the products varied between 3.40 to 5.20 mg $100g^{-1}$ DM. The percent bioavailability of iron from whole mungbean and dehusked mungbean was 7.31 and 8.00 %, respectively. Various processing techniques and use of ascorbic acid and iron rich vegetables helped to increase the bioavailability of iron from the developed recipes (Figure 3). The percentages of bioavailability of iron were determined, along with the percentage of increase over raw mungbean values, in recipes namely *Dhuli* mung *dhal* (10.20% bioavailability, 39.53% increase), *Sabut* mung *dhal* (8.14% bioavailability, 11.35% increase), *Parantha* (11.32% bioavailability, 54.86% increase), Mung *dhal khichri* (9.16% bioavailability, 25.31% increase), Mung spinach *saag* (11.31% bioavailability, 54.71% increase), Mung sprout salad (10.66% bioavailability, 45.83% increase), Sprouted mungbean *pulao* (8.82,% bioavailability, 20.66% increase), *Dahi bhalla* (9.55% bioavailability, 30.64% increase), Mung spinach *pakodas* (9.73% bioavailability, 33.10% increase), and Mung *namkeen* (12.62% bioavailability, 72.64 % increase). A number of studies reported that the iron availability of mungbean can be enhanced significantly through food preparation. Yang and Tsou (1997) observed a seven-fold increase in dialyzable iron when ascorbic acid treatment was combined with cooking. Wet heating has enhanced effect on iron bioavailability. The presence of ascorbic acid can prevent the formation of less soluble ferric compound, thus increasing iron bioavailability. The mungbean to tomato ratio of 6g $100g^{-1}$ when cooked resulted in a high iron bioavailability of 15%.

Impact of Iron-Rich Mungbean Recipes Intervention

About 54% of women tried at home two out of four recipes demonstrated while 16% tried all the four recipes (Table 5). On the other hand, 63% of women tried recipes given in the book but not demonstrated. The results showed that demonstration of recipes had greater impact on rural women than the distribution of recipe books alone. Among the recipes, Mung *namkeen* was the most popular (42%), followed by Mung sprout salad (33%) and Mung spinach *pakodas* (25%). Majority (88%) did not encounter any difficulty in preparing these recipes. Most of the women wanted to have new mungbean recipes.

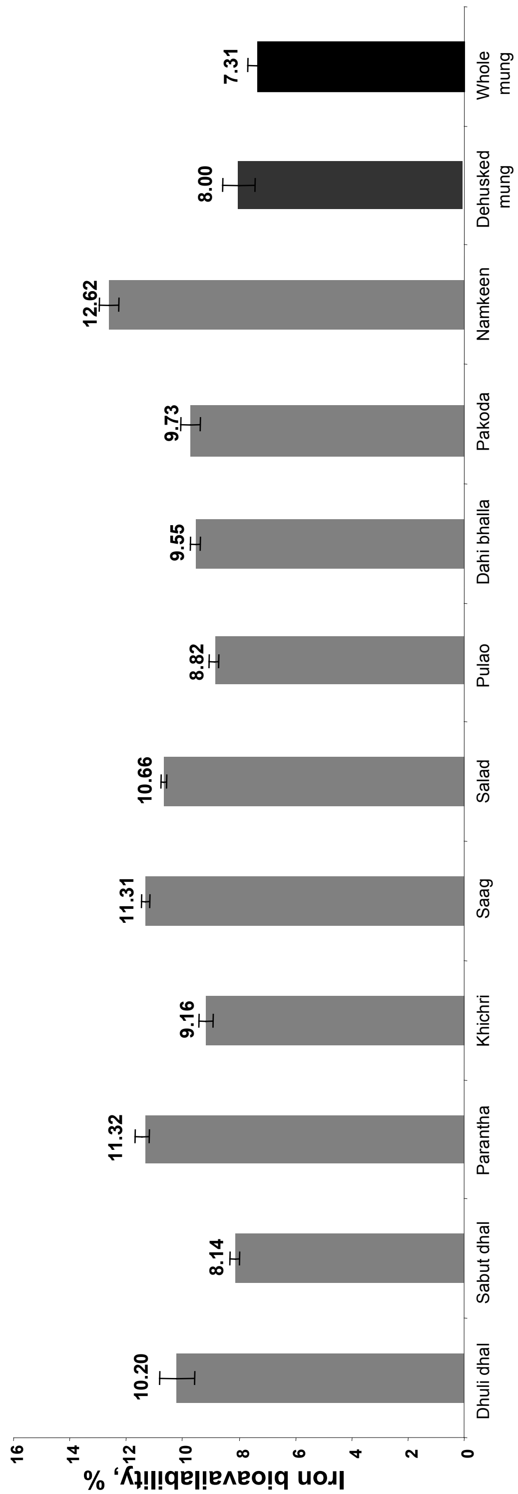

Figure 3. In vitro iron bioavailability from the recipes

Table 5. Impact of iron rich mungbean recipes intervention

Recipes tried at home	Percent of subjects
a) Demonstrated	
One	18
Two	54
Three	12
Four	16
b) In recipe book but not demonstrated	
One	25
Two	33
Three	5
Four	37
Best liked	
Mung *namkeen*	42
Mung sprout salad	33
Mung spinach *pakodas*	25
Difficulty in preparation	
Yes	12
No	88
New mungbean recipes	
Yes	92
No	8

There was an increase in the consumption of pulses (23.13 vs 26.60 g) and green leafy vegetables (85.6 vs 93.4 g) as shown in figure 4. An increase from 7.91 to 9.74 g in mungbean consumption after the intervention was observed (Figure 5) but the increase in food intake was statistically non-significant. However, a significant ($p \leq 0.01$) gain in KAP score ie 46.6 (77.7%) was observed (Table 6).

Table 6. Knowledge, attitude and practices (KAP) score of the rural women before and after the iron rich mungbean recipes intervention

	KAP score	Percent score
Before intervention	4.0 ± 0.5	6.5 ± 0.9
After intervention	50.6 ± 0.8	84.2 ± 1.5
Gain in knowledge	46.6***	77.7***

***Significant at 1 % level.

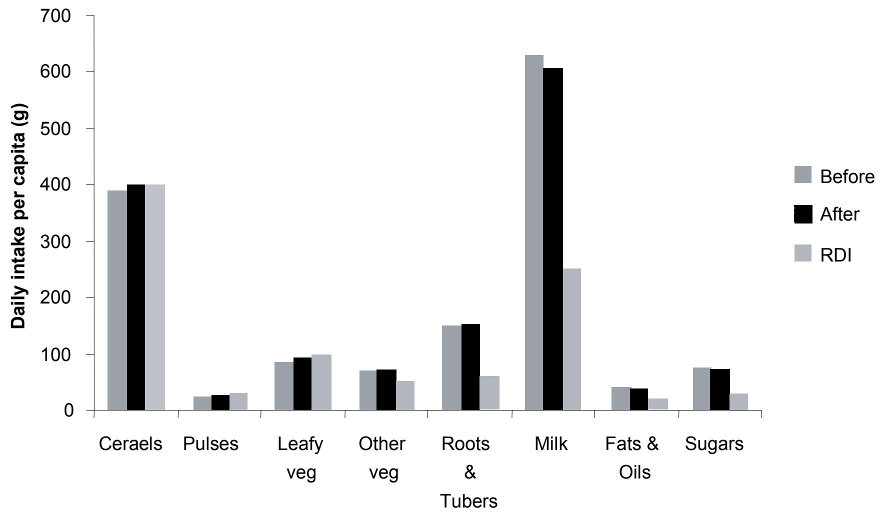

Figure 4. Daily per capita food intake before and after iron rich mungbean recipes intervention

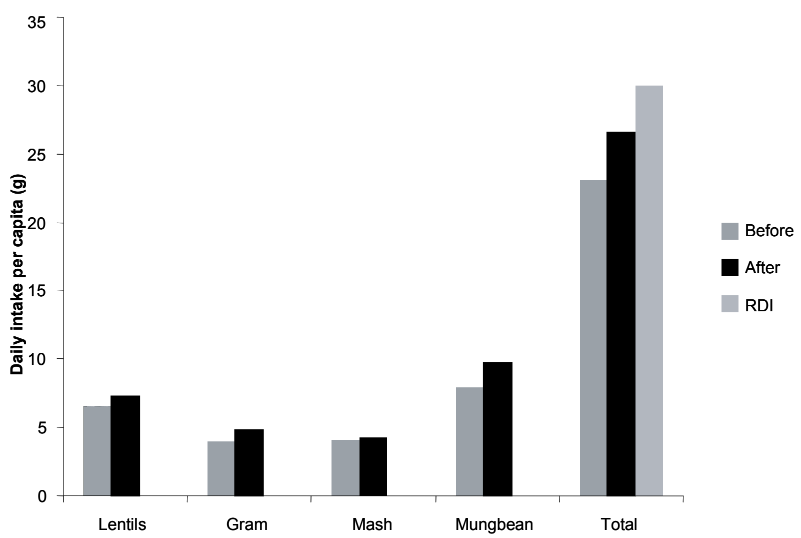

Figure 5. Daily per capita food intake of pulses before and after iron rich mungbean recipes intervention

Conclusions

The results of the study showed that undernutrition is scarce in Punjab. However, a significant number of women are suffering from iron deficiency anemia. Use of processing techniques (such as dehusking, soaking, pressure cooking, frying, sprouting), fermentation, and addition of iron and vegetables rich in ascorbic acid resulted in enhanced iron bioavailability of the mungbean recipes. Since the major cause of iron deficiency is low iron bioavailability from the diet, improving iron content by increasing the dietary iron bioavailability is the best way to combat iron deficiency. The demonstration of these recipes and distribution of recipe books to the rural women can be an important measure in preventing anemia but longer interaction with the women is needed to bring about desirable changes in their dietary pattern.

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Seed production, distribution and extension of Pusa Vishal in different states of India

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Abstract

Pusa Vishal is the first bold seeded variety of mungbean released by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties, for cultivation in spring/summer seasons for the North West Plain Zone (NWPZ) in June 2000. Pusa Vishal was developed out of a collaborative program between IARI and AVRDC in Taiwan. The variety was developed after repeated selections [for Mungbean Yellow Mosaic Viruses (MYMV) tolerance, determinate growth habit, synchronous maturity, bold seed size, and shining green color] for six generations from NM-92 obtained from AVRDC. Pusa Vishal is a short duration, MYMV-tolerant variety which is suitable for cultivation in fields vacated by Brassica, sugarcane, and potato. In the All India Coordinated program, its performance in agronomic trials was excellent, with yields of 1,541 kg ha^{-1} (1997 New Delhi), 1,724 kg ha^{-1} (1998 Ludhiana), 1,459 kg ha^{-1} and 1,614 kg ha^{-1} (1999 Ludhiana and Pantnagar, respectively). Although Pusa Vishal was released for NWPZ (Punjab, Haryana, Western Uttar Pradesh, Rajasthan, and parts of Jammu and Kashmir), it is also performing very well in other states such as Bihar, Orissa, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, Uttar Pradesh, Gujarat, and Maharashtra. The seeds of Pusa Vishal are produced and distributed by the Central State Farms Corporation and other state farm corporations for seed chain and minikit demonstration trials in farmers' fields in different states. Farmers prefer Pusa Vishal due to its short growth duration, MYMV tolerance, bold seed size, shiny green color, and its ability to fit in various cropping systems.

Introduction

Mungbean Pusa Vishal

Mungbean is an important crop in India. According to recent figures, area under this crop is 2.53 m.ha, with production of 0.86 m tons and productivity a mere 340 kg ha^{-1} (2001-2002). IARI has produced about a dozen mungbean varieties for spring/summer, *Kharif* and *Rabi* seasons. Some of these varieties such as

Pusa Baisakhi and PS-16 are with early maturity trait but have smaller seed size, indeterminate growth habit, and are susceptible to MYMV. At IARI, the main objectives of mungbean breeding are:

1. Breeding for 70-75 days duration varieties for spring season (mid-March sowing) with high yield potential (1,200-1,500 kg ha^{-1}) and MYMV resistance/tolerance in the field vacated by sugarcane, Brassica and potato, etc.

2. Breeding for short duration, MYMV-resistant, and high-yielding varieties (1,000-1,200 kg ha^{-1}) for the fields vacated by wheat (mid to late April sowing), with maturity period of 60 to 65 days, so that they can be harvested before the onset of monsoon around June 25.

3. Breeding for 75-80 days, MYMV-resistant, and high-yielding varieties (1,500-2,000 kg ha^{-1}) for planting in *Kharif* season as sole crop or inter crop with main *Kharif* crops.

4. Breeding for powdery mildew resistant varieties with high yield potential for the coastal areas of Andhra Pradesh, Tamil Nadu, and Orissa etc. for rice fallows in *Rabi* season.

For spring/summer season, two recently released varieties are Pusa Vishal and Pusa 9531. Pusa Vishal is the first bold-seeded variety released by the Central Sub-committee on Crop Standards, Notification and Release of Variety (CVRC) in June 2000. Pusa Vishal was developed out of a collaborative program between IARI and AVRDC, Taiwan since 1975. This variety has been developed after repeated selections for MYMV resistance/tolerance, while retaining its determinate growth habit, synchronous maturity, and bold seed size with shining green seed color.

Prior to its release in June 2000 by CVRC, the variety was tested for three years in various All India Coordinated Varietal Trials for yield potential, maturity duration, seed size, and reaction of various diseases, particularly MYMV root rot and root knot. These results are presented in Tables 1-7.

Table 1. Weighted mean of mungbean variety Pusa Vishal for years 1997, 1998 and 1999 during spring season in All India Coordinated Trials (NWPZ)

Variety	1997 AVT-1	1998 AVT-2	1999 AVT-1+2	Weighted Mean (3 years)	% increase over check
PS-16 (ch)	1,041 (5)	1,324 (3)	1,146 (4)	1,147 (12)	
K-851 (ch)	1,007 (5)	1,295 (3)	-	1,115 (8)	
PDM-54 (ch)	-	1,070 (3)	1,246 (3)	1,157 (6)	
Pusa Vishal	**1,226 (5)**	**1,630 (3)**	**1,231 (4)**	**1,329 (12)**	**-**
Pusa Bold-2	1,276 (5)	1,507 (3)	1,104 (4)	1,270 (12)	4.64[1]
HUM-9	1,221 (5)	1,332 (3)	924 (4)	1,152 (12)	15.36[1]
HUM-10	1,168 (5)	1,141 (2)	1,228 (4)	1,185 (11)	11.15[1]
HUM-6	1,198 (4)	984 (2)	1,212 (3)	1,155 (9)	15.06[1]
SML-390	-	1,112 (2)	568 (3)	785 (5)	-

[*]Percentage increase over qualifying varieties.
Numbers in parentheses = number of locations.
Ch = Check

Table 2. Weighted mean yield (kg ha^{-1}) of mungbean variety Pusa Vishal compared with other varieties in the summer season of 1997, 1998 and 1999 in NWPZ in All India Coordinated Trials

Variety	1997	1998	1999	Weighted Mean (3 years)	% increase over check
PS-16 (ch)	1,473 (2)	1,030 (1)	845 (3)	1,102 (6)	
K-851 (ch)	1,481 (2)	-	-	1,481 (2)	
PDM-54 (ch)	-	-	761 (3)	761 (3)	
Pusa Vishal	**2,166 (2)**	**1,788 (1)**	**1,017 (3)**	**1,528 (6)**	**-**
Pusa Bold-2	1,811 (2)	1,622 (1)	860 (3)	1,304 (6)	17.17[1]
HUM-9	1,717 (2)	1,380 (1)	-	1,604 (3)	-
HUM-10	1,747 (2)	1,145 (1)	850 (3)	1,198 (6)	27.54[1]
HUM-6	1,623 (2)	1,296 (1)	962 (3)	1,238 (6)	23.20[1]
SML-390	1,697 (2)	978 (1)	948 (3)	1,203 (6)	27.01[1]

[1]Percentage increase over qualifying varieties.
Number in parentheses = number of locations.
Ch = Check

Table 3. Seed yield (kg ha^{-1}) of promising genotypes of mungbean in spring as influenced by urea spray in agronomy trial

Genotype	Location – Ludhiana Grain yield (kg ha^{-1})	
	1998	1999
PDM 91-243	1,682	1,103
SML 357	1,957	1,614
IIPRM 3	1,475	937
Pusa Vishal	**1,724**	**1,459**
SML 134	1,629	1,488
PDM 11	1,375	903
Pusa 9531	1,777	1,577
C.D. 5%	28	107 (LSD P=0.05)
CV %	13.5	
Urea spray treatment	**Yield (kg ha^{-1})**	
No spray	1,595	NS
Spray (2% urea)	1,727	NS
C.D. 5%	47	NS
CV %	4.3	NS

Table 4. Yield (kg ha^{-1}) response of different varieties to different seed rates in Pantnagar, India in spring season, 1999

Genotype	Seed rate (kg ha^{-1})			
	25	30	35	Mean
PDM 11	1,363	1,553	1,375	1,430
Pusa 9531	1,487	1,636	1,671	1,589
Pusa Vishal	1,381	1,606	1,855	1,614
Pusa Bold 2	1,274	1,505	1,683	1,487
UPM 98	1,730	1,884	1,985	1,866
HUM 8	1,849	1,837	1,541	1,742
Mean	1,514	1,670	1,685	

	Genotype	Seed rate	Interaction
S.Em.$\pm$	68	48	117
LSD (P = 0.05)	196	139	138
CV %	12.5		

Table 5. 100-seed weight of mungbean variety Pusa Vishal in Spring 1997 and 1998 in different location

Variety/ Season	Spring 1997							Summer 1997			Spring 1998				Summer 1998
	Faridkot	Gurdaspur	Pantnagar	Raya	Hissar	Delhi	Zonal Mean	Faridkot	Delhi	Mean	Pantnagar	Gurdaspur	Delhi	Zonal mean	Delhi
Ps 16 (ch)	3.7	3.2	3.3	3.2	4.3	3.2	3.5	3.0	3.1	3.1	3.1	3.1	3.2	3.1	3.2
K 851 (CH)	3.7	3.1	3.2	3.2	4.4	4.0	3.6	3.3	3.5	3.4	3.1	3.1	3.8	3.5	-
Pusa Vishal	**4.9**	**5.3**	**6.4**	**5.2**	**7.4**	**6.6**	**6.0**	**5.2**	**5.8**	**5.5**	**5.5**	**5.1**	**5.8**	**5.7**	**5.9**
Pusa Bold 2	5.3	5.3	5.7	5.3	7.3	6.5	5.9	5.4	5.9	5.7	5.7	5.1	5.9	5.8	5.7
SML 357	3.6	3.1	3.2	3.2	4.3	3.2	3.4	-	-	-	4.0	3.1	3.9	4.0	-
HUM 9	3.4	3.1	3.6	3.4	4.1	3.7	3.6	2.8	3.0	2.9	3.3	3.1	3.5	3.3	3.7
TM 56-1	4.4	3.1	4.3	3.2	4.7	3.5	3.9	3.3	3.3	3.3	-	-	-	-	-
KM 2143	3.5	3.1	3.6	3.3	4.8	3.6	3.6	3.7	3.5	3.6	3.0	3.1	3.4	3.2	3.7

Table 6. Reaction of mungbean advanced varietal trial (AVT) entries to different diseases in spring 1998

Entry/ Disease	Yellow Mosaic Virus (1-9 scale)[a/]				Root rot (%)	Rootknot nematode (0-5 scale)[b/]
	Pantnagar	**Dholi**	**Kanpur**	**Hissar**	**Pantnagar**	**Ludhiana**
AVT-1						
UPM 98	1.0	2.0	1.0	1.0	0.0	1.4
UPM 97-34	1.0	4.0	1.0	1.0	0.0	1.6
Pusa Bold 4	1.0	4.0	1.0	2.0	0.0	2.6
AVT-2						
PDM 11	1.0	3.0	3.5	1.0	2.0	3.2
Pusa 9531	3.0	3.0	1.5	1.0	6.0	4.6
Pusa 9631	3.0	3.0	2.0	1.0	0.0	3.2
Pusa 9632	1.0	3.0	4.5	1.0	4.0	2.4
HUM 8	1.0	2.0	1.5	1.0	4.0	3.2
HUM 9	3.0	3.0	2.5	1.0	0.0	2.8
Pusa Vishal	**3.0**	**2.0**	**1.0**	**1.0**	**0.0**	**1.6**
Pusa Bold 2	3.0	3.0	3.5	1.0	0.0	2.0
IIPRM 3	1.0	2.0	3.0	1.0	4.0	2.2
KM 2143	5.0	5.0	5.0	2.0	8.0	2.0
Pusa 9331	3.0	4.0	2.5	1.0	6.0	3.6
Pusa 9332	3.0	5.0	3.0	1.0	0.0	3.4
PDM 91-243	1.0	3.0	1.5	1.0	2.0	2.2
SML 357	1.0	5.0	1.5	1.0	2.0	1.6
L.ch./ K 851	3.0	9.0	4.0	3.0	6.0	5.0
L.S.I.	2.1	3.6	2.4	1.3	2.4	2.7

a/1 = no disease, 3 = severely infected.

b/1 = no nematode lesions, 5 = severe lesions.

Table 7. Seed production of mungbean variety Pusa Vishal (2001-2003)

Farmer/ Agency	Quantity of seed produced (t)	Source
IARI, Seed Production Unit, New Delhi	2001-2003: 4.4	Dr. J.N. Singh, Principal Scientist
IARI, Regional Station, Karnal, Haryana	2002: 0.9 2003: 1.8	Dr. S.N. Sinha, Head, IARI, Karnal
IARI, Regional Station, Pusa, Bihar, Samastipur	2002: 0.5 2003: 0.7	Dr. S. Chaowdhry, Head, IARI, Pusa, Bihar
State Farm Corporation of India (SFCI)	2002: 6.6 2003: 43.6	Dr. M.R.C. Reddy, SPO, SFCI
Malook Singh, Village: Rasoolpur, Distt. Hapur, Uttar Pradesh	2002: 1.5 2003: 0.7	Shri. Malook Singh, Village: Rasoolpur, Hapur
Sunil Kr. Chaturvedi Tirupati Krishi Kendra Babarpur, Ajitmal Distt. Etawah, UP	2003: 0-8	Shri Sunil Kumar, Chaturvedi (Farmer)

Seed Production

Breeder's seed – The mandate to produce breeder's seed lies with the concerned breeder against the indent of Ministry of Agriculture. At IARI, 50 to 100 kg seeds of Pusa Vishal are produced every season in the last two to three years. Certified seed is produced by the National Seeds Corporation, State Farm Corporation of India (SFCI), and various state seed corporations of various States. The seed produced by SFCI are listed in Table 8. Seed demand for Pusa Vishal is increasing in Punjab, Haryana, Delhi, UP, Maharashtra, MP, and Bihar.

In the future, large-scale seed multiplication of Pusa Vishal is planned to meet the growing demand of farmers. Pusa Vishal may likely replace many old mungbean varieties, including Pusa Baisakhi, T-44, PS-16, K-851, ML-5, ML-267, etc. in various states.

Descriptor of Pusa Vishal

1. General	
1.1 Name of the variety	***Pusa Vishal***
1.2 Pedigree	Selection of NM-92
1.3 Year of development	1993-1997
1.4 Year of release	June 2000
1.5 Origin (name of the institute)	IARI, New Delhi-110012
2. Growth habit	Determinate, erect and early
3. Leaf characters	
3.1 Simple compound	Compound
3.2 Shape of the leaf panicle	Ovate
3.3 Color	Green
3.4 Pubescence/ glabrous	Pubescent
4. Stem color	Green
5. Flower color	Cream
6. Pod color	Light brown
7. Seed color	Green shining
8. Agronomic traits	
8.1 Days to 50% flowering	40-45 days (spring) and 35-40 days (summer)
8.2 Days to maturity	65-70 days (spring) and 60-65 days (summer)
8.3 Plant height (cm)	44.5 cm
8.4 No. of primary branches	3-4
8.5 Pods per plant	20-25
8.6 No. of seeds per plant	12-13
8.7 100 seeds weight (gm)	5.5-6.0
9. Disease reaction	MYMV-resistant in spring/summer
10. Pest reaction	Resistant to most of the pests
11. Quality character	Good in cooking & uniform in sprouting

Recommendation of Central Sub Committee on crop standard, notification and release of varieties for Agricultural crops on 20 June 2000*

Mungbean

1. Pusa Vishal – Recommended for release and for cultivation for Punjab, Haryana, Western UP, Rajasthan, Jammu, and Kashmir, and the Plains of Himachal Pradesh. It is recommended for spring/summer season.The Committee also decided to change the name of cultivar to Pusa Vishal from Pusa Bold-1 to avoid confusion with another variety of Pusa Bold in rape seed and mustard.
   Notification No.: S.O.-92(E) dated 2.2.2001

2. Pusa 9531 – recommended for release and for cultivation for Punjab, MP, Western UP, and Haryana. It is suited in summer season for mid April sowing after wheat harvest.
   Notification No. S.O.-92(E) dated 2.2 2001

*Source: Proceeding of the 33rd meeting of CVRC held on 20 June 2000.

Scope of mungbean (*Vigna radiata* (L.) Wilczek) in Rajasthan (India) : Technology and extension gaps in productivity

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Abstract

Mungbean (*Vigna radiata* (L.) Wilczek) is an important crop of Rajasthan (India). In Rajasthan where irrigation facilities are available summer mungbean can be raised successfully after Brassica (*Raya*) or wheat. To evaluate the economic feasibility of technology transfer and adoption in mungbean in semi-arid region of North-West Rajasthan, 282 front line demonstrations were conducted in Sriganganagar district of Rajasthan during 1991-2000. Adoption of improved technology had significant impact on grain yield vis-à-vis yield gaps in mungbean. Improved technology enhanced mungbean yield from 532 kg ha^{-1} (farmer's practice) to 712 kg ha^{-1} (improved practice), an overall increase of 33.8 per cent. The overall adoption index percentage of various inputs increased from 5.54% (1991) to 18.15% (2000). Among the critical inputs, variety/genotype ranked first, followed by fertilizer, pesticide, weeding, and irrigation. The comparative profitability due to improved technology over a decade period changed from 0.93 to 2.72 and for local practices from 0.81 to 1.88, respectively. The narrowed gap between average benefit-cost ratio of improved technology (2.00) and local practice (1.44) proves adoption of improved technology by the farmers. However, to further bridge the gap between technology developed and technology transfer, there is a need to strengthen the extension network. Fine-tuning recommendations for specific locations is also required.

Introduction

In Rajasthan, although the area under mungbean increased from 373,863 ha to 457,940 ha during the decade 1990-2000, production and productivity decreased drastically. In 1990 the production and productivity of the crop was 130,396 t and 349 kg ha^{-1} respectively, which went down to 79,318 t and 173 kg ha^{-1} respectively in 2000. Individual year production figures of the state indicates drastic increase and decrease in productivity levels ranging between 99 kg ha^{-1} (1999) and 410 kg ha^{-1} (1996). This happened primarily due to erratic distribution of monsoon and relegation of pulses to marginal lands with low fertility and under rainfed situation (Kaushik, 1993). Non-availability of quality seeds of promising cultivars and susceptibility to pest and diseases are the major constraints, which limit pulse production. To boost mungbean production and productivity in the state, the special program of 'Front Line Demonstrations' under National Pulses Improvement Project was initiated in the year 1990-1991. This program aims to demonstrate potential benefits from latest production and protection technologies vis-à-vis traditional farming practices.

Materials and Methods

Over the decade 1991-2000, a total of 282 front line demonstrations were conducted on mungbean crop at farmers' fields in Sriganganagar district, which is situated in the semi-arid region of North-West Rajasthan. The soils at the demonstration sites were sandy loam, low in organic carbon (0.2%), medium in P (24 kg ha^{-1}) and high in K (320 kg ha^{-1}) with alkaline reaction (pH 8.4). All the demonstration plots were planted on irrigated fields with fallow-mungbean, wheat-mungbean, and mustard-mungbean rotations which are the cropping systems prevalent in the area. Recommended inputs under package and practices of the zone for 0.2 ha block were provided to the farmers.

The sowing in demonstration plots was done during first fortnight of July every year with improved mungbean varieties K 851, MUM 2, and Ganga 8 using seed rate of 16 kg ha^{-1} with row-to-row spacing of 30 cm and plant-to-plant spacing of 10 cm, respectively. A basal application of 20 kg N and 40 kg P2O5 ha^{-1} was made to the crop. To protect the crop from seed-borne pathogen, seed treatment with captan or thiram at 3g kg^{-1}seed was done. The soils in the demonstration site suspected of termite infestation were applied with 25 kg quainalphos (1.5%) per hectare. Incidence of yellow mosaic virus was kept below threshhold level by controlling sucking pest through foliar application of Phosphomidon 85 WSC 250 ml/ha. The first spray was applied 15-20 days after sowing. The crop was protected against pod borer attack by spraying Endosulfan 35 EC at 1200 ml ha^{-1} at flowering and pod formation stage. To check bacterial and fungal invasion spray mixture of streptocycline 5 g and copper oxychloride 300 g in 100 litre of water was used. The crop received three irrigations, one at pre-sowing and the remaining two at vegetative and pod formation stage. Finally, yields were obtained and cross sectional data on output and input/ ha were collected from Front Line Demonstration plot. Similarly, observations from an equal-sized area were also recorded on traditional practices followed by the farmers of the corresponding locations.

The cost-benefit ratio was calculated based on gross returns. To estimate the technology gap, extension gap, and technology and adoption indices, the following formulae were used:

Technology gap	= Potential yield (Pi) –Demonstration yield (Di)
Extension gap	= Demonstration yield –Farmer's yield
Technology index	= Pi – Di/ Pi x 100
Adoption index (Ai)	= Ai/ Ri x 100

Where
Pi = Potential yield of the ith crop,
Di = Demonstration yield of ith crop,
Ai = Adoption score obtained by the farmers for ith crop
Ri = Possible maximum score of the ith crop

Potential yield refers to the yield level reported by the research scientist of the concerned technology included in the package of practices. Farmer's yield is the yield reported by the farmers observed in his own plot using his own practice of cultivation.

Adoption index (Ai) is calculated by taking six major components of technological practices in mungbean crop, viz. seed rate, seed treatment, weeding, fertilizer, irrigation, and pesticides use. Each component is assigned score of '2' for full adoption, '1' for partial adoption, and '0' for no adoption. Thus, maximum score of 12 can be obtained by a farmer if he follows complete adoption of all the six components. The maximum possible score 'Ri' is the product of number of farmers to whom the demonstration has been given and maximum obtainable score by a farmer, i.e. 12.

Results and Discussion

Out of 300 front line demonstrations allotted to the Agricultural Research Station, Sriganganagar by the Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India under the All India Coordinated Research Programme (AICRP) on Pulses during the decade 1991-2000, 282 front line demonstrations were conducted. Out of said FLDs, 45 yielded within the range of 1000-1500 kg ha^{-1}, 184 between 500-1000 kg ha^{-1} and 53 in the lower yielding category (<500 kg ha^{-1}), which may be attributed to biotic (whitefly/MYMV) and abiotic (soil heterogeneity, water scarcity, high temperature) stresses during different years.

Yield Gaps

Data presented in Table 1 indicate an overall average increase of 33.8% in yield due to adoption of improved technology. The yearly increase in yield in different years ranged between 26.1 to 44.8 percent. However, there seems to be possibilities for further improvement in yield under improved technology category as the potential yield of mungbean in different years had a margin over yield under improved technology. The weather conditions, microclimatic situations, and soil fertility may also be responsible for the gap between average potential yield (820 kg ha^{-1}) and front line demonstration improved practice yield (712 kg ha^{-1}). To bridge this gap, location-specific recommendations are needed (Kadian *et al*.,1997; Siag *et al*.,2002). The comparative data on productivity, however, indicated higher productivity of mungbean in the Ganganagar district (413 kg ha^{-1}) compared to productivity of the state (234 kg ha^{-1}) and country (385 kg ha^{-1}).

Technology and Extension gaps

The technology gap during the period of study ranged between 0.40 to 1.75 compared to marginally higher value (1.35 – 2.11) of extension gap. The narrow gap between two components, i.e. technology (1.08) and extension (1.80), suggest a little bit further improvement in the extension activities which may result in better adoption of improved technology. Therefore, efforts are needed from both sides, i.e. research and extension, to strengthen their activities which will enhance the average productivity of mungbean in the zone. Productivity is still lower than potential yield of the crop in the district which is between 600 and 1000 kg ha^{-1}.

Technology and Adoption Index

Technology index works as yard stick of adoption of improved technology. Data indicates a narrow gap of only 0.90 per cent between technology index (13%) and adoption index (12.10%) over a decade of study. Improvement in extension network or further refinement in technology based on regional approach may ultimately bridge this gap (Kadian *et al.*, 1997; Prasad *et al.,* 1993; Siag *et al.,* 2000).

Comparison of Yield and Cost Benefit Ratio

Though the individual year data indicate erratic upward and downward trend in yield due to biotic and abiotic pressure, an average increase of 180 kg ha^{-1} has been achieved due to adoption of improved practices in front line demonstrations (Suryawanshi and Prakash, 1993; Siag *et al.*, 2000).

Table 1. Yield gaps between technology and extension gap for mungbean in different years (*Kharif* 1991-2000)

Year	Allot-ted	Con-ducted	Yield (kg ha^{-1})			% increase over control	Productivity (kg ha^{-1})			Tech. gap	Ext. gap	Tech. index (%)	Adopt index (%)	B : C ratio	
			Poten-tial[1]	I/P[2]	F/P[3]		SGNR	Raj.	India					IP	FP
1991	30	27	800	636	439	44.8	341	349	399	1.64	1.97	20.5	5.54	2.28	1.04
1992	30	30	800	728	566	28.6	500	121	389	0.72	1.62	9.0	7.0	1.27	0.88
1993	30	30	600	543	394	37.8	420	125	471	0.57	1.49	9.5	6.82	0.93	0.81
1994	30	30	800	664	515	28.9	502	387	419	1.36	1.49	17.0	9.82	1.93	1.78
1995	30	30	1000	857	646	32.7	306	306	369	1.43	2.11	14.3	11.95	2.43	1.80
1996	30	30	1000	932	739	26.1	509	411	303	0.68	1.93	6.8	13.88	2.33	1.81
1997	30	30	800	691	503	37.4	252	260	425	1.09	1.88	13.6	13.92	1.80	1.30
1998	30	30	1000	825	616	33.9	500	110	316	1.75	2.09	17.5	16.85	2.72	1.88
1999	30	15	800	680	478	42.3	400	99	380	1.20	2.02	15.0	17.22	2.36	1.76
2000	30	30	600	560	425	31.8	400	173	381	0.40	1.35	6.7	18.15	2.00	1.35
Av. of 10 yrs	300	282	820	712	532	33.8	413	234	385	1.08	1.80	13.0	12.1	2.00	1.44

[1] Research Data SGNR - Sriganganagar
[2] Demonstration Yield Raj - Rajasthan
[3] Farmers Practice Tech - Technology
Ext. - Extension
I/P - Improved practice
F/P - Farmer practice

The economic viability of front line demonstrations was shown by the cost benefit ratio between improved and traditional farmer practices. Economic studies of individual years over a decade indicated that adoption of improved practices yielded more profit compared to farmer's practice, though the difference was marginal. The comparative profitability due to improved technology over a decade changed from 0.93 to 2.72 and for local practices from 0.81 to 1.88, respectively.

The gap between average cost-benefit ratio of improved technology (2.00) and local practice (1.44) was narrowed down which proves adoption of improved technology by the farmers. Clearance: On the start of the study in 1991 the gap between IP and FP was 1.24 (2.28-1.04) which was narrowed down to 0.65 (2.00-1.35) (Table 1). On overall mean basis, the gap is only 0.54 (2.00-1.44) which means that the gap has been covered due to adoption of the technologies by the farmers.

Impact of Front Line Demonstration on Adoption Index

The comparative study of adoption index percentage of different inputs revealed maximum increase of 45.6% under varietal component where adoption index increased from 1.2% (1991) to 16.7% after completion of study (2000). Fertilizer component ranked second, exhibiting overall per cent increase in yield of 38.2. The percent adoption index under this component increased from 3.1 to 17.8 per cent over a decade. The other input component which were ranked III, IV and V in terms of per cent increase in yield in descending order of merit were pesticide (34.2%), weeding (27.9%), and irrigation (23.1%). The adoption index percentage under these components increased from 4.3 to 18.3% (pesticide), 9.9 to 20.0% (weeding) and 9.2 to 17.2% (irrigation) (Tables 2 & 3). The overall adoption index percentage of various inputs increased from 5.54% (1991) to 18.15% (2000) over a decade. Similar observations have been made by Siag *et al.* (2000, 2002) in chickpea crop.

Table 2. Percentage of adoption index in Front Line Demonstrations of mungbean from 1991-2000 for different components

Component	Year		Difference in adoption index	Rank
	1991	2000		
Variety/ Genotype	1.2	16.7	15.5	I
Fertilizer	3.1	17.8	14.7	II
Pesticides	4.3	18.3	14.0	III
Weeding	9.9	20.0	10.1	IV
Irrigation	9.2	17.2	8.0	V
Adoption Index percent	5.54	18.15		

Table 3. Percentage of increase in the grain yield of mungbean by individual factors over traditional practices

Component	Percent increase in comparison to traditional practices
Variety/ Genotype	45.6
Fertilizer	38.2
Pesticides	34.2
Weeding	27.9
Irrigation	23.1

Conclusion

Many areas can be planted to summer mungbean in Rajasthan after wheat or Brassica *(Raya)* where irrigation facilities are available. There is a dire need to reduce the grain yield gap by adopting improved production technology. Among various inputs, improved variety is the most important followed by fertilizer, pesticides, and weeding. There is then a great need to strengthen the extension network for transferring the new technology.

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Development of Pant Mung-5 and its potential expansion in Uttar Pradesh

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Abstract

Elite mungbean lines from the 21st International Mungbean Nursery (IMN) 1996 were introduced by AVRDC - The World Vegetable Center in Taiwan. A trial of 13 early-maturing entries, along with checks, was laid out in spring and rainy seasons of 1997. Of these, VC 6368 (46-40-4) tested as UPM 98 gave significantly higher yield (1181 and 884 kg ha^{-1}, in spring and rainy season, respectively) than the check Pant Mung-2 (994 and 574 kg ha^{-1}, respectively). In 1997, seed was multiplied and individual plants with resistance to foliar diseases were tagged. UPM 98 was entered in the All India Coordinated trials and was tested in rainy season of 1999 and 2000 and in spring season of 1998 and 1999. It was also tested in rainy season of 1999 and in spring season of 2000 in Uttar Pradesh state level trials. Based on these trials, UPM 98 was released in 2002 for commercial cultivation in the entire Uttar Pradesh for both rainy and spring seasons. UPM 98 matures in 65-79 days in rainy season and 62-78 days in spring season. It is resistant to MYMV, *Cercospora* leaf spot, and *Anthracnose* diseases. It has shining seed with a 100 grain weight of 4.82 g in rainy season and 5.52 g in spring season. It has given 22% and 25% yield increase over Pant Mung-2 during the rainy and spring seasons, respectively.

Introduction

In Uttar Pradesh, mungbean is grown in 0.11 m ha area and its production is 0.05 m tons. The productivity of mungbean is 450 kg ha^{-1}. The *Kharif* (rainy) season crop is prone to attack by mungbean yellow mosaic virus (MYMV), *Cercospora* leaf spot (CLS), *Rhizoctonia* blight, and insect-pests such as hairy caterpillar. In recent years, farmers in western Uttar Pradesh sowed mungbean crops late in the rainy season, i.e. in the month of August. But some of the farmers were able to grow successful crops of mungbean in spring/summer season in between two cereal crops, i.e. rice in rainy season and wheat in *Rabi* (winter) season. For these niches, short duration (60-65 days) mungbean varieties with resistance to foliar diseases were needed. In view of these considerations, a request was made to the Asian Vegetable Research and Development Center (AVRDC) in 1996 to provide seeds of elite lines. In response, AVRDC provided the 21st International Mungbean Nursery (IMN) with two elite lines, one of which was UPM 98 that was released as Pant Mung-5. The methodology of the development of Pant Mung-5 and its performance vis-à-vis Pant Mung-2, a popular variety in Uttar Pradesh, is presented in this paper.

Evaluation of 21st International Mungbean Nursery

AVRDC provided two groups of varieties. One group is composed of 17 entries of long duration varieties (75-85 days) suitable for rainy season, and the other is composed of 13 short duration varieties (60-65 days) suitable for spring/summer season. The seeds of these entries were released by the National Bureau of Plant Genetic Resources (NBPGR) in January 1997. In spring season of the same year, a trial of 13 short duration entries was laid out along with two checks, namely Pant Mung-2 and MUM-2. The data on yield and yield components were recorded in Table 1. In the rainy season of 1997, these entries were tested along with three checks, namely Pant Mung-2, Pant Mung-4, and MUM-2. Data on yield, yield components, and MYMV reaction were recorded in Table 2.

A trial of 17 long duration entries along with three checks, namely Pant Mung-2, Pant Mung-3, and Pant Mung-4 was conducted in rainy season of 1997. Data on yield, yield components as well as reaction of MYMV were recorded in Table 3.

Of the check cultivars, Pant Mung-2 and MUM-2 were of short duration (60-65 days) and released for cultivation in Uttar Pradesh. both in rainy and spring seasons. Based on the evaluation of the IMN entries in spring and rainy seasons, two entries VC 6368 (46-40-4) and VC 6370 (30-65), designated as UPM 98 and UPM 98-1, were selected. Both these entries were synchronous in maturity, of same duration with Pant Mung-2 (Tables 1 & 2), and were resistant to MYMV (Table 2). In addition these had larger seeds than Pant Mung-2.

Multilocation Testing

Seeds of these entries were multiplied in rainy season of 1997 and individual plants showing tolerance to MYMV, CLS, and *Rhizoctonia* blight were tagged and their progenies were grown next year. UPM 98 and UPM 98-1 were tested in the All India Coordinated Trials in 1998 and in state level trials in Uttar Pradesh in 1999. UPM 98, based on its performance, has been released by the State Varietal Release Committee in 2002 as Pant Mung-5 (Figure 1). It has given 22.2% higher

Table 1. Performance of short duration entries of 21st International Mungbean Nursery (IMN) in spring (dry) season of 1997 at Pantnagar

Entry	Days to first pod maturity	Pods $plant^{-1}$	Clusters $plant^{-1}$	Pods $cluster^{-1}$	Pod length (cm)	Seeds pod^{-1}	100 seed weight (g)	Yield (kg ha^{-1})
VC 6773 C	69	21.2	8.5	2.5	9.7	9.8	8.1	736.1
VC 6371-94	67	20.6	8.3	2.5	8.5	9.7	6.0	708.3
VC 3960A-88	68	16.9	5.4	3.2	8.4	8.9	6.3	736.1
VC 6369 (53-97)	66	15.8	5.1	3.2	9.7	9.3	6.4	972.2
VC 3960-89	66	23.8	7.7	3.1	8.3	10.3	4.7	1,394.5
VC 6368 (46-40-4)	62	17.1	5.2	2.2	8.8	9.2	6.3	1,180.6
VC 6370 (30-65)	65	14.4	5.5	2.7	8.9	9.0	6.5	1,027.8
Pant Mung-2 (check)	64	30.3	9.6	3.2	7.3	9.5	3.8	994.4
VC 6370 (21-16)	68	22.5	9.1	2.5	9.9	11.1	6.5	1,263.9
VC 6141 – 90	66	19.4	6.6	2.9	7.6	9.3	4.4	1,180.6
VC 6368 (46-7-2)	62	14.5	5.3	2.8	10.0	9.1	6.8	986.1
VC 6370-92	64	13.9	5.0	2.8	8.5	7.3	6.3	618.1
VC 6372 (45-8-1)	65	12.1	4.2	2.9	9.0	8.7	6.7	548.6
VC 6373 A	69	17.4	7.2	4.5	10.7	9.0	8.6	534.7
MUM-2 (check)	70	23.2	7.9	3.0	7.2	9.2	3.6	215.3
C.D. 5%								187.6
C.V. (%)								27.93

Table 2. Performance of short duration entries of 21st International Mungbean Nursery (IMN) in *Kharif* (rainy) season of 1997 at Pantnagar

Entry	Pedigree	Days to maturity	Pods $plant^{-1}$	Seeds pod^{-1}	100 seed weight (g)	MYMV score (1-9)	Yield (kg ha^{-1})
VC 6773 C	VC 1560 A x VC 6370-92	69	21.9	10.9	4.87	6.0	645.8
VC 6371-94	VC 2768 A x VC 6141-36	75	23.1	11.3	3.40	5.0	550.9
VC 3960 A-88	VC 1482 E x VC 6306	67	21.7	11.0	3.83	4.0	958.3
VC 6369 (53-97)	VC 6141-51 x VC 6370-92	66	21.8	12.0	4.46	3.0	842.6
VC 3960 – 89	VC 1482 E x V 6306	68	26.2	11.6	3.28	5.0	814.8
VC 636 (46-40-4)	VC 6370-92 x VC 6141-96	65	22.3	11.0	4.37	3.0	884.3
VC 6370 (30-65)	Gamma-ray induced mutant in VC 6370-92 at 30 kR	65	17.1	10.7	4.48	2.0	1,025.4
Pant Mung-2 (Ch)	Gamma ray induced mutant in ML-26 at 10 kR	68	28.3	10.9	2.73	4.0	574.0
VC 6370 (21-16)	VC 2768 B x VC 6141-36	67	26.3	10.9	4.05	4.0	784.7
VC 6141-90	VC 1973 A x V 3484	69	20.7	11.1	3.16	6.0	861.1
VC 6368 (46-7-2)	VC 6370-92 x VC 6141-96	65	19.8	10.4	4.23	4.0	865.7
VC 6370-92	VC 2768 B x VC 6141-36	66	19.9	10.8	4.61	5.0	1,055.5
VC 6372 (45-8-1)	VC 6370-92 x VC 6371-93	66	24.7	11.3	4.05	5.0	888.9
VC 6373 A	VC 1560 A x VC 6370-92	68	20.9	10.7	5.15	6.0	942.0
MUM-2 (Ch)	EMS 0.2% induced mutant in K 851	79	25.8	10.9	2.57	5.5	768.4
UPM 96-14	UPM 79-7 x ML 45	69	25.7	10.1	2.60	5.0	893.5
Pant Mung-4 (Ch)	T-44 x UPU-2	70	27.1	11.8	2.50	2.0	988.5
UPM 96-15	UPM 79-7 x ML-45	69	41.1	11.5	4.61	5.0	972.2
UPM 97-34	Pant Mung-2 x SML-100	79	35.3	11.9	2.47	5.5	1,187.5
C.D. 5%							280.4
C.V. (%)							19.5

Table 3. Performance of long duration entries in the 21st International Mungbean Nursery (IMN) in *Kharif* (rainy) season of 1997 at Pantnagar

Entry	Pedigree	Days to maturity	Pods $plant^{-1}$	Seeds pod^{-1}	100 seed weight (g)	MYMV score(1-9)	Yield (kg ha^{-1})
VC 6379 (23-2-1)	VC 2754 A x VC 6141-36	68	34.8	11.5	5.03	6.0	729.1
VC 6173 B-6	VC 1560 A x VC 6370-92	68	29.5	12.2	5.68	3.0	319.4
VC 6367 (44-55-2)	VC 6371-93 x VC 6141-96	68	30.5	10.9	5.01	5.0	763.8
VC 6372 (45-8)	VC 6370-92 x VC 6371-93	66	28.9	12.0	4.32	3.0	666.6
VC 6379 (23-11)	VC 2754 A x VC 6141-36	67	32.7	11.6	4.40	2.0	1,013.8
VC 6375 (41-13-6)	VC 3726 x VC 6371-93	67	31.4	11.5	5.14	2.0	611.1
VC 6148 (50-12)	VC 6370-92 x VC 1560 A	67	22.7	11.4	6.23	3.0	791.6
VC 6370-92	VC 2768 B x VC 6141-36	66	28.2	10.5	4.60	5.0	1,208.3
VC 6153 B-20 P	VC 3902 A x VC 6370-92	67	32.7	11.3	5.26	3.0	472.2
VC 6144 B-12	VC 6370-92 x VC 3902 A	72	30.7	10.9	4.57	6.0	722.2
VC 6173 B-13	VC 1560 A x VC 6370-92	68	28.0	11.0	6.00	7.0	694.4
VC 6144 (47-28-2)	VC 6370-92 x VC 3902 A	79	42.4	11.3	4.83	7.0	708.3
VC 6173 B-10	VC 1560A x VC 6370-92	67	28.9	10.5	5.74	6.5	895.8
VC 6173 B-11	VC 1560A x VC 6370-92	67	22.3	10.8	7.29	3.0	861.1
VC 6153 B-19	VC 3902 A x VC 6370-92	66	23.6	11.3	5.50	5.0	361.1
Pant Mung-4 (check)	T- 44 x UPU-2 (check)	80	56.3	9.7	3.03	2.0	1,006.9
VC 6173 B-14	VC 1560 A x VC 6370-92	80	39.0	11.3	4.73	5.0	652.7
Pant Mung-3 (check)	LM 294-1 x L-80	80	59.2	11.2	2.80	3.0	902.7
VC 6173 B-33	VC 1560 A x VC 6370-92	67	29.5	10.8	4.59	3.0	611.1
Pant Mung-2 (check)	Gamma-ray induced mutant of ML-26 at 10 kR	67	43.0	10.7	2.56	5.0	541.6
C.D. 5%						345.3	
C.V. (%)						22.7	

yield than Pant Mung-2 in rainy season (Table 4) and 25.0, 9.4 and 13.6% higher yield than Pant Mung-2, PDM-11 and HUM-2, respectively in the spring season (Table 5).

Figure 1. Pant Mung-5

Table 4. Performance of UPM 98 as compared to checks in various trials conducted in *Kharif* (rainy) season in Uttar Pradesh

Variety	**Station trial 1997 (1)**	**Coordinated trial**		**State level trial 1999 (2)**	**Weighted mean**			
					Yield		Days to maturity	100-seed weight (g)
		1999 (2)	2000 (1)		kg ha^{-1}	% higher to check		
UPM –98	884.3	389.5	1088.0	860.5	745.2(6)	-	73(7)	4.8(3)
Pant Mung –2	574.0	-	-	627.5	609.7(3)	22.2	78(4)	2.7(1)
Pant Mung –4	998.5	-	-	752.0	834.1(3)	-	81(4)	2.5(1)
Pusa –105	-	-	963.0	-	963.0(1)	-	74(1)	3.5(1)
Pusa Bold	-	-	1065.0	-	1,065.0(1)	-	75(1)	4.7(1)

Figures in parenthesis are number of locations.

Table 5. Performance of UPM-98 as compared to the checks in various trials conducted in spring (dry) season in Uttar Pradesh

Variety	Station trial 1997 (1)	Coordinated trial 1998 (1)	State level trial 2000 (4)	Weight (mean)			
				Yield		Days to maturity	100-seed weight (g)
				kg ha^{-1}	% of higher to check		
UPM –98	1180.6	826	679.0	787.1	-	71(9)	5.52(5)
Pant Mung-2	994.4	-	-	-	25.0	71(4)	3.43(4)
PDM-11	-	755	-	-	9.4	75(4)	3.10(4)
PS-16	-	822	-	-	-	69(1)	3.10(4)
K 851	-	8-6	-	-	-	68(1)	3.10(1)
HUM-2	-	-	597.5	-	13.6	80(4)	-

Figures in parenthesis are number of locations

Agronomic Evaluation

An experiment was conducted in year 2000 to determine an optimum date of sowing and row spacing for UPM 98 under *terai* conditions of Uttaranchal during rainy season. Ten treatments consisting of five sowing dates and two row spacings were tested in a split plot RCBD design with planting dates in main-plots and row spacing as sub-plots with four replications. The yield from July 31 sowing date was comparable with those from August 10 and August 20, but significantly higher than those from August 30 and September 9 sowing dates. Statistically, the differences among different dates of sowing in the month of August were not significant. Yield of UPM 98 was unaffected by row spacing (Table 6).

Cooking Quality and Proximate Composition

UPM 98 and Pant Mung-2 cultivars were subjected to cookability tests before and after soaking in water for different durations (Table 7). Hundred percent cooking took place with Pant Mung-2 in 60 minutes while it took 70 minutes for UPM 98. However, soaking of the grains prior to cooking for 6 and 12 hrs resulted in 100% cooking in 20 minutes for both the cultivars.

Table 6. Grain yield of UPM 98 (*Kharif*, 2000) as influenced by sowing dates and row spacing (N.P. Singh and Co-workers)[1]

Treatment	Grain yield (kg ha^{-1})
Sowing date	
July 31	1,636
August 10	1,587
August 20	1,532
August 30	1,329
September 9	731
C.D. 5%	306
Row Spacing	
20 cm	1,379
30 cm	1,348
C.D. 5%	NS
C.V. (%)	13.9

[1]Department of Agronomy, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar, NS not significant at 5% level.

Table 7. Percent cookability of mungbean grains before and after soaking in water for different durations (Rita Singh Raghuvanshi)[1]

Variety	Per cent cookability before soaking							Per cent cookability after 6 h soaking				Per cent cookability after 12 h soaking		
	Minutes													
	30	40	50	55	60	65	70	10	15	20	25	10	15	20
UPM 98	53.00 ± 1.15	65.33 ± 0.33	87.00 ± 0.58	96.00 ± 0.58	99.33 ± 0.67	99.33 ± 0.67	100.00 ± 0.00	89.33 ± 0.89	93.33 ± 0.33	100.00 ± 0.00	100.00 ± 0.00	95.66 ± 0.86	99.33 ± 0.33	100.00 ± 0.00
Pant Mung- 2	62.33 ± 0.88	75.66 ± 1.67	98.00 ± 1.15	98.66 ± 0.88	100.00 ± 0.00	100.00 ± 0.00	100.00 ± 0.00	89.33 ± 0.67	94.00 ± 0.58	100.00 ± 0.00	100.00 ± 0.00	95.33 ± 0.88	99.33 ± 0.67	100.00 ± 0.00

(Source: Rita Singh Raghuvanshi) [1]Department of Foods and Nutritions, College of Home Science, G.B. Pant University of Agriculture & Technology, Pantnagar

UPM 98 had higher content of total ash (4.46%), fibre (6.70%), fat (1.80%), protein (24.72%), iron (5.39 mg 100 g^{-1}) and calcium (261 mg/100 g) where as it had lower carbohydrate content (62.32%) and energy (364 K/cal) than Pant Mung-2 (Table 8).

Potential Expansion of Pant Mung-5 in Uttar Pradesh

In Uttar Pradesh, mungbean is cultivated during rainy and spring/summer seasons. The important rainy season mungbean producing districts are Jhansi, Mahoba, Lalitpur, Unnao, Hamirpur, Banda, Raebareli, Fatehpur, Varanasi, Jalaun, Pratapgarh, and Bulandshahr. The important spring/summer mungbean producing districts are Etah, Aligarh, Mainpuri, Mathura, Bulandshahr, Pratapgarh, Allahabad, Faizabad, and Kanpur (rural). There is a great potential in the state to increase the area under spring/summer mungbean provided adequate irrigation facilities are available. The area vacated after the harvest of potato, linseed, mustard, and sugarcane could be planted to spring mungbean. Some area after the harvest of wheat can also be planted to mungbean. Pant Mung-5 would be an ideal choice because of its shorter maturity duration and resistance to MYMV, a critical disease-causing virus in spring/summer season. Pant Mung-5 would also be suitable in intercropping during the spring planting of sugarcane, as well as in late sowing in August after the harvest of forage sorghum/pearl millet/maize in Western Uttar Pradesh. It is expected that an additional area of 25,000 ha could be planted with Pant Mung-5 in the future in the new niches of rainy as well as spring/summer seasons.

Acknowledgment

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Table 8. Proximate composition of mineral content of mungbean grain

Variety	Moisture (%)	Total ash (%)	Crude fibre (%)	Crude fat (%)	Crude protein (%)	Carboh-ydrate (%)	Energy (k/cal)	Iron (mg 100 g^{-1})	Calcium (mg 100 g^{-1})
UPM –98	12.37 ± 0.005	4.46 ± 0.003	6.70 ± 0.003	1.80 ± 0.001	24.72 ± 0.04	62.32 ± 0.03	364.00 ± 0.10	5.39 ± 0.06	261.00 ± 33.00
Pant Mung-2	11.05 ± 0.00	3.63 ± 0.01	5.48 ± 0.01	1.60 ± 0.01	22.75 ± 0.04	66.54 ± 0.02	372.00 ± 0.10	5.07 ± 0.03	224.00 ± 0.00

(Source: Rita Singh Raghuvanshi) *Department of Foods and Nutritions, College of Home Science, G.B. Pant University of Agriculture & Technology, Pantnagar

Opportunities for the cultivation of extra short duration mungbean in Tamil Nadu, India

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Abstract

The opportunities for the cultivation of extra-short duration mungbean in Tamil Nadu, India is discussed in this paper. An extra-short duration mungbean variety Pusa Bold (Pusa Vishal) which matures in 55 days and recorded a yield increase over the traditionally cultivated mungbean varieties ADT 2 (43.3%) and ADT 3 (26.5 %) in rice fallows. After the harvest of rice, this variety utilizes the residual moisture and nutrition available in the rice fields, and it escapes terminal drought because of its early-maturity trait. As a pure crop in different agro-climatic zones, Pusa Bold recorded a yield range of 820 to 950 kg ha^{-1}. This yield is almost double, considering the average yield of mungbean in the state. Besides rice-fallow situation, the possibilities for cultivating extra-short duration mungbean in intercropping in crops like sugarcane, cassava, and banana and coconut gardens of the state has been discussed. Moisture and nutrient stresses affecting the extra-short duration mungbean, especially during its growth period of 25 to 45 days in contrast to the traditional varieties of 150-170 days, is indicated. The recent breeding efforts taken to cross Pusa Bold with the traditional variety of Vellore local (and some promising selections made in F3) to incorporate tolerance to moisture stress is also presented. The nutritional superiority of Pusa Bold over the local variety for its iron content and the results of feeding trials conducted is likewise discussed. Pusa Bold variety is found to be susceptible to powdery mildew in cooler seasons and efforts are underway to incorporate powdery mildew resistance in this variety.

Introduction

In Tamil Nadu, mungbean is normally cultivated in an area of 126,000 ha with a production of 57,000 t annum^{-1} with a productivity of 452 kg ha^{-1}. The productivity fluctuates from 408 to 543 kg ha^{-1}.

The area, production, and productivity fluctuation is mainly due to the amount and distribution of rainfall during the cropping period, since nearly more than 85 percent of the mungbean cultivated in the state is under rainfed situation.

Table 1. Area, production, and productivity of mungbean in the past seven years in Tamil Nadu

	1997-98	1998-99	1999-2000	2000-01	2001-02	2002-03	2003-04
Area in '000 ha	1,076	1,243	1,293	1,274	1,290	1,280	1,330
Production in '000 tons	439	675	603	615	535	509	610
Productivity kg ha^{-1}	408	543	466	482	415	398	459

Source: Commissioner and Director of Agriculture, Chepauk, Chennai 600 005, National Pulses Development Project. XV State Level Implementation Committee, Agenda Notes 2001-02 and 2003-04.

Mungbean varieties ranging in their duration from 65 to 85 days are cultivated by the farmers of the state. In 1998, a new variety Pusa Bold (Pusa Vishal) was introduced from IARI, New Delhi to Tamil Nadu and it was first tested at Agricultural Research Station, Bhavanisagar. The crop was sown in February and matured in 55 days with a yield of 940 kg ha^{-1}. Considering the extra-short duration, this variety Pusa Bold (Pusa Vishal) was tested in different agroclimatic zones of the state. The performance of Pusa Bold at 1) Coconut Research Station, Veppankulam of Thanjavur District, 2) Agricultural Research Station, Paramakudi of Ramanathapuram District, and at 3) Regional Research Station, Vridhachalam of Cuddalore District representing Cauvery Delta zone, Southern zone and North Eastern zone respectively was quite promising and the yield ranged from 820 kg to 950 kg ha^{-1} in various trials and the variety matured in 55 days.

Considering the state average of 450 kg ha^{-1} with varieties maturing in 65 to 85 days, Pusa Bold which matures in 55 days, with a yield potential of almost twice the earlier varieties caught the farmers' interest to cultivate said variety, especially after the harvest of rice crop. In rice-fallow situations, farmers normally grow ADT 2 and ADT 3 mungbean varieties which mature in 70 days. Pusa Bold (Pusa Vishal) was compared with ADT 2 and ADT 3 under rice fallow situations at Tamil Nadu Rice Research Institute at Aduthurai. Rice fallow mungbean utilizes the residual moisture and nutrients available in the rice field after the harvest of rice in its entire growth. Under this situation Pusa Bold matured in 58 days and recorded a mean yield of 430 kg ha^{-1} in various trials, compared to the mean yield of 300 and 340 kg ha^{-1} by ADT 2 and ADT 3, respectively, registering a yield increase of 43.3% and 26.5% respectively over the traditional varieties of

ADT 2 and ADT 3 mungbean. ADT 2 and ADT 3 matured in 70 days while Pusa Bold (Pusa Vishal) matured 15 days earlier. The early maturity of this variety helped in escaping the terminal drought which is often experienced during the pod filling stage. Moreover, the 100 seed weight of pusa bold is 6.4 g where as in the traditional varieties it ranged from 3.5 to 4.0 g (Table 2).

Table 2. Mean performance of Pusa Bold in various trials under rice fallow situations

Character	Pusa Bold/ Pusa vishal	ADT 2	ADT 3
Duration (days)	58.0	70.0	70.0
Plant height (cm)	45.9	35.0	38.0
Number of branches plant^{-1}	5.0	3.0	4.0
Number of clusters plant^{-1}	5.3	4.5	4.8
Number of pods plant^{-1}	18.0	13.0	15.0
Pod length (cm)	9.5	6.6	7.0
Number of seeds pod^{-1}	12.0	8.8	11.2
100 seed weight (g)	6.4	4.0	3.5
Yield (kg ha^{-1})	430.3	300.4	340.2

Sugarcane, banana, and tapioca are slow growing crops in the initial two months and the interspaces can be utilized for the cultivation of extra-short duration mungbean varieties. This cultivation not only results in extra income to the cultivator but also helps control weed growth in the interspaces, since mungbean serves as a cover crop under this situation. It also improves the fertility of the soil, enabling the main crop to give a better yield compared with the sole crop of sugarcane/banana/tapioca (cassava).

In Tamil Nadu, the normal area under sugarcane is 316,000 ha and there is a potential to intercrop extra-short duration mungbean in about 150,000 ha. Similarly, areas under banana is 80,000 ha and nearly 38,000 ha in gardland situation can be intercropped with short duration mungbean. The area under cassava (tapioca) in the state is 82,000 ha and there is an opportunity to cultivate the extra-short duration mungbean in an area of about 45,000 ha. A total of 233,000 ha of short duration mungbean, as an intercrop in the state, can add production of at least 116,000 t of mungbean/annum to the state which will not only reduce the average negative growth rate in area, production, and productivity of mungbean in the state, but will also substantially increase the nutritional security of the region.

Young coconut gardens in the state, offer yet another opportunity to cultivate extra-short duration mungbean in the interspaces. The normal area under coconut in the state is nearly 216,000 ha. Nearly 20 per cent of the area is under young plantation, i.e. less than 1 ½ years old. These coconut gardens are best suited for cultivating mungbean and the opportunity exists in an area of about 52,000 ha with a production potential 20,000 t of mungbean per annum.

Recent Breeding Efforts with Extra Short Duration and Bold Seeded Mungbean Varieties

Moisture and nutrient stresses are some of the notable stress conditions experienced by this extra short duration mungbean varieties. From experiences, it is concluded that the variety should be provided with adequate moisture in fertile soil to realize the potential yield within 55 days. The traditional local mungbean varieties are cultivated in the state under rainfed situations in marginal soils. These varieties which are longer in duration are benefited by the bi-modal rainfall and they tolerate intermittent drought in marginal soils. Hence breeding efforts were taken up to cross the local traditional varieties with extra short duration bold seeded varieties. One such effort is to cross the local Vellore variety (which has a viny habit and the growth duration is about 150-170 days) with the extra short duration and bold seeded Pusa Bold and VC 6173-B-10.

The average 100 seed weight of Pusa Bold and VC 6173 B10 is 6.4 g and 8.2 g, respectively whereas Vellore local is only 3.5 g. In the F3 generation, individual plants that mature in 55 to 58 days with a 100 seed weight of not less than 6.5 g, respond to low moisture, and have low fertility levels were selected. They will be further evaluated.

During the cooler seasons Pusa Bold is found to be susceptible to powdery mildew. Therefore, Pusa Bold was crossed with powdery mildew resistant RU 19-5, TARM 1 and TARM 2 lines (Reddy *et al.*, 1996). Since the resistance to powdery mildew disease in mungbean appears to be controlled by polygenes (Satyanarayana *et al.*, 1996), recurrent selection procedure is adopted to accumulate maximum number of genes for powdery mildew resistance.

Nutritional Studies With Pusa Bold Mungbean Developmental Efforts – Setup of Feeding Trial

Consumption of mungbean in India is expected to increase both in low as well as high income groups (Grover *et al*., 2003). Mungbean is easily available at all seasons in Tamil Nadu and consumed by all income groups. Mungbean is used in different forms such as whole mungbean, mungbean dhal, sprouted mungbean and dehulled mungbean. In addition to its value as a protein-rich food, mungbean also has a relatively high iron content. This is especially true for the new variety Pusa Bold (Pusa Vishal) which contains 6 mg of iron per 100 grams of raw seed (Vijayalakshmi *et al*., 2001), compared with 3.3 to 3.5 mg in the traditional varieties (Gopalan *et al*., 2000). Considering the above fact, a quantity of 3.6 t of Pusa Bold (Pusa Vishal) mungbean was produced in different farmers holdings in Coimbatore and Erode districts with the technological support from TNAU and the same was supplied to Avinashilingam Institute for Home Science & Higher Education for Women to conduct feeding trials during the years 1999 and 2000. For the feeding trial, children in the age group of 10-12 years were selected from a total of two government higher secondary schools of two villages in the Periyanaicken Palayam block in Coimbatore City located in Tamil Nadu, India.

Children from one village served as the experimental group and the children from the second village served as control. A total of 225 school children (113 boys and 112 girls) participated in the study. Health parameters and physical stamina of children were examined before and after supplementation for treatment groups and control group. One treatment group received a traditionally-prepared dish with a normal *in vitro* iron bioavailability at around 7% while two groups received iron availability enhanced dishes at around 12%.

The results indicated that supplementation improved health parameters. Children receiving supplementation suffered from less clinical deficiency symptoms after supplementation. For biochemical parameters, the improvement was significantly larger for the two groups (IR 1 and IR 2) receiving iron bioavailability-enhanced supplementation than for the group (TR) receiving a supplementation with a low iron bioavailability. In the two groups IR 1 and IR 2, hemoglobin levels increased by an average of 10% while in the group that received the traditional preparation (TR), hemoglobin levels increased by an average of 5% (Vijayalakshmi *et al*., 2003).

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Biological nitrogen fixation in mungbean: An overview

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Abstract

The greatest asset that pulses possess is the biological nitrogen fixation (BNF) that is highly beneficial in the present energy crisis. The BNF is known to be more economical and environmental friendly. In Punjab (India), rice-wheat is the predominant cropping system. The mungbean (*Vigna radiata (*L.) Wilczek) is an important crop of the state and is highly preferred by masses in their diet. Recently extra-short-duration (about 60 days) variety SML 668 has been developed at the Punjab Agricultural University, Ludhiana which fits well in between wheat and rice as a catch crop. Estimates indicate that SML 668 left 37 kg N ha^{-1} for the succeeding crop after meeting its own requirement. The seed inoculation with *Rhizobium* not only increases the grain yield of mungbean but also enhances nitrogen fixation through symbiosis. The response of *Rhizobium* inoculation is determined by the efficiency of strain used, the native population of rhizobia and the competitiveness of the inoculant strain. Carrier and liquid inoculants did not show any difference in their efficiency. However, a synergistic effect of *Rhizobium* phosphate solubilizing bacteria (PSB) and plant growth promoting rhizobacteria (PGPR) on the microbial traits and grain yield of mungbean was observed. Various biotic and abiotic factors also influence the *Rhizobium* efficiency, nodulation and nitrogen fixation. The mungbean crop sown at appropriate time either in summer or *Kharif* (rainy season) showed greater number of nodules with higher dry weight and good leghaemoglobin. Similarly under good soil moisture conditions nodulation and nodule mass was significantly higher than the stressed conditions. Nutrients such as phosphorus and sulphur are highly beneficial for BNF.

Introduction

Mungbean, being a leguminous crop, has a unique role in fixing atmospheric nitrogen through the process of biological nitrogen fixation (BNF). The biological nitrogen fixed by mungbean not only meets its own requirement but also leaves nitrogen after harvest, which is beneficial to the next crop. The mungbean fixes

31-85 kg N ha^{-1} (Sekhon *et al.*, 2002). The rice-wheat system in Punjab, which produces more than 10 t ha^{-1} grains, removes 500-700 kg ha^{-1} major nutrients from the soil annually (Biswas *et al.*, 2001). Thus, there is a great need to sustain soil fertility and productivity by growing a pulse crop in cereal-based cropping systems. *Rhizobium*/*Bradyrhizobium* sp., which supplies about 20-40 kg N ha^{-1}, can be considered as a complementary and supplementary source of plant nutrients. Inoculation of *Rhizobium* to mungbean enhances nodulation, nitrogen fixation, and grain yield. Yield increases from 10 to 37% following inoculation have been reported in mungbean (Morton *et al*., 1982). In this paper the biological nitrogen fixation and microbial traits studied in experiments conducted under the DFID-AVRDC Project on mungbean, are presented and discussed briefly.

Mungbean *Rhizobium*

Mungbean rhizobia are aerobic, rod shaped, motile, pleomorphic, and gram negative heterotrophic bacteria. They grow on a wide range of carbohydrates and may either be fast or slow-growing rhizobia under two separate genera, *Rhizobium* and *Bradyrhizobium*, respectively (Elkan, 1992). Both fast-growing *Rhizobium* species and slow-growing *Bradyrhizobium* sp. can infect a broad range of diverse legume hosts (Table 1).

Table 1. Mungbean *Rhizobium* association

Rhizobia	Host
A. Fast growers, *Rhizobium* sp.	Tropical legumes; pigeonpea, mungbean, urdbean, clusterbean, cowpea, etc.
B. Slow growers, *Bradyrhizobium* sp.“Cowpea”	Tropical legumes; chickpea, pigeonpea, mungbean, urdbean, clusterbean, cowpea, etc.

Source: (Elkan; 1992, Sharma *et al*.,1993)

The fast-growing rhizobia form 3-6 mm diameter colonies on yeast extract mannitol agar (YEMA) after 3-4 days while the slow growing kind form 0.1 mm sized colonies after 5-7 days at 28 C. Both types of rhizobia utilize most of the carbon sources, suggesting that slow growers also possess glycolytic pathways similar to those present in fast growers. Both fast and slow growers produce acidic reaction (pH 4.4 to 5.6) in culture media. Mungbean is regarded as symbiotically promiscuous with nodules produced when infective strains of the cowpea cross-inoculation group of *Bradyrhizobium* sp. (*Vigna*) are present in the soil. However, strains within this group differ in how effectively they nodulate mungbean. For an introduced strain to be effective, it should produce N_2 fixing nodules over a wide range of soil conditions and be competitive in nodule formation and subsequent N_2 fixation with indigenous or native strains already present in the soil.

Distribution of Rhizobia in Soil

The distribution of rhizobia in soil profile varies with soil types, cropping system and climatic factors. Maximum population was in top (5-15 cm) soil layer in Vertisol and decreased with depth in Entisol, and maximum cell density was at 30-45 cm depth (Wani *et al*.,1997). Pandher *et al.*(1984) revealed good population of mungbean in rhizobia where mungbean was sown earlier (Table 2).

In general, loamy sand soils were found to have good population of mungbean rhizobia compared with sandy loam soils. Low fertility soils were found to respond more favorably to inoculation compared with high fertility soils, but maximum yield was achieved with the basal application of 25 kg N ha^{-1}. The Punjab soils have been found to be deficient in effective rhizobia. Poor nodulation at farmers' fields could either be due to low rhizobial population in soil, burning of straw, excess use of fertilizer, pesticides etc. In order to provide rhizobia in the vicinity of roots, it is advisable to inoculate the seed each year before sowing.

Table 2. Estimated number of mungbean rhizobia in different types of soil

Soil with cropping history	Most Probable Number (MPN) estimate
Sandy loam, without any mungbean crop for a number of years, cotton-clusterbean-wheat-ground-nut rotation	0.9×10^3
Sandy loam, with 2 crops of mungbean during the past 5 years	23.0×10^4
Loam, with 2 crops of mungbean during the past 5 years	42.4×10^3
Loam, without a mungbean crop, maize- wheat rotation	9.2×10^4
Sandy loam, exposed to rice for the past 3 years	91.8×10^2
Loam, exposed to rice for the last 3 years	14.7×10^2
Charcoal culture	3.75×10^7
Charcoal culture (Viable count)	4.47×10^7

Source: (Pandher *et al*., 1984)

Host Specificity of Rhizobia

Many hypotheses were discovered for the specific adherence of compatible rhizobia on host roots (Verma, 1992). Lectin recognition occurs when particular polysaccharides on the bacterial surface specifically bind to host lectins. Host specificity at molecular level has been studied in detail in other legumes (Phillips *et al*., 1995). Host genotypes differ in nodulation and N_2 fixation in response to inoculation with the same strain of *Rhizobium* under controlled conditions.

Response to Rhizobium Inoculation

Significant variations in nodulation and grain yield among mungbean genotypes due to inoculation have been reported in many field studies. Under the All India Coordinated Pulses Improvement Project (AICPIP), BNF researchers have developed efficient rhizobial strains under different agroclimatic conditions, interacting with wide range of host cultivars of different pulse crops. Inoculation in pulses became more popular with the inception of AICPIP in late 60s. The prime aim of inoculation is to introduce sufficient population of effective rhizobia in the root zone for better nodulation and BNF. However, inoculation response varies with crop management, strain, location, and genotype. Average of data from 1999 to 2002 indicated that higher grain yield ranging from 8.5% (Coimbatore) to 44.5 % (Pantnagar) due to inoculation (Table 3) was reported in different research farms in India with varying agroclimatic zones.

Table 3. Response of mungbean to *Rhizobium* inoculation at different research farms (Average, 1999-2002)

Location	Yield (kg ha^{-1})		% increase over uninoculated
	Uninoculated	Inoculated	
Coimbatore	619	672	8.5
Ludhiana	935	1067	14.1
Vamban	486	570	17.2
Pantnagar	556	803	44.5
Durgapura	482	658	36.5

Yield of mungbean can be increased substantially in different parts of the country through rhizobial inoculation. The study has demonstrated the positive effect of BNF at research farms, which was further validated in the farmers' fields (Table 4).

Table 4. Effect of *Rhizobium* inoculation on mungbean grain yield in on-farm trials (Average, 1999-2002)

Location/ State	Number of trial	Grain yield (kg ha^{-1})		% increase over uninoculated
		Uninoculated	Inoculated	
Punjab	7	818	920	12.4
Coimbatore	9	545	617	13.3
Durgapura	3	450	550	22.2
Uttar Pradesh	9	905	1062	17.4
Maharashtra	21	590	663	12.3
Gujarat	2	625	702	12.3
Karnataka	3	425	463	8.94

Source: AICPIP Consolidated Reports on *Kharif* pulses (Microbiology)

A significant response to inoculation was associated with the *Rhizobium* population of less than 100 cells per g soil and marginal increase in grain yield were observed at 107 cell per g soil. *Rhizobium* strain acceptability depends primarily on the host, moisture, native population of rhizobia, and mineral N content in soil (Khurana and Dudeja, 1997).

Method of Seed Inoculation

Several inoculation methods have been tried in the past. However, the best method is charcoal-based, which allows maximum survival of rhizobia to colonize roots and forms the highest number of nodules under field conditions. More population of rhizobia on seed can be loaded using adhesives (Mor *et al.*, 1995). Liquid suspension of inoculant applied (Table 5) on seed at sowing resulted in better nodulation and leghemoglobin content than the carrier based treatment method (PAU, 2003).

Seed inoculation will not be effective when carrier-based seed is treated with incompatible pesticides, and fungicides as well as when native population is quite high and effective, seed coat is fragile, and seed exudates are toxic to inoculated rhizobia. Pandher *et al.* (1995) found out that Thiram and Captan had mild action

Table 5. Evaluation of liquid and carrier based *Rhizobium* inoculants

Treatment	Number of nodules plant^{-1}	Dry weight of nodules plant^{-1} (mg)	Leghemoglo-bin content (mg g^{-1} of nodules)	Grain yield (kg ha^{-1})
Uninoculated control	16.0	48	1.28	1070
Carrier based inoculant (CRM-6)	24.0	56	1.95	1285
Liquid inoculant (CRM-6)	28.6	62	2.20	1320
20 kg N ha^{-1}	17.3	51	1.40	1085
C.D. at 5%	4.4	4.6	0.68	186

Source: (PAU, 2003)

in mungbean. These fungicides reduced the viability of inoculum on seeds. A number of rhizobia on seeds without fungicides were also greatly reduced in storage for seven days. This may be attributed to the toxic seed coat factors. Sharma and Khurana (2002) reported that the interaction of Thiram (recommended dose at 3 g kg^{-1} seed) with *Rhizobium* was compatible and both the treatments can be applied simultaneously (Table 6).

Table 6. Effect of Thiram and *Rhizobium* inoculation on symbiotic parameters (55 days after sowing) and grain yield of *Kharif* mungbean (1995-1997)

Treatment	Number of nodules plant^{-1}	Nodule biomass (mg plant^{-1})	Leghemoglobin content (mg g^{-1} of nodules)	Grain yield (kg ha^{-1})
Uninoculated control	25	48	1.85	855
Rhizobium (R)	37	65	2.35	977
Thiram (T)	32	55	1.87	875
R + T	35	60	2.33	985
C.D. at 5%	NS	8.75	0.28	21

NS-not significant at 5% level.

Role of Plant Growth Promoting Rhizobacteria (PGPR)

Rhizosphere micro-organisms such as plant growth promoting rhizobacteria (PGPR) are known to improve BNF by enhancing the number of nodules and biomass and encourage nitrogenase activity by colonizing root system and suppressing growth of deleterious organisms (Gupta *et al.*, 1998). The combined inoculation of all the three inoculants (R + PSB + PGPR) showed synergistic effect on nodulation, leghaemoglobin content, nodule occupancy, and grain yield (Table 7) compared with single inoculation of *Rhizobium* in mungbean (PAU, 2001 and 2002).

Table 7. Synergistic effect of *Rhizobium* (R), phosphate solubilizing bacteria (PSB) and PGPR in mungbean ML 613 (Average, 2001-2002)

Treatment	No. of nodules plant^{-1}	Dry weight of nodules plant^{-1} (mg)	Leghaemoglobin content (mg g^{-1} of nodules)	Nodule occupancy (%)	Grain Yield (kg ha^{-1})
Uninoculated control	17.5	41	0.81	-	1129
R	24.5	47.5	1.28	20	1276
PSB	22.5	41.0	0.85	-	1197
PGPR	22.0	43.5	0.87	-	1197
R + PSB	26.8	51.0	1.29	22	1332
R _ PSB + PGPR	31.5	59.0	1.53	28	1368
C.D. at 5%	5.2	6.4	0.28	4.0	93.5

Source: PAU (2001 and 2002)

Estimate of N_2 Fixation

The capacity of legumes for symbiotic fixation of dinitrogen is the major factor in improving soil N fertility. George *et al.*, (1995) reported considerable variation in nitrogen fixation in two cultivars of mungbean. Pagasa 2 cultivar fixed much higher nitrogen (90 kg N ha^{-1}) than the cultivar Pagasa 1 (61 kg N ha^{-1}). People *et al.* (1991) observed that nitrogen fixation mungbean was 119-140 kg N ha^{-1} in the Philippines, whereas it was 0-55 kg N ha^{-1} in Pakistan (Shah *et al.*, 1997).

Residual Effect

Mungbean, like other legumes, is reported to benefit the succeeding cereal crops. Mungbean produced 0.9 t grain ha^{-1} and after the harvest incorporation of crop residues, it gave a rice yield increase equivalent to 25 kg N fertilizer ha^{-1} (Meelu and Morris, 1988). A part of the nitrogen released by the nodules is added to the soil and hence helps in reducing input of chemical fertilizer to the subsequent crop. Mungbean cultivation helps increase nitrogen content in soil (Table 8). It is also not always possible to measure the residual effect on the basis of yield increases of succeeding crop as yield is a function of many uncontrollable variables under field conditions. It is then useful to determine the N-mineralisable potential of soil as an indicator of N-availability to growing crop.

Table 8. Soil nutrient status (0-15 cm soil layer) at sowing and after harvest of summer mungbean in 2002

Nutrient	At sowing	After harvest		
		No- tillage	Tillage	Straw incorporation
Organic carbon (%)	0.32	0.32	0.32	0.32
N (kg ha^{-1})	106	143	142	139
P (kg ha^{-1})	16.8	17.1	15.9	16.2
K (kg ha^{-1})	292	285	288	291

Source: (PAU, 2002)

Effect of Soil and Agronomic Management Practices on BNF

Soil Moisture

Soil moisture affects survival of native as well as introduced rhizobia, nodulation and N_2 fixation process. In rice-fallow, rice-rice and rice-wheat cropping sequences excess moisture may reduce rhizobial population in soil (Toomsan *et al.,* 1982). Excess moisture adversely affects root nodulation, nodule development and acetylene reduction activity (ARA) which can be attributed to anoxia. *Bradyrhizobium* strains are more tolerant in drought than fast-growing strains of *Rhizobium* because the former retain less water within the cells (Bushby and Marshall, 1977). Pulses like mungbean, which are amide exporter and produce indeterminate nodules, are more tolerant to stress than ureide exporter legumes with determinate nodules. At Ludhiana, in loamy sand soil 2 irrigations showed less nodulation, whereas 3 and 4 irrigations significantly improved nodulation in summer mungbean (PAU, 2003) (Table 9).

Table 9. Nodulation as influenced by irrigation in summer mungbean variety SML 668

Treatment	Number of nodules plant^{-1}	Nodule dry weight plant^{-1} (mg)
Irrigation		
2	18.8	28.0
3	24.3	44.7
4	32.0	46.0
C.D. 5 %	2.06	3.0

Source : PAU (2002)

Straw mulch maintains the soil moisture and lowers temperature. Mulch improved nodulation and N_2 fixation in summer mungbean and was responsible for better yield than no mulch treatment (Table 10).

Table 10. Nodulation as influenced by straw mulch in summer mungbean variety ML668

Treatment	Number of nodules plant^{-1}	Nodule dry weight plant^{-1} (mg)
No mulch	21.3	34.3
Mulch at sowing	25.6	40.7
Mulch at 25 DAS	28.2	43.6
C.D. at 5%	2.78	3.99

Source : PAU (2003a)

Tillage and Crop Residue Management Practices

Tillage is done to physically manipulate the soil to create aeration and porosity. However, direct seeding of seeds into soil is becoming popular (Gautam 2000). Experiments conducted at PAU, Ludhiana in 2002 and 2003 showed that tillage and no-tillage treatment showed better nodulation than tillage+crop residue management. The crop growth was slow in straw incorporated plots which might be caused by high C/N ratio. Nelson (1996) reported that some chemical compounds are released from dead tissue of plant straw that cause adverse effect on the growth of crop and reduced biological nitrogen fixation.

Time and Method of Sowing

Time of sowing considerably affects germination, development of nodules, and nitrogen fixation. In summer, mungbean nodulation varied significantly with different dates of sowing (Table 11). The crop sown in March produced many small nodules but lacked leghemoglobin. On the other hand, April-sown crop produced less number of large-size, pinkish nodules due to leghaemoglobin. Drastic decrease in nodule size was observed in May and June crop, while remarkable nodulation was observed in July sowing. Decline in the number of nodules and biomass in May and June crops was due to increase in temperature during these months.

Table 11. Nodulation as influenced by date of sowing in mungbean variety SML 668 (30 DAS) (2003)

Date of sowing	No. of nodules plant^{-1}	Dry weight of nodules plant^{-1} (mg)	Date of sowing	No. of nodules plant^{-1}	Dry weight of nodules plant^{-1} (mg)
March 10	34.3	17.6	June 10	21.9	19
March 20	35.3	15.6	June 20	21.2	28
March 30	31.7	30.0	June 30	21.0	20
April 10	20.3	28.0	July 10	19.7	40
April 20	18.7	37.0	July 20	22.3	56
April 30	19.4	33.0	July 30	14.0	43
May 10	20.3	25.0	August 10	16.0	46
May 20	15.3	23.0	August 20	19.0	36
May 30	11.3	26.0	August 30	10.0	31.1

Source : (PAU, 2003b)

Starter Dose of Nitrogen

Pulses largely meet their N requirement through BNF and need only a starter dose of 20-25 kg N ha^{-1} for early growth. Singh and Mishra (1998) observed that application of nitrogen as starter dose was found to be more beneficial compared with N applied at other growth stages in mungbean. Wani *et al.* (1997) suggested that this blanket recommendation is not suitable for all situations. These results show that there is a need to review the earlier recommendations on the initial input of N-fertilizer to legume crops. Thus, the application of manures and fertilizers are the major factors that affect mineral N in soil.

Plant Nutrients

Generally, legumes have less developed root system, particularly root hairs, which reduces their capacity to absorb nutrients particularly phosphorus (P). In low to medium available P soils, response of 17-26 kg P ha^{-1} has been found in most of pulse crops. In 173 multilocation trials conducted at farmers' fields under the All

India Coordinated Agronomic Research Project on the response of phosphorus, it was observed that to each kg of P applied at 13 kg P ha^{-1} resulted in 1.6 kg increase in grain (Ali and Mishra, 2000). Sarkar and Banik (1991) reported significant improvement in nodulation and grain yield with the application of 26 kg P ha^{-1} in mungbean.

The deficiency of sulphur (S) is more pronounced in pulses than cereals due to comparatively higher S need of the former in producing grain. Under AICPIP (1991-94) multilocation trials, mungbean responded up to 20 kg S ha^{-1} and different sources of S, i.e. gypsum, pyrite and single super phosphate (SSP), were almost identical in their efficacy. Molybdenum (Mo) application favourably affected the productivity of mungbean, as in the observed response of up to 4 g kg^{-1} seed in summer mungbean (Mishra and Ali, 1998).

Constraints in BNF

Shortage of Quality Inoculants

The quality of *Rhizobium* inoculant is one of key factors in the validation of BNF technology at farmers' fields. In India, the total production of inoculants may not cover more than 10% of the area. Inoculants are not readily available off the shelf as chemical fertilizers and pesticides. One of the major constraints in the adoption of *Rhizobium* inoculant technology is the nonavailability of quality inoculant. Strict quality control measures should be mandatory on all biofertilizer producers irrespective of their status as government/ private or public sector to ensure better quality inoculants.

Inadequate Demonstrations

The extension process for BNF technology has not been thoroughly applied in farmers' fields. There is a great need to create awareness among farmers through various extension agencies on the use of inoculant.

Status of Native Rhizobia and Soil Nitrogen

Competition between native and introduced *Rhizobium* at the infection site in the roots is the most important parameter in evaluating the response of inoculation. Based on mathematical models (Thies *et al.,* 1991; Singleton *et al.*, 1992), excellent response was observed in soils that contain less than 100 rhizobia per g of soil, while response with larger number of rhizobia was poor. Similarly, no response of *Rhizobium* inoculation can be expected if there is sufficient available nitrogen and there is available native rhizobial population present in the soil to meet the nitrogen demand of plant. The competitiveness of the inoculated strains at higher inoculum rate (40 g kg^{-1} of seed) on seed possibly increases their number in proximity of germinating seed in mungbean (Pareek *et al.*, 2002).

Conclusion

Inclusion of extra-short duration mungbean in wheat-rice system is very essential in improving the soil fertility and sustaining crop productivity. To enhance the biological nitrogen fixation, farmers must inoculate the seed with *Rhizobium* culture. However, the strain used should be efficient and of good quality. Agronomic factors like sowing the crop at appropriate time, applying recommended dose of nutrients, and irrigation according to the need of the crop help greatly in improving nodulation and nitrogen fixation.

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Status of mungbean yellow mosaic virus resistance breeding

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Abstract

Mungbean (*Vigna radiata* (L.) Wilczek) is an important pulse crop attacked by several diseases. Major diseases are Mungbean Yellow Mosaic Virus (MYMV), *Cercospora* leaf spot (CLS), bacterial leaf spot (BLS), anthracnose (anth), and powdery mildew (PM) in certain locations subject to environmental conditions. But the major constraint is MYMV. Before 1998, the whitefly-transmitted MYMV was not a problem in summer/spring season in Punjab and elsewhere in India because most cultivars grown were resistant (resistance was available in cultivated and germplasm genotypes). Recently, resistance does not hold up anymore. This may be due to a changing scenario in cropping patterns, environmental conditions, and variability of the virus. In the present situation, it is essential to give high priority on the determination of virus variability, and identification and deployment of suitable resistance genes. Along this line, efforts are being made to generate information on the status of MYMV resistance and molecular characterization of viral strains.

Introduction

Mungbean (*Vigna radiata* (L.) Wilczek) is an important pulse crop in South and Southeast Asia. It ranks third among pulses after chickpea and pigeonpea in area and production. It is rich in protein (20-24% per 100g of dry grains) and iron (0.0006% per 100 g of dry grains), and is a popular, easily digestible component of the diet. It also improves soil fertility by adding atmospheric nitrogen.

In the Indo-Gangetic Plains countries, such as India, Bangladesh, Nepal, and Pakistan of South Asia, rice-wheat has become the major cropping system. In India alone, this system covers about 10.5 million ha in the states of Punjab, Haryana, Uttar Pradesh, Uttaranchal, Bihar, West Bengal, Madhya Pradesh, Himachal

Pradesh, and Rajasthan. The rice-wheat cropping system has been adopted by farmers in large scale for the last several decades because of its higher yield potential, stability of the crops, good procurement policy, and minimum support price provided by the government. This cropping system has made India not only self-sufficient in food grain production but also led to surplus. At the same time, this system had many negative effects such as depletion of water and nutrients, and increased diseases, insect-pests, and air pollution due to burning of straw. There are also concerns on the lack of storage facilities and transportation for food grains. There is an urgent need to diversify this system by incorporating a short duration crop, such as mungbean between wheat and rice, and popularization of mungbean cultivation by capturing the area vacated by potato, vegetables, sugarcane, oilseeds (rape seeds and mustard) and fodders, etc.

The growing of two crops of mungbean during spring/summer and *Kharif* can very well compete with rice (Singh *et al.*, 2002). Our experiences in the last two years through the DFID/AVDRC Mungbean Project in Punjab showed that there is tremendous expansion of area and realized increase in production in the Indo-Gangetic Plains of India, where 10.5 million ha area under rice-wheat can become available for growing at least one crop of short duration mungbean during summer. The appearance and high incidence of mungbean yellow mosaic virus (MYMV) and its effect on mungbean, however, needs to be addressed.

Before 1998, MYMV was a big problem in *Kharif* season (July-September) and of minor importance in the spring/summer (March-June) season. MYMV-susceptible summer mungbean varieties such as SML 32 and SML 134 were recommended by the Punjab Agricultural University in Ludhiana because MYMV was usually absent in Punjab and other parts of the country in spring/summer season. Interestingly, mungbean varieties, breeding, and germplasm lines, which, for the last five to seven years, had consistently shown high MYMV resistance were recently found infected with the virus. Summer mungbean varieties SML 32 and SML 134 also showed increased MYMV susceptibility from 1998 onwards.

Consequently, the Punjab Agricultural University had to withdraw both varieties from general cultivation in the Punjab. The reasons for the shift from resistance to susceptibility are not clear. The occurrence of different viral strains and some change in climatic conditions which might affect the whitefly vector and its host are suspected to play a role. MYMV has a wide host range, including several leguminous crops and 75 wild plant species (Rathi and Nene, 1974). At present, efforts are being made to generate information on the status of host plant resistance to MYMV and other diseases like *Cercospora* leaf spot (CLS) (*Cercospora cruenta* Sacc., *C. canescens* Ell. and Martin), bacterial leaf spot (BLS) (*Xanthomonas* *campestris* pv. Phaseoli (Smith, Dowson), anthracnose (Anth.) (*Colletotrichum lindemuthianum* (Sacc. and Magn.)(Bri. and Cav) and pod rot (*Fusarium moniliforme* Sheldon, F. *oxysporum* Schlecht emend Synder & Hansen) and on the molecular diversity of MYMV in India.

Materials and Methods

The Punjab Agricultural University (PAU) in Ludhiana is one of the major centers involved in research related to the legume crops covered by the All India Coordinated Pulses Improvement Program. It has been addressing disease resistance breeding, particularly for MYMV, because of its location in the virus hot spot area. From 1977 to 2003, 10,695 mungbean lines were screened for resistance to MYMV, CLS, BLS and *Anthracnose* under artificial epiphytotic conditions following the method of Singh *et al.* (1988). In addition to these diseases, another set of 935 breeding and germplasm lines, some of which had been generated through interspecific hybridization by Asian Vegetable Research and Development Center (AVRDC-The World Vegetable Center) in Taiwan, were tested for pod rot resistance. This disease has been reported for the first time from Punjab and was severe in *Kharif* 2001 and very severe in summer and *Kharif* 2003. PAU and its Regional Research Centre in Gurdaspur have made great efforts to enhance the MYMV resistance through intra- and interspecific hybridization (Singh *et al.*, 1997). In all the years of testing (1997-2003), 100% mortality was observed in Indicator-cum-Infector rows, mainly due to MYMV. Observations on MYMV were recorded by using a 1 to 9 point rating scale as given below (Singh *et al.*, 1992).

Rating scale for CLS, BLS, and *Anthracnose*

Rating	% disease intensity on leaves	Reaction
1	0.1 – 5.0	Resistant
3	5.1 – 15.0	Moderately resistant
5	15.1 – 30.0	Moderately susceptible
7	30.1 – 75.0	Susceptible
9	75.1 – 100.0	Highly susceptible

Rating scale for MYMV

Rating	Percentage foliage affected	Reaction
1	No visible symptoms or minute yellow specks covering 0.1-5% leaf area	Resistant
3	Mottling of leaves covering 5.1-15% leaf area	Moderately resistant
5	Yellow mottling and discoloration of 15.1-30% leaf area	Moderately susceptible
7	Pronounced yellow mottling and discoloration of leaves, pods, reducing in leaf size, stunting of plants, 30.1-75% foliage affected	Susceptible
9	Severe yellow mottling and discoloration of leaves, stunting of plants, failure of flowering and fruit setting 75.1-100% foliar affected	Highly susceptible

To determine variability in MYMV strains, leaf samples of different mungbean varieties from different locations in Punjab, India in summer and *Kharif* 2002 and 2003, and some MYMV-infected seeds from Ludhiana, were collected. Viral DNA was isolated from the leaf samples of varieties SML 434 and SM 489 collected in summer 2002. KM 12 and ML 1108 from Ludhiana and UF2 and KM 51 from Faridkot during *Kharif* were purified. For isolation of MYMV DNA from infected leaf, PCR technique with primer pair PACTV 1978 B and AVIC 715 H were used. DNA was extracted from leaves by the method of Gilberton *et al.,* 1991. Viral DNA was amplified by polymerase chain reaction (PCR) using the begomovirus-specific degenerate primers pair PALTV1978B/PAR/C715.

Results and Discussion

From 1977 to 1997, 6,961 mungbean germplasm and advanced breeding lines were screened for resistance to MYMV. A number of resistant sources were identified and used in national and international disease resistance breeding programs (Singh *et al.*, 1980; Verma *et al.*, 1991; Singh *et al.*, 1997). These include 31 lines resistant to MYMV, CLS and15 lines resistant to CLS. Most of the MYMV and CLS lines were also resistant to BLS and 12 lines with multiple disease resistance (BLS, CLS, MYMV) were also identified (Singh and Bhan, 1998) (Table 1).

Table 1. Disease resistant donors of mungbean recommended by AICPIP[1] at national level

Disease	Donors
Mungbean yellow mosaic virus	ML5, 131, 267, 337, 353, 406, 408, 443, 500, 505, 515, 520, 537, 553, 611, 616, 626, 627, 631, 653, 656, 668, 682, 688,713, 729, 735, 746, 759, 769, PDM 84-139 and 84-143 .
Cercospora leaf spot	ML 5, 443, 453, 515, 610, 611, 613, 682, 688, 713, 729, 735, 746, 759 and 769
Bacterial leaf spot	Most of MYMV and CLS resistant lines were resistant to BLS
Multiple disease resistance (MYMV, BLS, CLS)	ML 443, 515, 611, 613, 682, 688, 713, 729, 735, 746, 759 and 769

[1]All India Coordinated Pulses Improvement Project.

Mungbean varieties recommended since the early nineties, such as ML 5, ML 131, ML 267, and ML 613 were resistant to MYMV and also had desirable resistance to other diseases. But in *Kharif* 1998, the MYMV resistant varieties, viz. ML5, ML131, ML 267 and ML 613 and other mungbean lines known for their high resistance, were reported to be infected with MYMV. They showed moderate to susceptible reaction to MYMV (Table 2).

Table 2. Variable reaction of varieties and promising mungbean lines to MYMV over years

Line No.	MYMV rating[2]		
	1995-97	1998	1999-2003
ML 267[1]	2.0	5.0	5.0
ML515	1.8	4.5	5.0
ML 613[1]	2.3	5.0	5.0
ML 682	1.8	5.0	6.0
ML 713	2.0	4.5	4.0
ML 776	1.7	5.0	5.0

[1]Recommended mungbean varieties.
[2]Ratings: 1=Resistant, 3=Moderately resistant, 5=Moderately susceptible, 7=Susceptible, 9= Highly susceptible.

From 1997 to 2003, 1,435 mungbean germplasm and advanced breeding lines of India and AVRDC derived through intra- and interspecific hybridization were screened for resistance to MYMV and only 5.9 and 13.5 % of the total lines had low MYMV ratings of 1 and 2, respectively (Table 3) in comparison to 18.7 and 16.8% of the 2,460 lines tested from 1987 to 1996 (Singh *et al.*, 1997).

Table 3. Reaction of mungbean germplasm, advance breeding lines and varieties to MYMV

Rating	1997	1998	1999	2000	2001	2002	2003	Total	% of total lines
1	17	-	14	48	-	-	4	83	5.9
2	35	-	38	50	20	8	42	193	13.5
3	59	4	49	36	63	47	75	333	23.2
4	21	42	36	24	88	54	59	324	22.5
5	20	78	10	23	35	24	24	214	14.9
6	9	28	3	5	10	16	21	92	6.4
7	-	8	1	4	5	7	37	62	4.3
8	-	5	-	4	4	4	42	59	4.1
9	-	13	3	-	4	5	50	65	5.2
Total	**161**	**178**	**154**	**194**	**229**	**165**	**354**	**1,435**	**100**

The number of entries resistant to MYMV varied over years (Table 3). Only three lines, viz. ML 818, ML 1221 and PDM 84-139, showed a MYMV rating of 2.0 or below 2.0 and were considered resistant. Thus, other 17 ML lines gave MYMV ratings between 2.0 and 3.0 (Table 4).

Table 4. Mungbean lines resistant to MYMV from 1999-2003

Line No.	No. of years of testing	MYMV (Rating)
ML 505	3	2.8
ML 591	3	2.9
ML 688	2	2.5
ML 707	5	2.4
ML 729	4	2.9
ML742	5	2.7
ML 759	5	2.4
ML 803	3	2.5
ML 818	5	1.9
ML 933	5	2.9
ML 935	5	2.4
ML 936	4	2.5
ML 939	5	2.9
ML 985	5	2.5
ML 1040	4	2.2
ML 1044	3	2.5
ML 1086	4	2.4
ML 1137	4	2.5
ML 1221	3	2.0
PDM 84-139	4	2.0
Susceptible check	5	9.0

During the operation of the DFID–AVRDC Mungbean Project, 713 mungbean lines including AVRDC lines were tested in both summer and *Kharif* seasons of 2002 and 2003 with main focus on short duration, high yield, resistance to MYMV, bold seed, and synchronous maturity which fit well between wheat and rice cropping system. The performance of short duration genotypes was better in summer season with respect to MYMV resistance. Overall, these lines showed comparatively less MYMV infection in summer season compared with *Kharif* seasons (Table 5).

Table 5. Reaction of short duration mungbean genotypes during summer and *Kharif* season (2002-2003)

Genotype	Days to Maturity (summer)	MYMV		Disease Rating		
		Summer	*Kharif*	CLS	BLS	Anth.
SML 668[1]	63	1.4	*5.7*	2.0	2.0	1.0
Pusa Vishal[1]	64	2.2	*6.0*	2.0	3.0	3.0
VC 6372-45-8-1	68	2.7	*6.5*	2.0	3.0	4.0
VC-3960-88	68	3.0	*5.3*	2.0	3.0	4.0
Pusa Bold-1[1]	71	4.8	*3.0*	3.0	3.5	2.5
Pusa 9531[1]	65	2.2	*5.5*	3.0	4.0	2.0
Pusa 9971	66	2.2	*4.2*	-	-	-
NM 66	66	2.2	*3.0*	-	-	-
NM 92	70	5.0	*6.0*	2.0	3.0	2.0
SML 134 (Susceptible check)	72	7.5	*9.0*	2.0	4.0	4.0

[1] Recommended cultivars (after these tests were done).

Identification of MYMV strains by molecular markers

In recent time, MYMV and its whitefly (*Bemisia tabaci*) have assumed dangerous proportion due to changing environment scenario and cropping pattern particularly in north-western states of India. This may be due to variability in virus and its vector. Both biotic stresses (virus and vector) are causing substantial losses in yield. A few years back, there was no occurrence of MYMV in the summer season in India, but now it is appearing every year in serious proportions. Differences in the symptoms on MYMV-infected plants and variation in varietal reaction of previously resistant varieties in different agro-climatic zones of the country and different countries indicate the occurrence of different strains/variants of the virus (Biswas and Varma, 2000). The MYMV-resistant mungbean varieties such as ML 131, ML 5, ML 267, and ML 613 and germplasm lines recommended up to 1998 showed reduced resistance and loss of resistance from 1998 onward. Resistance in varieties and available germplasm is limited. It is high time to give priority on determining the variability in virus strains, environmental interactions, and identification and deployment of new resistance genes for different situations/zones/ countries. Twenty-four leaf samples from several mungbean varieties (SML 668, Pusa Vishal, Pusa Bold 1, Pusa 9531, VC 6372-(45-8-4), SML 134, Pusa 9531, SML 489, KM-12, ML 1108, KM-13, UF-1, UF-2, 2KM-51, and 2KM-61) were collected in 2002 for MYMV detection. Viral DNA was amplified by polymerase chain reaction (PCR) using the begomovirus-specific degenerate primer pair

PAL1v1978B/PAR1c715H, which amplified a 1.4kb fragment of DNA-A. Nine samples, including two from SML 668 and one from SML 134, SML 489, KM-12, ML 1108, KM 13, UF-1 and 2KM-51, respectively, yielded the expected PCR products. The 1.4kb PCR products from variety SML 134 and 2KM-51 leaf samples were cloned and sequenced. The DNA-A top sequence of isolate from SML 134 leaf sample showed highest sequence identity of 97% with Mungbean yellow mosaic India virus-[Akola] and that from 2KM-51 leaf sample showed highest sequence identity of 97% with Dolichos yellow mosaic virus from Varanasi, India. However, the DNA sequences of these two isolates have high sequence identity of 96% and are considered to be closely related strains of same virus.

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Insect pest management of mungbean

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Abstract

The mungbean crop is attacked by a number of insect pests. The most serious pest problems include the whitefly (*Bemisia tabaci)*, bean thrips (*Megalurothrips distalis*), gram pod borer (*Helicoverpa armigera*) and legume pod borer (*Maruca vitrata*). Keeping in view the harmfulness of these pests, experiments were conducted in 2002 and 2003 to identify host plant resistance, test and recommend promising insecticides, and evaluate the effect of different cultural practices on the incidence of these pests in order to develop integrated pest management (IPM) modules for the management of major insect pests. Seventy entries of summer mungbean were screened in 8 trials against *M. distalis* where NM 92 and Pusa 2032 were identified as resistant and could be used in hybridization program. Similarly, out of 170 entries of rainy season mungbean tested in 14 trials, entry ML 881 was identified as resistant for *B. tabaci*. Among the insecticides tested against *M. distalis*, Hostathion 40 EC (triazophos) at 1500ml ha^{-1} gave excellent control of the pest. Seed treatment with Actara 25 WG (thiomethoxam) at 2 g kg^{-1} seed + foliar spray of Hostathion 40 EC (triazophos) at 0.04% gave the best control of *B. tabaci* in mungbean (rainy season). For the management of *M. vitrata* during rainy season mungbean Avaunt 14.5 SC (indoxacarb) at 500 ml and Thiodan 35 EC (endosulfan) at 2.5 l ha^{-1} were found to give better control. Effect of various cultural practices, viz. tillage and residue, irrigation and fertilizer, date of sowing and seed rate, mulching and irrigation, and variety and spacing on *M. distalis* was studied. Data indicated that the population of the pest increased at higher seed rate of 37.5- 40 kg ha^{-1} compared with low seed rate (25-30 kg ha^{-1}). Narrow row-to-row spacing of 20 cm attracted more thrips compared with wider spacing of 30 cm. Lesser fertilizer and more irrigations were effective in lowering thrips population but this finding needs further testing. Other agronomic practices did not have any significant effect on the population of thrips.

Introduction

Mungbean is one of the important pulse crops of India. The crop has good potential but the farmers get low yield due to many factors. Damage by insect pests is one of the major reasons for low yield. Chhabra and Kooner (1998) reported that mungbean is damaged by as many as 198 insect pests; however, Chhabra (2001) listed 283 insect pests. Major insect pests of summer mungbean include bean thrips (*Megalurothrips distalis*), gram pod borer (*Helicoverpa armigera*), til caterpillar/til hawk moth (*Acherontia styx*). On the other hand, major insect pests of munbean during rainy season are the whitefly (*Bemisia tabaci*), Bihar hairy caterpillar (*Spilosoma obliqua*), green semi-looper (*Anomis flava*), legume pod borer (*Maruca vitrata*), bean mite (*Polyphagotarsonemus latus*) and black aphid (*Aphis craccivora*). The most critical among these insect pests are *B. tabaci*, *H. armigera*, *M. distalis,* and *M. vitrata*. Some insect pests like *B. tabaci*, *H. armigera*, *S. obliqua,* and *M. distalis* caused epidemics in past years that led to heavy losses and sometimes total failure of the crop. The whitefly has been reported to cause losses ranging from 30-70% particularly by spreading mungbean yellow mosaic virus (MYMV) (Marimuthi *et al.*, 1981).

In Punjab, the whitefly appeared in epidemic form during rainy season in 2001 (10.33-41.67 whiteflies /cage at farmers fields) causing up to 100% yield loss. Thrips stay in flowers and do damage such that flowers shed before opening. The plant attains a bushy growth. The crop looks very dark green in color. In case of severe incidence, there is 100% yield loss (Kooner *et al.*, 1983). Chhabra and Kooner (1985a) reported a 54.3% yield loss in summer mungbean due to pest complex especially *M. distalis.* The legume pod borer larvae coat the leaves and inflorescence with web and then feed inside the flowers, flower buds, and pods, causing flower shedding. Being photonegative, the pests feed during the night. Losses due to *M. vitrata* on pigeonpea have been estimated to be US $ 30 million annually in India (ICRISAT, 1992).

Several trials were conducted at the farms of PAU in Ludhiana to identify sources of resistance; test and recommend more effective, economical, and eco-friendly insecticides; and determine the effect of some cultural practices on the incidence of *M. distalis* to be able to develop possible IPM modules for the management of these insect pests.

Objectives:

1. Identification of resistant/tolerant genotypes of summer mungbean against thrips (*M. distalis*) and of mungbean (rainy season) against whitefly (*B. tabaci*), and MYMV to be able to use the identified resistant donors in breeding resistant/tolerant varieties with other desirable characters. These resistant varieties may serve as an important component of IPM to manage these pests;
2. To screen available insecticides against thrips (*M. distalis*), whitefly (*B. tabaci*), and legume pod borer (*M. vitrata)* to be able to recommend more effective, economical, and eco-friendly insecticides for the management of the pest; and
3. To work out and recommend possible management of thrips and *M. distalis* through various cultural practices including date of sowing, seed rate, mulching, irrigation, spacing, tillage, etc. as one of the components of IPM.

Materials and Method

Identification of host plant resistance/tolerance

Bean thrips, *M. distalis*

Only one trial was conducted during summer 2002 while 8 trials were conducted during summer 2003 for screening entries against *M. distalis*. In all the trials, the test entries were sown horizontally whereas the Infester rows were sown vertically on both sides of the test entries. The Infester row included a mixture of entries highly susceptible to *M. distalis*, viz. MH 399, PDU 5, S37, DU 2, JU 77-41, PDU 8, UPU 83-1, G 65, 11/395, MG 189, MG 122, MUG 161, MUG 185, MUG 193, PDM 76, UPM 83, NPRG 1, NPRG 3, SML 107, SML 118, and SML 122. The trials were kept free from insecticides. The details of the experiment are given in Table 1. Recorded observations on the population of thrips were taken by randomly collecting 10 flowers per replication per entry at flowering stage. Each flower was thoroughly shaken on a white paper and carefully examined for the population of thrips.

Table 1. Details of different trials conducted for screening summer mungbean against thrips, *M. distalis* in 2002 and 2003

Trial	Entries	Sowing date	Plot size
FYT (2002)	11	22.4.02	2+1 of 4.5 m with one row as gap between 2 entries
FYT (2003)	15	1.4.03	-do-
AVT (2003)	20	1.4.03	2+1 of 4 m at 22.5 cm with 1 row as gap
AVT 1&2 (2003)	8	28.4.03	4.0 m x 22.5 cm
IVT (2003)	15	28.4.03	4.0 m x 1.35 m
Promising material 2nd year (2003)	6	1.4.03	2+1 of 4 m at 22.5 cm with 1 row as gap
Promising material 3rd year (2003)	4	1.4.03	-do-
Promising material 4th year (2003)	2	1.4.03	-do-

2+1 = 2 rows sown and 1row as gap; 1+1 = 1 row sown and 1 row as gap
Experimental design= RBD (all trials), Replications=3 except AVT 1 & 2 (=4)
FYT (Final Yield Trial), AVT (Advanced Varietal Trial), IVT (Initial Varietal Trial)
Checks: 2002= SML 32, SML134; 2003= SML 668

Whitefly, *B. tabaci*

During rainy season of 2002 and 2003, six and seven trials respectively were conducted to identify host plant resistance/tolerance against *B. tabaci*. In all the trials, the test material was sown horizontally and surrounded by the Infester rows sown vertically on both sides of the test entries. The Infester comprised of a mixture of entries highly susceptible to the whitefly and MYMV, viz. ML 5, ML 395, ML 604, ML 439, ML 505, Pusa 9072, Pusa 8771, Pusa 8773, PDM 87, MUM 3, RMG 117, and RMG 268. The trials were kept free from insecticides. The details on plot size, sowing date, etc. of all the trials are given in Table 2. The population of whitefly was recorded with the help of 'Kooner Cage' (height 60 cm, diameter 45 cm; Figure 1). The population of whitefly was recorded from two spots/replication/entry.

Figure 1. Kooner Cage for very efficient and accurate recording of whitefly/ jassid population on mungbean

Table 2. Details of different trials conducted for screening mungbean (rainy season) against *B. tabaci* in 2002 & 2003

Trial	Entry		Plot size	
	2002	2003	2002	2003
IVT	19	11	1+1	2+1
FYT	23	14	1+1	1+1
FYT-II (Summer)	-	19	-	2+1
AYT	23	13	1+1	2+1
Promising material 2nd year	18	19	2+1	2+1
Promising material 3rd year	4	5	2+1	2+1
Promising material 4th year	-	2	2+1	2+1

IVT = Initial Varietal Trial; FYT = Final Yield Trial, AYT= Advance Yield Trial
DOS = During 2002 was 16.7.2002 and during 2003 was 15.7.2003
-Experimental design= RBD (all trials), Replications= 3 (all trials)
-Check varieties: 2002- ML5, ML267, ML613; 2003- ML5,ML267,ML613,SML668;
In IVT 2003- ML5,ML267,ML613,SML668,ML818,BM 4
Plot size: 2002- Row to row distance= 30 cm, Row length= 4 m
2003 - Row to row distance= 30 cm, Row length=5 m

Identification of promising insecticides

Bean thrips *(M. distalis)*

A field trial was conducted to test the efficacy of three insecticides at three different doses along with recommended insecticide, water spray, and control. Spray treatments were given at flower initiation stage. The details of the experiment are given in Table 6. Observations were recorded on the population of thrips from 10 flowers taken randomly from each replication of a treatment three days after spray. Grain yield was also recorded from each plot.

Whitefly *(B. tabaci)*

Efficacy of some insecticides was tested as seed treatment, and as spray for the control of whitefly on mungbean. The details of the experiment are given in Table 7. The population of whitefly was recorded with the help of 'Kooner Cage' from three spots per replication per treatment, three and seven days after spray. Grain yield was also recorded from each plot.

Legume pod borer *(M. vitrata)*

Two on-farm trials were conducted to test the efficacy of four insecticides at two doses each against legume pod borer, *M. vitrata* on mungbean (rainy season). The details of the trials are given in Table 8. Observations were recorded on the larval population of the borer from 10 twigs taken randomly from each replication of a treatment three and seven days after spray.

Evaluation of cultural practices for the management of insect pests

Eight cultural field trials were conducted jointly with an agronomist to determine the effect of different cultural practices on *M. distalis* in 2002 and 2003. The details of the trials are given in Table 3. The population of thrips was recorded by randomly collecting 10 flowers per replication per treatment at flowering stage.

Table 3. Details of different trials on the effect of different cultural practices on the incidence of bean thrips *M. distalis*, in summer mungbean in 2002 and 2003

Trial	Treatment		Sowing date		Plot size	
	2002	2003	2002	2003	2002	2003
Effect of tillage & residue management	3[1]	-	23.4.02	-	16 m x 2.7 m.	-
Effect of irrigation & N&P fertilizer	12[2]	12[2]	24.4.02	29.4.03	6 m x 2.4 m	6 m x 2.4 m
Effect of date of sowing & seed rate	-	10[3]	-	28.3.03, 21.4.03	-	5 m x 2.4 m
Effect of mulching & irrigation	-	9[4]	-	28.3.03	-	5 m x 2.9 m
Effect of varieties & spacing	-	12[5]	-	28.3.03	-	5 m x 3.3 m
Effect of inputs	-	8[6]	-	2.4.03	-	5 m x 2.5 m
Effect of different irrigation levels (Termination of irrigations)	-	6[7]	-	2.4.03	-	5 m x 2.5 m

1 - Tillage, no tillage, tillage + straw
2 - Irrigations = 2,3,4,5; fertilizer = Control (F1), Recommended (F2), Recommended N+50% higher than recommended P (F3)
3 - Sowing dates = 28.3.03(D 1), 21.4.03 (D 2), Seed rate (kg/ha) = 25, 30, 35, 37.5, 40
4 - Mulching =No mulch, mulch at sowing, mulch at 1st irrigation; Irrigation levels=2 (25, 45 DAS); 3 (25, 40, 50 DAS), 4 (25, 33, 41, 49DAS)
5 - Varieties=4(Pusa Vishal, Pusa 9531, MH96-1, SML668); Spacing =3 (20 cm x 10 cm, 25 cm x 10 cm, 30 cm x 10 cm)
6 - Control, fertilizer, weed control, plant protection, fertilizer + weedicide, fertilizer + plant protection, fertilizer + plant protection and fertilizer + weedicide + plant protection.
7 - 6 (Termination of irrigation 47, 54, 61, 68, 75, 82 DAS)
No. of replications: 3 (4 in last trial)
Variety: SML 668 (all trials)
Design: SPD (RBD in trials on tillage x residue management, effect of inputs and trial on termination of irrigation levels)

Results and Discussion

Identification of host plant resistance/tolerance

Bean thrips *(M. distalis)*

The population of thrips in FYT in summer 2002 ranged from 17.00-34.67 per 10 flowers against 31.33-32.00 and 42.00 on the checks and the Infester, respectively (Table 4). Entries SML 9, SML1, and NM 92 had less thrips infestation. In summer 2003, the incidence of thrips was low and varied between 0.33-2.67 on the test entries, while it was 1.33 and 5.00 per 10 flowers on the checks and Infester, respectively. Entries BMC 29, HUM 16, PDM 11, TM 99-37 were identified least susceptible.

In summer 2003 in AVT, AVT 1 & 2, and IVT trials, the incidence was 0.00-15.00, 0.67-10.00 and 5.67 per 10 flowers on the test entries, checks and the Infester, respectively. Entries BMG 29, HUM 16, PDM 11, T 99-37, SM 03.34, SM 03.33, SM 03.10, SM 03.62, SM 03.60, -19, -51, -52 were found to be better than others. In the trials on testing of promising material in 2nd, 3rd and 4th year, the population of thrips per 10 flowers fluctuated between 0.33-2.33, 2.00-2.67, 5.00-5.67 on the test material, checks, and the Infester, respectively. The entries with low thrips infestation in these trials included SML 1, SML 9, SML 475, SML 689, HUM 14, NM 92, and Pusa 2032. The entries NM 92 and Pusa 2032 had consistently low thrips infestation for four years and therefore may be classified as resistant to *M. distalis* and may be useful in hybridization program.

Chhabra and Kooner (1998) reported that mungbean genotypes PIMS 2, PIMS 3, 12-333 at Badnapur, Co 3 at Coimbatore, ML 5, ML 337 at Durgapura are resistant to thrips. Chhabra and Kooner (1994a) reported SML 99 and SML 100 as thrips-resistant genotypes of summer mungbean. It was further investigated that low content of free amino acids, total phenols, total minerals, total sugars, non-reducing sugars, calcium, potassium, and high content of total carbohydrates were responsible for contributing resistance in SML99 and SML100 (Chhabra *et al.*, 1994). Kooner and Malhi (2004) screened 30 summer mungbean genotypes and found SML 189, SML 346, and MG 414 as least susceptible to *M. distalis*.

Whitefly *(B. tabaci)*

In all screening trials conducted on rainy season mungbean during 2002, the range of mean whitefly population was 0.66-4.33, 2.33-4.66 and 6.66-8.33 whitflies/cage on the test material, checks and the Infester, respectively (Table 5). Entries MH

Table 4. Incidence of bean thrips *M. distalis,* in summer mungbean entries in different trials in 2002 and 2003

Trial	Entries tested	Range of mean population of thrips per 10 flowers			Resistant/tolerant entries identified
		Test entry	Check	Infester	
FYT (2002)	11	17.00-34.67	31.33-32.00	42.00	SML 9 SML1 NM 92
FYT (2003)	15	0.33-2.67	1.33	5.00	SML 489 SML 732 HUM 15
AVT (2003)	20	0.33-2.00	0.67	5.67	BMC 29 HUM 16 PDM 11 TM 99-37
AVT 1&2 (2003)	8	5.75-12.00	8.75	-	SM.03.34 SM.03.33 SM.03.10
IVT (2003)	15	0.00-15.00	10.00	-	SM.03.62 SM.03.60 SM .03.10 SM .03.52 SM .03.51
Promising material 2nd year (2003)	6	0.33-2.33	2.00	5.00	SML1 SML9 HUM14
Promising material 3rd year (2003)	4	0.33-1.67	2.33	5.33	SML 475 SML 689
Promising material 4th year (2003)	2	0.33	2.67	5.67	NM 92 Pusa 2032

FYT (Final Yield Trial), AVT (Advanced Varietal Trial), IVT (Initial Varietal Trial) - Infester not sown

96-1, ML 818, TPM 99-125, ML 1191, ML 1229, ML 1259, ML 1263, ML 1274, ML 1286, ML 1256, ML 1260, ML 881, and Pusa 9837 had the lowest infestation. In 2003, the incidence of whitefly varied between 0.50-6.83, 1.83-8.17 and 5.83-8.00 whiteflies/cage on the test entries, checks and the Infester, respectively in different trials. The list of entries found least susceptible included ML 1165, ML 1108, ML 818, ML 1274, ML 1299, ML 1259, ML 1262, ML 1265, ML 1260, ML 1329, ML 1330, ML 1318, ML 1325, ML 1327, ML 1229, ML 1270, ML 1277, ML 1191, ML 1256, ML 881, and SM 66. As entry ML 881 was consistently less susceptible for four years, it may be used as resistant donor to develop whitefly resistant mungbean for rainy season.

Table 5. Incidence of whitefly, (*B. tabaci*) in mungbean entries (rainy season) in different trials conducted in 2002 and 200

Trial	Entries tested		Range of mean population of whitefly per cage						Resistant/tolerant entries identified	
			Test entry		Checks		Infester			
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
IVT	19	11	1.33-4.33	1.00-6.83	2.66-4.66	3.67-8.17	7.33	8.00	MH96-1, ML818, TPM99-125	ML1165, ML1108, ML818
FYT	23	14	1.33-2.33	0.50-5.33	2.66-4.00	3.17-5.83	6.66	6.67	ML1191, ML1229, ML1259, ML1263, ML 1274	ML1274, ML 1299, ML 1259, ML 1262, ML 1265, ML 1268
FYT-II (Summer)	-	19	-	1.00-7.00	-	1.83-5.67	-	5.83	-	SM 66
AYT	23	13	0.66-2.33	0.67-6.33	2.33-3.66	2.17-5.67	7.33	5.83	ML 1286	ML1329, ML1330, ML1318, ML 818, ML1325, ML 1327
Promising material 2nd year	18	19	1.33-2.66	1.33-6.50	2.33-4.00	4.00-7.33	7.33	6.33	ML1191, ML1256, ML1259, ML1260, ML1274	ML1229, ML1262, ML1270, ML1277
Promising material 3rd year	4	5	2.00-3.00	1.33-2.50	2.66-4.33	4.33-6.67	8.33	6.17	ML881	ML1260, ML191, ML1256
Promising material 4th year	-	2	1.66	1.67-6.83	2.66-3.66	5.00-6.67	7.00	5.83	-	ML 881

FYT (Final Yield Trial), AYT (Advanced Yield Trial), IVT (Initial Varietal Trial)

Kooner (1998) screened 48 mungbean genotypes and identified ML 508 and ML 537 as resistant donors against *B. tabaci* and MYMV. Chhabra and Kooner (1994b) reported ML 395, ML 505, and ML 543 as resistant to *B. tabaci* and MYMV. Chhabra and Kooner (1993) screened 42 entries against whitefly and MYMV and isolated Pusa 326, ML 272, ML 267, and ML 326 as less susceptible to whitefly.

Identification of promising insecticides

Bean thrips *(M. distalis)*

The lowest population of thrips was recorded in plots treated with Hostathion 40 EC at 1500 ml ha^{-1} (Table 6). Fosmite 50 EC at 2000 ml ha^{-1} and Thiodan 35 EC at 2250 ml ha^{-1} were on par with Hostathion 40 EC at 1500 ml ha^{-1}. Hostathion 40 EC at 1500 ml ha^{-1} was significantly better than all other treatments, standard check, water spray and the control. Maximum reduction in thrips population (74.36%) was observed in this treatment. The highest grain yield of 1514 kg ha^{-1} was also recorded in Hostathion 40 EC at 1500 ml ha^{-1} and it was on par with Fosmite 50 EC at 2000 ml and Thiodan 35 EC at 2250 ml ha^{-1}.

Table 6. Comparative efficacy of some insecticides as spray formulations for the control of flower thrips *(M.distalis)* on summer mungbean

Location	:	P.A.U. Ludhiana
Date of Sowing	:	22.4.2002
Design	:	RBD
Variety	:	SML 668
Plot Size	:	4.25m x 4 m (17 m2)
Replications	:	3
Treatments	:	11+1

Treatment	Dose (ml ha^{-1})	Mean population of thrips/10 flowers, 3 days after spray[1]	% reduction in thrips population after spray[2]	Grain yield (kg ha^{-1})
Hostathion 40 EC (triazophos)	500ml	22.67(4.86)b	50.18(45.09)	1,422
-do-	1000ml	22.00(4.78)b	51.65(45.94)	1,429
-do-	1500ml	11.67(3.55)a	74.36(59.58)	1,514
Fosmite 50 EC (ethion)	1000ml	23.00(4.89)b	49.45(44.66)	1,378
-do-	1500ml	23.67(4.96)b	47.99(43.82)	1,424
-do-	2000ml	14.33(3.89)a	68.50(55.98)	1,474
Thiodan 35 EC (endosulfan)	750ml	28.33(5.39)b	37.73(37.63)	1,363
-do-	1500ml	23.33(4.91)b	48.71(44.20)	1,415
-do-	2250ml	17.00(4.23)a	64.83(53.62)	1,455
Rogor 30 EC (dimethoate) (standard check)	250ml	28.67(5.40)b	36.99(36.90)	1,363
Water spray	-	26.67(5.22)b	41.39(39.68)	1,289
Control (no treatment)	-	41.00(6.47)b	9.89(16.43)	1,293
C.D. at 5%	-	(0.88)	(12.76)	73

[1]Figures in parentheses are the transformed means ($\sqrt{n+1}$ values)
[2]Figures in parentheses are transformed means (arc sine values)

Chhabra and Kooner (1985b) tested 11 insecticides against *M. distalis* and reported that dimethoate at 75 g a.i./ha and monocrotophos at 100 g a.i. ha^{-1} gave effective control of the pest. Irulandi and Balasubramanian (2000) reported neem seed kernel extract 5% (NSKE) and neem oil 2% to be as effective as monocrotophos 0.05%.

Whitefly *(B. tabaci)*

The minimum population of whitefly was recorded in the treatment Triazophos + Hostathion which was significantly better than all other treatments and the control, three and seven days after spray (Table 7). The highest grain yield of 1025 kg ha^{-1} was also recorded in this treatment.

Table 7. Comparative efficacy of some insecticides as seed treatment and as spray for the control of whitefly (*B. tabaci*) on mungbean (rainy season)

Locations	:	PAU, Ludhiana
Date of sowing	:	15.7.2003
Replications	:	3
No. of treatments	:	5+1
Design	:	RBD
Date of spray	:	5.9.2003
Plot size	:	6 m x 5 m

Treatment	Dose/ Conc.	No. of whiteflies/cage[1] 3 days after spray	7 days after spray	Grain yield (kg ha^{-1})
T_1 dimethoate (Rogor 30 EC)	5 ml kg^{-1} seed	4.56(2.36)	4.22(2.28)	864
T_2 thiomethoxam (Actara 25 WG)	2 g kg^{-1} seed	3.44(2.11)	2.78(1.94)	960
T_1 + foliar spray of triazophos (Hostathion 40 EC)	0.04%	4.00(2.23)	3.89(2.21)	936
T_2 + foliar spray of triazophos (Hostathion 40 EC)	0.04%	1.78(1.67)	1.22(1.49)	1,025
Hostathion 40 EC foliar spray	0.04%	4.11(2.26)	4.00(2.23)	890
Control	-	6.00(2.64)	5.11(2.47)	778
C.D. at 5%		(0.25)	(0.18)	38

[1]Figures in parentheses are the transformed √ n+1 values

Kooner and Singh (1980) investigated that application of aldicarb and disulfoton at 2 kg a.i. ha^{-1} gave effective control of *B. tabaci* and MYMV. Chaudhary *et al.* (1981) found that disulfoton at 1.5 kg a.i. ha^{-1} as basal application at sowing gave significant reduction in whitefly population. Vadodaria and Vyas (1987) reported that combination of phorate 10 G and monocrotophos was most effective to manage this pest.

Legume pod borer *(M. vitrata)*

The least population of *M. vitrata* larvae 3 days after spray was recorded in Avaunt 14.5 SC at 500 ml (1.33 larvae/10 twigs) which was on par with Thiodan 35 EC at 2500 ml (2.00) and Avaunt 14.5 SC at 250 ml (2.33). Avaunt 14.5 SC at 500 ml was significantly better than all other treatments (3.67-7.00) and the control (9.67) at Location 1 (Table 8). Similar results were obtained seven days after the spray. Data recorded from 2nd location three and seven days after spray indicated that the minimum population of 1.33 and 0.67 larvae/10 twigs was recorded again in Avaunt 14.5 SC at 500 ml. Thiodan 35 EC at 2500 ml was on par with Avaunt 14.5 SC at 500 ml while all other treatments and the control had significantly higher population. Analysis using factorial RBD revealed that the interaction between insecticide and dose was non-significant.

Table 8. Comparative efficacy of some insecticides for the control of legume pod borer (*M. vitrata*) on rainy season mungbean in 2003 (on-farm trials)

Locations	:	(Two) 1. Village Boparai Kalan, Ludhiana 2. Village Goindwal, Raikot, Ludhiana			
Date of sowing	:	2nd week of July, 2003			
Variety	:	SML 668			
Replications	:	3	No. of treatments	:	8+1
Design	:	RBD	Plot size	:	20m x 5m

Treatment	Dose ha^{-1} (formulation)	No. of larvae per 10 twigs[1]			
		Location 1		Location 2	
		3 days after spray	7 days after spray	3 days after spray	7 days after spray
Thiodan 35 EC (endosulfan)	1250 ml	3.67(2.16)	2.33(1.82)	4.33(2.31)	3.67(2.16)
-do-	2500 ml	2.00(1.72)	1.67(1.61)	1.67(1.63)	1.33(1.52)
Dursban 20 EC (chlorpyrifos)	1250 ml	5.67(2.57)	4.00(2.23)	7.33(2.88)	4.33(2.31)
-do-	2500 ml	4.67(2.38)	2.67(1.90)	4.33(2.31)	3.67(2.16)
Ekalux 20 AF (quinalphos)	1250 ml	7.00(2.82)	3.67(2.16)	5.33(2.52)	3.67(2.16)
-do-	2500 ml	5.67(2.58)	2.67(1.91)	3.33(2.08)	3.00(1.99)
Avaunt 14.5SC (indoxacarb)	250 ml	2.33(1.82)	1.67(1.63)	4.00(2.23)	3.33(2.08)
-do-	500 ml	1.33(1.52)	0.66(1.28)	1.33(1.52)	0.67(1.28)
Control	-	9.67(2.26)	7.66(2.94)	8.33(3.05)	7.67(2.94)
C.D. at 5%		(0.33)	(0.36)	(0.29)	(0.33)

[1]Figures in parentheses are the transformed $\sqrt{n+1}$ values

Rahman (1991) observed that foliar application of cypermethrin (0.008%) or dimethoate (0.07%) at flowering in pigeonpea and repeating after 10-15 days provided effective protection against the pest. Samolo and Patnaik (1986) found that monocrotophos and endosulfan at 0.5 kg a.i. ha^{-1} were most effective in checking the pest on pigeonpea. Sundarababu and Rajasekaran (1984) reported that spray of endosulfan at 0.07% gave maximum reduction in borer damage.

Evaluation of cultural practices for the management of M. distalis in summer mungbean

Effect of tillage and residue management on *M. distalis*

It is evident from data that the incidence of thrips in summer 2002 varied between 27.00-39.75 thrips/10 flowers in different treatments. The lowest incidence of 27.00 thrips was recorded in the treatment no tillage (direct sowing) which was on par with tillage + straw incorporation treatment (31.00 thrips) (Table 9).

Table 9. Effect of tillage and residue management on the incidence of thrips (*M. distalis*) 2002

Location	: PAU, Ludhiana	Replications	: 4
Date of sowing	: 28.3.2003	Design	: RBD
Plot size	: 16.0 m x 2.7 m	Variety	: SML 668
No.of treatments	: 3		

Treatment	No. of thrips/10 flowers[1]
No Tillage (direct sowing)	27.00(5.28)
Tillage	39.75(6.38)
Tillage + Straw incorporation	31.00(5.64)
C.D. at 5%	(0.55)
C.V. (%)	(5.52)

[1]Figures in parentheses are the transformed $\sqrt{n+1}$ values

Effect of irrigation and fertilizers on *M. distalis*

The data presented in Table 10 reveals that in 2002, there was no significant effect of fertilizers on the population of thrips. The effect of irrigations was also non –significant. However, the interaction of fertilizer and irrigation was significant. The population of thrips ranged between 33.67-47.67 thrips/10 flowers in different treatments. The lowest incidence of 33.67 thrips in 2002 was recorded in the treatment with 5 irrigations and no fertilizer. During summer 2003 the incidence varied from 7.67 to 14.67 thrips per 10 flowers. The treatments with lesser fertilizer had significantly lesser population of thrips compared with higher doses of fertilizer. The treatment I1 (2 irrigations) had significantly higher thrips population than all the treatments of irrigation. The interaction of fertilizer and irrigation was also significant. Overall, it was observed that lesser fertilizer and more irrigations were effective in lowering thrips population.

Effect of date of sowing and seed rate on *M. distalis*

It may be inferred from Table 11 that the incidence of thrips in different treatments during summer 2003 varied from 0.67- 3.67 thrips /10 flowers. In case of dates of sowing, the effects were non- significant. As regards seed rate, higher seed rates of 37.5 and 40 kg ha^{-1} attracted significantly more thrips as compared to lower seed rates (25, 30, 35 kg ha^{-1}). The interaction of dates of sowing and seed rate was significant.

Table 10. Effect of irrigation and N & P fertilizer on the incidence of thrips (*M. distalis*) 2002 and 2003

Location	:	PAU, Ludhiana	Replications	:	3
Date of sowing	:	24.4.2002 29.4.2003	Design	:	SPD
Plot size	:	5.0 m x 1.8 m (2002) 6.0 m x 2.40 m (2003)			
Variety	:	SML 668	Treatments	:	12

Irrigation levels	Fertilizer :
I1 : 2 (20, 40 DAS)	F1 = Control
I2 : 3 (20, 30, 40 DAS) (12.5, 40)	F2 = Recommended N, P kg/ha
I3 : 4 (15, 25, 35, 45 DAS)	F3 = Rec. N & P (50% additional)
I4 : 5 (15, 23, 31, 39, 47 DAS)	

Irrigation	No. of thrips/10 flowers[1] (2002)			
	Fertilizer			
	F1	F2	F3	Mean
I1	39.67(6.38)	41.33(6.50)	36.67(6.12)	(6.33)
I2	43.00(6.62)	37.00(6.16)	45.67(6.81)	(6.53)
I3	47.67(6.97)	44.67(6.75)	41.67(6.53)	(6.75)
I4	33.67(5.88)	41.67(6.52)	45.00(6.78)	(6.39)
Mean	(6.46)	(6.48)	(6.56)	

C.D. at 5% Fertilizer= NS Irrigation= NS Fertilizer X Irrigation=0.54
C.V. (%) = 4.93

Irrigation	No. of thrips/10 flowers[1] (2003)			
	Fertilizer			
	F1	F2	F3	Mean
I1	8.67(3.10)	12.33(3.64)	14.67(3.95)	(3.57)
I2	9.33(3.21)	7.67(2.94)	12.67(3.69)	(3.28)
I3	8.67(3.10)	9.00(3.16)	13.00(3.74)	(3.33)
I4	12.00(3.59)	10.67(3.41)	10.67(3.41)	(3.47)
Mean	(3.25)	(3.29)	(3.70)	

C.D. at 5% Fertilizer= NS Irrigation= NS Fertilizer X Irrigation=0.54
C.V. (%) = 4.93
[1]Figures in parentheses are the transformed √ n+1 values

Table 11. Effect of dates of sowing and seed rates on the incidence of thrips (*M. distalis)*, 2003

Location : AU, Ludhiana Replications : 3
Date of sowing: D1= 28.3.2003 Design : SPD2= 21.4.2003
Plot size : 5.0m x 2.40 m
Seed rates (kg ha^{-1}): S1=25, S2= 30, S3= 35, S4= 37.5, S5= 40
Variety : SML 668

Date of sowing	No. of thrips/10 flowers[1] (2003)					
	Seed Rate					
	S1	S2	S3	S4	S5	Mean
D1	1.33(1.52)	1.33(1.52)	1.67(1.63)	2.67(1.91)	3.67(2.16)	(1.75)
D2	0.67(1.29)	1.33(1.49)	1.67(1.63)	3.00(1.99)	3.33(2.06)	(1.73)
Mean	(1.41)	(1.51)	(1.63)	(1.95)	(2.11)	

C.D. at 5% Seed Rate = 0.26 Date of sowing = NS Date of sowing X Seed Rate = 0.42
C.V. (%) = 14.18
[1]Figures in parentheses are the transformed √ n+1 values

Effect of irrigation and mulching on *M. distalis*

The incidence of thrips in different treatments during summer 2003 fluctuated between 0.33- 3.67 per 10 flowers. No effect of mulching was observed on the population of thrips. Treatments with 2 or 3 irrigations had significantly lower population (0.33–2.00 thrips/ 10 flowers) compared to four irrigations (3.00–3.67 thrips/ 10 flowers) (Table12). Least population of thrips was recorded from the treatment with 2 irrigations and no mulching.

Table 12. Effect of irrigation and mulching on incidence of thrips *(M. distalis)* 2003

Location :	PAU, Ludhiana	Replications:	3
Date of sowing:	28.3.2003	Design :	SPD
Plot size :	5.0m x 2.90 m	Variety :	SML 668
Irrigation levels		Mulching :	
I1: 2 (25, 45 DAS)		M_1 = No mulching	
I2: 3 (25, 40, 50 DAS)		M_2 = Mulch at sowing	
I3: 4 (25,33,41,49 DAS)		M_3 = Mulch at first irrigation	

Irrigation	No. of thrips/10 flowers[1] (2003)			
	Mulching			
	M1	M2	M3	Mean
I1	0.33(1.14)	1.33(1.52)	1.00(1.41)	(1.36)
I2	1.33(1.49)	2.00(1.72)	1.67(1.58)	(1.59)
I3	3.33(2.08)	3.00(2.00)	3.67(2.16)	(2.07)
Mean	(1.57)	(1.76)	(1.72)	

C.D. at 5% Mulching = NS Irrigation = 0.26 Mulching X Irrigation = NS
C.V. (%) = 14.12
[1]Figures in parentheses are the transformed $\sqrt{n+1}$ values

Effect of varieties and spacings on *M. distalis*

The differences in thrips population were non- significant in different varieties during 2003. The effects of spacing were significant. Closer spacing of 30cm and 25cm had significantly higher incidence of thrips population compared with wider spacing. The interaction of spacing and variety was non- significant (Table 13).

Table 13. Effect of varieties and spacing on the incidence of thrips *(M. distalis)* 2003

Location : PAU, Ludhiana
Date of sowing : 28.3.2003
Plot size : 5.0m x 3.3 m
Spacing:
S1: 20cm x 10cm
S2: 25cm x 10cm
S3: 30cm x 10cm

Replications : 3
Design : SPD
Varieties:
V1 = Pusa Vishal
V2 = Pusa 9531
V3 = MH 96-1
V4 = SML 668

Variety	No. of thrips/10 flowers[1] (2003)			
	Spacing			
	S1	S2	S3	Mean
V1	3.00(1.99)	1.67(1.58)	1.00(1.38)	(1.65)
V2	2.00(1.72)	1.33(1.49)	1.00(1.38)	(1.53)
V3	3.33(2.08)	2.67(1.88)	1.33(1.49)	(1.81)
V4	2.00(1.72)	1.00(1.38)	0.67(1.28)	(1.46)
Mean	(1.87)	(1.58)	(1.38)	

C.D. at 5% Spacing = 0.28 Variety = NS Spacing X Variety = NS
C.V. (%) = 14.18
[1]Figures in parentheses are the transformed $\sqrt{n+1}$ values

Effect of different inputs (fertilizer, weedicide and insecticide) on *M. distalis*

The population of thrips in different treatments ranged from 0.33-4.67 per 10 flowers during summer 2003. The data indicate that the treatments that have insecticide component were having significantly lower population of thrips (0.33-1.00) compared with other treatments (2.33-3.33) and control (4.67) (Table 14).

Table 14. Effect of different inputs (fertilizers, weed control and plant protection) on incidence of thrips *(M. distalis)* in summer mungbean 2003

Location : PAU, Ludhiana
Date of sowing : 2.4.03
Variety : SML 668
Replications : 3
Design : RBD
Plot size : 5.0 m x 2.5 m

Treatment	No. of thrips /10 flowers[1]
Fertilizers	3.00(1.99)
Fertilizers + weed control	3.33(2.08)
Fertilizers + weed control + plant protection	0.67(1.28)
Weed control	2.33(1.82)
Weed control + plant protection	1.00(1.38)
Plant protection	0.33(1.14)
Fertilizers + plant protection	1.00(1.38)
Control	4.67(2.38)
C.D. at 5%	(0.47)
C.V. (%)	(15.86)

[1]Figures in parentheses are the transformed $\sqrt{n+1}$ values

Effect of termination of irrigations on *M. distalis*

The population in different treatments ranged from 0.50 to 2.25 thrips per 10 flowers during summer 2003. The differences in population were non-significant; however, treatments with early termination of irrigation had more population of the thrips (Table 15).

Table15. Effect of different terminations of irrigation on incidence of thrips *(M. distalis)* in summer mungbean 2003

Location : PAU, Ludhiana Replications : 4
Date of sowing: 2.4.03 Design : RBD
Variety : SML 668 Plot size : 5.0 m x 2.5 m
Treatments : 6 = Termination of irrigation
47, 54, 61, 68, 75, 82 Days after sowing (DAS)

Treatment (Termination of irrigation)	**No. of thrips /10 flowers[1]**
47 DAS	2.25(1.80)
54 DAS	1.25(1.47)
61 DAS	1.25(1.47)
68 DAS	1.50(1.57)
75 DAS	0.75(1.31)
82 DAS	0.50(1.21)
C.D. at 5%	(NS)
C.V. (%)	(18.09)

[1]Figures in parentheses are the transformed $\sqrt{n+1}$ values

A very limited work has been reported on the control of *M. distalis* on summer mungbean through agronomic practices. However, Jayraj (1988) reported that intercropping of mungbean with cotton had a least incidence of thrips compared with sole crops.

Conclusion

Management of insect pests is one of the important factors to produce higher grain yield of mungbean. Efforts were made in 2002 and 2003 to develop some IPM modules for the control of important insect pests. For summer mungbean, NM 92 and Pusa 2032 were identified as resistant to *M. distalis*. Hostathion 40EC (triazophos) at 1500 ml ha^{-1} was found most effective to control this pest. Among the cultural practices tested, higher seed rate of 37.5- 40 kg ha^{-1} and wider row to row spacing attracted more thrips. The genotype ML 881 was found to be resistant to *B. tabaci* in rainy season. Seed treatment with Actara 25WG (thiomethoxam) at 2 g kg^{-1} seed + foliar spray of Hostathion 40EC at 0.04% gave better control of the whitefly. Avaunt 14.5SC (indoxacarb) at 500 ml and Thiodan 35EC (endosulfan) at 2.5 l ha^{-1} were found effective against *M. vitrata*.

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Opportunities for extension in area and production of spring/summer mungbean (*Vigna radiata* (L.) Wilczek) in Haryana (India)

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Abstract

At CCS Haryana Agricultural University, Hisar (India), the breeding objective of mungbean is to evolve early maturing, short duration, heat tolerant, high yielding and mungbean yellow mosaic virus (MYMV) resistant varieties for cultivation in spring, summer and *Kharif* seasons. The major emphasis is on the development of extra-short duration (55-60 days) variety/varieties which may fit well in rice-wheat rotation system. Recently MH 03-18 was identified. It is erect, compact, dwarf, high yielding, and resistant to MYMV. It matures in 61 days and is earlier about a week than the recommended variety Muskan (MH 96-1). Its pods are long and seed size is 3.46 g 100^{-1} seed. In 2003, 99 germplasm lines were grown for evaluation and use in crossing program. Most of these lines had better resistance to MYMV. The early maturing lines include BDYR 2, SMH 99-1, 2KM 112, T 44, GP 182, 2KM 151, and ML 803. Production technology is also being worked out to realize the yield potential of improved varieties. For spring season, February 15 to March 25 is the best time of sowing while for summer mungbean April 10-15 is the most suitable time. Plant spacing of 20 cm x 10 cm is adequate. A dose of 25 kg N and 40 kg P2O5 ha^{-1} as a basal application is recommended. Beside proper irrigation schedule, weed control at proper time is essential. In Haryana, many areas can be planted wth summer mungbean after the harvest of wheat. It will not only provide better returns to the farmers in a short period but will also help sustain the productivity of cereal system.

Introduction

Mungbean (*Vigna radiata* (L.) Wilczek) is one of the most important pulse crops which has made rapid advances in irrigated areas of north India as a spring/summer crop under intensive crop rotations. Being a short duration crop, it fits well in various cropping systems. In Haryana, mungbean is generally cultivated in *Kharif* season with the onset of rains. Mungbean crops occupy an area of about 14,000 ha and a production of 5,200 t. The average yield is 377 kg ha^{-1}. In recent years, the farmers have started growing it as a catch crop in spring/summer season. Its sowing is done from mid February to end of March. At present, summer mungbean is only grown in pockets with assured irrigation. In parts of northern India with assured irrigation, mungbean is grown in the fields vacated by potato, sugarcane, mustard, etc. during spring season. Mungbean can be raised successfully during summer season after the harvest of wheat.

Since short duration (60-65 days) varieties like SML-668 and Pusa Vishal are available, the farmers may get around 1-1.5 t ha^{-1} in a short period. It has tremendous potential for cultivation between wheat and rice in Indo-Gangetic plains. Systematic crop improvement and production technology work is in progress at the CCS Haryana Agricultural University (HAU) in Hisar. The university has developed and recommended a number of varieties for cultivation, along with suitable package of practices. Research on the development of suitable variety for spring/summer season is expected to give the desired results soon.

Crop Improvement

The breeding objectives at Hisar include early maturity with short duration, heat tolerance, high yielding, disease resistance against the prevalent diseases in the State, and adaptation to spring, summer and *Kharif* seasons. The period between Feb. 15 and March 20 is good for sowing the spring crop. For summer, the crop growth period is available after wheat harvest from April 10 to April 15 and, therefore, the variety which matures in about 55-60 days is suitable for the summer season. Resistance to MYMV is most important in *Kharif* season. Leaf curl disease is another production constraint in *Kharif* season. A systematic crop improvement program is underway to achieve these objectives.

The new variety Muskan, developed at HAU, is highly resistant to MYMV. It is now in seed chain and sufficient quantity of nucleus and breeder seed is available for further multiplication and distribution. The variety is suitable for both spring and *Kharif* seasons. To improve it further in terms of shattering tolerance, efforts are underway and a number of suitable crosses have been attempted and subjected to selection accordingly. The other promising genotypes, viz. MH1K 24, MH1K 25 and MH1K 27, are in the pipeline and have been sent for testing in the All India Coordinated trials. All these genotypes have done well during *Kharif* season in multi-location and other trials. MH1K 24 and MH1K 25 are also being tested in coordinated trials in spring season this year.

Promising Genotype MH 03-18

We have been able to select an erect, compact, dwarf, and high yielding mungbean genotype MH 03-18 which is resistant to MYMV. The genotype matures in 61 days, the earliest among all the genotypes/breeding material/germplasm available to us. Its plants are dwarf (69.4 cm) and compact, and its fruiting zone is equal to the tall growing Muskan. However, its proportion of fruiting zone is 54.5% compared with 35.9% in Muskan, the number of its pods are higher (34.4 plant^{-1}) and are larger in size (8.2 cm) each, with about 10 medium-sized and attractive seeds. The grain yield per plant is more than double compared to check variety Muskan and per hectare grain yield (2361 kg ha^{-1}) is more than 80% higher than Muskan (Table 1). The genotype is being extensively tested in spring, summer and *Kharif* season in multi-location trials.

In addition, MH 3-3 and MH 3-11 have also been found promising in normal and late-sown conditions. MH 3-17 and MH 3-19 have significantly higher yield than the checks.

Table 1. Characteristic features of MH 03-18 compared with MH 96-1 (Muskan)

Character	MH 03-18	Muskan	Superiority over Muskan
Days to 50% flowering	31	40	Early in flowering
Days to maturity	61	68	Early in maturity
Plant height (cm)	69.4	103.6	Dwarf in height
Primary branches per plant	3.2	4.0	-
Length of fruiting zone	37.8	37.2	-
Fruiting zone in proportion to plant height	54.5%	35.9%	Higher proportion of fruiting zone
Number of pods plant^{-1}	34.4	20.0	More pods than Muskan
Pod length (cm)	8.2	7.45	Longer pods
Number of seeds pod^{-1}	9.75	8.10	More seeds per pod
100 seeds weight (g)	3.46	2.97	Bolder seeds
Yield plant^{-1} (g)	12.78	5.78	Better yield per plant
Yield in kg ha^{-1}	2361	1302	Better yield per hectare
Yellow mosaic reaction	Free	5%	Yellow mosaic free

In multi-environment and multi-location testing, MH 2-15, MH 2-46, MH 2-21, MH 2-16, and MH 2-22 have also performed very well. These genotypes were also found to be resistant to MYMV.

In 2003, a number of new crosses were made. Suitable plants and progenies from advance generations were selected and genotypes over locations were evaluated (Table 2).

All the selections were made under field conditions that fully expose them to disease pressure of MYMV. Only the resistant plants were selected. Progenies that are grown during *Kharif* season, early-maturing, and short-duration will be bulked and tested in spring/summer season.

Germplasm Evaluation

A total of 99 germplasm lines were grown for rejuvenation, evaluation, and use in crossing program. Most of these lines have better reaction against MYMV. These lines were evaluated for morphological, yield components, yield, and disease reaction under field conditions. The promising early flowering and early maturing lines include BDYR2, SMH 99-1,2KM 112,T44,GP 182, 2KM 151, and ML 803. The germplasm lines which have longer pods are M 169, 2KM 114, 2KM 112, 1358 C and SML 668. There were a number of lines which had more seeds per pod (MH 98-1, SMH 99-4, ML 776, 2KM 138, ML 1108, ML 506, GP 69, ML 735, Pusa 105, PLM 10, 2KM 160, GP 354, and SMH 99-3); bold seeds (2KM 111, M 1358C, SML 668, 2KM 114, GP 182, SMH 99-1, M 1361B, PMB 14, M 516, and BDYR 1); and higher in yield per plant (EC 103196, ML 839, ML 506, SMH 99-1, ML 682, 2KM 160, SML 668, M 516, COGG 902, and ML 1108). The lines identified for these economic traits will be used in hybridization program. These germplasm lines have also been tested for resistance against MYMV, leaf curl, and other diseases.

Table 2. Details of selections made during *Kharif* 2003

Generation	Number of			
	Crosses	Progenies grown	Single plants selected[1]	Progenies bulked[1]
F3	17	Bulk	398	-
F4	19	764	358	28
F5	8	239	81	4
F6	10	102	39	1
F7	1	5	7	-
Total	55	1110+17 B	883	33

[1]Include a number of early selections expected to do well in spring/summer season.

Advanced Varietal Testing

Sixty-one (61) genotypes were tested in four trials using a RCBD. Some of them were in multi-environment and multi-location during *Kharif* and spring/summer seasons. We have been able to develop a number of suitable genotypes which are not only high-yielding but also early-maturing, short-duration, and resistant to MYMV (Table 3). Some of these genotypes will be proposed for multilocation testing. Some are still being extensively tested for adaptation in spring/summer and *Kharif* seasons.

Table 3. Details of evaluation of elite genotypes during *Kharif* 2003

Trial	Genotype	Reps	Checks	Promising Genotypes
SST 1 (E1)	18	3	Muskan, Asha	MH 03-11(1181kg ha^{-1}) MH 03-3 (1122 kg ha^{-1}) MH 03-10(1118 kg ha^{-1}) MH 03-1(1105 kg ha^{-1}) MH 03-7(1070 kg ha^{-1})
SST 1 (E2)	18	3	Muskan, Asha	
SST 2	12	3	Muskan, Asha	MH 3-18 (2361 kg ha^{-1}) MH 03-17 (1858 kg ha^{-1}) MH 03-19 (1731 kg ha^{-1}) MH 03-23 (1602 kg ha^{-1}) MH 03-25(1505 kg ha^{-1})
LST (Summer)	28	4	Muskan, Pusa 9531, T 9,SML 668	MH 2-37(1224 kg ha^{-1}) MH 2-16 (1174 kg ha^{-1}) SML 668 (1146 kg ha^{-1})

Cont..Table 3

LST (Summer, Bawal)	28	3	Muskan, Pusa 9531 SML 668	Pusa 9531 (858 kg ha^{-1}) MH 2-24 (829 kg ha^{-1}) SML 668 (796 kg ha^{-1})
Trial	**Genotype**	**Reps**	**Checks**	**Promising Genotypes**
AYT Hisar)	7	2	Muskan, SML 668	MH 1K-24 (538kg ha^{-1}) MH 1K-23 (471kg ha^{-1}) MH 1K-25 (463 kg ha^{-1})
LST(E 1)	28	3	Muskan, Asha, SML 668, T 9	MH 2-15(2063 kg ha^{-1}) MH 2-46(1718 kg ha^{-1}) MH 2-21 (1709 kg ha^{-1}) MH 2-37 (1604 kg ha^{-1}) UMAH 10(1481 kg ha^{-1})
LST (E 2)	28	3	Muskan, Asha, SML 668, T 9	
MLT (Hisar)	15	3	Muskan, Asha	MH 1K-23(1293 kg ha^{-1}) MH 2-16 (1270 kg ha^{-1}) MH 2-15 (1267 kg ha^{-1}) MH 1-25(1252kg ha^{-1}) MH 2-37 (1247 kg ha^{-1}) MH 2-22 (1222 kg ha^{-1})

Production Technology

The following major problems are hindering the successful cultivation of spring/ summer mungbean in Haryana :

- Long duration varieties /limited cultivars
- Asynchronous maturity
- Poor crop establishment
- Non-availability of quality seed
- Moisture stress
  a) Poor quality of sub soil water
  b) Dependent only on supply of canal water irrigation schedules
- Pre-harvest sprouting due to onset of rains early in season
- Sensitivity to high temperature

Recently, very short duration varieties of spring/summer mungbean were developed. However, to realize the yield potential of these improved varieties, proper practices need to be developed. The most important agronomic factors are date of sowing, plant population, nutrient dynamics, irrigation schedule, and weed control.

Dates of Sowing

Results of trials showed that sowing mungbean from mid-February to March 25 proved quite successful in Haryana. A significant yield reduction was recorded in mungbean sown after the March 25 (Table 4). Early-sown crop also showed low grain yield, possibly due to low temperature that adversely affects germination. Previous work reported by Jaiswal (1995) showed the importance of dates of sowing. Late sown crop is highly risky due to early onset of monsoon rains which badly affects grain quality.

Table 4. Grain yield of mungbean as affected by dates of sowing

Treatment	Grain yield (kg ha^{-1})		
	1990	1991	Pooled
Date of sowing			
15 March	1190	-	-
25 March	1450	1500	1470
5 April	1060	1420	1240
C.D. 5%	240	NS	223

Source: (Jaiswal, 1995)

Plant Population

Adequate plant population is an indication of high productivity. During spring/summer, it is difficult to establish the desired plant population because of limited moisture. Low soil moisture causes poor germination which results in poor plant population. Thus, grain yield of mungbean is significantly reduced. To obtain good plant population, spring/summer crop should be sown under good soil moisture at a row-to-row distance of 20 cm, with 10 cm as intra row spacing (Table 5). During spring/summer, seed rate of 25 to 30 kg ha^{-1} is recommended to obtain the required plant population. Lower seed rate results in low plant population and low grain yield.

Table 5. Grain yield of summer mungbean as influenced by different plant populations at Hisar (Haryana)

Treatment	Grain yield (kg ha^{-1})		Pooled yields
	1987	1988	
Plant Populations (cm)			
P1 – 5,00,000 (20 cm x10 cm)	1442	934	1188
P2 – 4,00,000 (25 cm x 10 cm)	1423	824	1124
P3 – 3,33,000 (30 cm x10 cm)	1308	717	1013
C.D. 5%	NS	152	

Source: (Malik, 1994)

Nutrient Dynamics

In mungbean, the application of nutrients plays a significant role in enhancing the grain yield. The basal dose of nitrogen at 25 kg N ha^{-1} helps in the early establishment of seedlings when nodules are not fully developed. Applied nutrients help in better development of root biomass which will ultimately extract more moisture and absorb more nutrients. The application of phosphorus not only improves biological nitrogen fixation and hastens growth but also enhances reproductive growth. To raise a good crop of spring/summer mungbean, 25 kg N+ 40 kg P_2O_5 + 20 kg K_2O ha^{-1}, must be applied as a basal dose (Tables 6 and 7).

Table 6. Grain yield of mungbean as influenced by production input factors

Treatment	Grain yield (kg ha^{-1})
Farmers Practice	797
Full Package of Practice (FPP)	1,411
FPP minus fertilizer	1,130
FPP minus inoculation	1,319
FPP minus insect and disease control	1,233
FPP minus weed control	1,086
CD 5%	220

Source: (Singh and Sekhon, 2002)

Table 7. Grain yield of mungbean as influenced by levels of phosphorus

Treatment	Grain Yield (kg ha^{-1})
Level of phosphorus (P_2O_5 kg ha^{-1})	
0	1,105
20	1,346
40	1,497
CD 5%	130

Source: (AICPIP, 1987)

Irrigation Schedule

During summer season, water requirement of mungbean is quite high as the prevailing temperatures inhibit its proper growth and development. Water need of the crop may vary with the climatic condition and type of soil. Irrigation scheduled at an appropriate time and with the right amount are important factors to realize good grain yield of summer mungbean (Sekhon *et al.*,1990). The results obtained at Hisar confirm these findings(Table 8).

Table 8. Grain yield as influenced by schedule of irrigation

Treatment	Grain yield (kg ha^{-1})		Average
	1987	1988	
Schedule of irrigation			
I_1 = ID : CPE, 0.2	1290	587	939
I_2 = ID : CPE, 04	1480	890	1185
I_3 = ID : EPE, 0.6	1402	998	1200
CD 5%	142	152	-

Source: (Malik, 1994)

Weed Control

Hand weeding three weeks after sowing resulted in significantly higher grain yield over no weeding (Singh and Sekhon, 2002). Pre-emergence application of pendimethalin at 0.75 kg a.i. ha^{-1} proved most effective for the control of weeds in summer mungbean. It showed good control of *Trianthema portulacastrum* and *Digitaria sanguinalis* but *Cyprus rotundus* remaind uncontrolled (PAU, 2002).

Stage of Harvesting

The mature crop should not stay for long period in the field to avoid shattering of over-matured pods. The crop should be harvested when about 90% of the pods have matured. Monsoon rains may also adversely affect the quality of grains.

Conclusion

In Haryana summer mungbean has a great potential and can be sown as a catch crop in rice-wheat cropping system, especially the extra-short duration varieties(55-60 days) that are now available. There is a great need to develop strategies for production and protection technology to achieve higher productivity of short duration mungbean.

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Prospects of mungbean in rice – wheat cropping systems in Indo-Gangetic Plains of India

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Abstract

The development of short-duration varieties (60-70 days) with synchronized maturity and resistance to yellow mosaic virus in mungbean (PDM 11, PDM 54, ML 267, Pusa 105, Pusa 9531, Samrat, Pant M2, SML 668, Pusa Vishal, and Pant Mung 5) has paved the way for the introduction of mungbean as a catch crop during summer season in a wide range of intensive cropping sequences. These varieties have caught the imagination of farmers and consequently, the area under spring/ summer mungbean is gaining ground in the Indo-Gangetic Plains (IGP) of India. Besides assured irrigation, the system requires careful selection of varieties of wheat and rice so that the field is vacated in time for mungbean sowing somewhere in the end of March or first week of April. Efforts are required to further reduce the crop duration of mungbean varieties to 50-55 days. For rice – wheat – mungbean system, mungbean plant type has to be determinate with fast initial growth, photo-thermo-insensitivity and synchronous maturity within 50-65 days and possibly have a clear-cut demarcation between the vegetative and the reproductive phases. The plant should be able to retain complete build up of its morphological frame by flowering time and healthy leaves till grain filling. Mungbean can be successfully grown during spring (March-May) after the harvest of short duration post-rainy season crops such as mustard, potato, pea, or sugarcane. Spring cultivation of mungbean is increasing rapidly with the availability of MYMV and high yielding (0.8 to 1.0 ton ha^{-1}) mungbean varieties such as PDM 11, Pant Mung 2 and MH 81-1-1. About 200,000 ha area in the states of Punjab, Haryana and western Uttar Pradesh are currently occupied by spring mungbean and black gram. The area can be further substantially increased.

Introduction

Mungbean like other pulse crops has been recognized for its soil ameliorative effect and high protein content. It has the ability to fix atmospheric nitrogen (N) in its root nodules and add substantial amounts of nitrogen rich biomass to the soil and rhizosphere which keeps the soil productive and healthy.

By including mungbean in cropping systems, nitrogen demand of intensive cereal based cropping systems such as rice-wheat can be partly met besides improving the physical and chemical properties of the soil. Mungbean in rotation with cereals not only improves cereal productivity but also economizes on nitrogen use up to 35 kg N ha^{-1} (Ali, 1992). In addition, mungbean has been reported to smother weed flora appreciably (20-45%) when intercropped with crops like pigeonpea and consequently minimizes the cost of weeding (Ali, 1988). However, the magnitude of reduction in weed population and growth varies to a great extent on crop species, genotypes, plant density, ratio of component crops, spatial arrangement, moisture and fertility status of soil, and tillage practices.

Indo-Gangetic Plain

The Indo-Gangetic Plain (IGP) is the most important food production domain in India. It covers the states of Punjab, Haryana, Delhi, Uttar Pradesh, Bihar, West Bengal and small parts of Jammu & Kashmir, Himachal Pradesh, and Rajasthan. The western part of IGP (Punjab, Haryana, Delhi and western Uttar Pradesh) has a semi-arid climate with annual rainfall of 500-800 mm whereas the eastern part (eastern Uttar Pradesh, Bihar and West Bengal) experiences a humid climate with annual rainfall of 1000-2000 mm. The summer and winter temperatures are extreme in the western IGP whereas in the eastern part they are moderate. The soil texture becomes heavier and drainage is impeded as one moves from west to east. Agricultural productivity and farm returns also show a declining trend from the western to eastern IGP.

Rice-Wheat System

In the IGP of India, the major cropping system is rice-wheat that covers 10.5 million ha irrigated area. During the post-green revolution period, rice and wheat replaced more than 20 crops each in *Kharif* and *Rabi* seasons. As a result, both the crops have shown remarkable ascent in area and now constitute 58% of the total area devoted to food grain production in the country (Table 1). The situation in the IGP is further aggravated as rice and wheat together account for 82% of the total area devoted to food grain production in the region. In Punjab and West Bengal, more than 95% area of food grain production is now under rice and wheat. This phenomenon relegated pulses and coarse cereals to marginal land. In the states like Bihar, Haryana, Punjab, Uttar Pradesh, and West Bengal the pulses area has declined from 8.03 m ha in 1971-75 to 5.22 m ha at present, giving way to rice in *Kharif* and wheat in *Rabi* seasons. Continuous cultivation of cereals has caused heavy tolls resulting in deteriorating soils, declining water tables, frequent outbreak of insect pests and disease epidemics, and other environmental problems. The second-generation problems appearing in the major cereal based cropping systems in general and rice-wheat in particular are as follows:

***Declining total factor productivity*:** In intensively cropped areas, more energy in the form of chemical fertilizers is required to produce the same quantity of grains, i.e. response to fertilizer application has reduced from 50.25 kg in 1969-70 to 12.21 kg grains per kg of $N+P_2O_5+K_2O$ in 2001-02.

***Depletion of soil fertility due to over mining of native nutrient reserve*:** An estimated nutrient (NPK) uptake of 663 kg against the applied 400 kg ha^{-1} to yield 8.8 t ha^{-1} in rice-wheat rotation, and 438 kg against the applied 358 kg ha^{-1} to yield 6.3 t ha^{-1} in rice-rice rotation.

***Imbalanced use of major nutrients*:** Against the optimum ratio of 4: 2: 1 of NPK, it has widened to 8.5: 3.1: 1 at national level and western IGP has maximum distortion (37.1: 8.9: 1) where rice and wheat are grown in sequence in 82% of the total cropped area.

Emergence of secondary and micronutrient deficiency: Recent soil tests showed that in several regions, soils have become deficient in sulphur due to over mining. Multiple micronutrient deficiencies (zinc, manganese, copper, boron, molybdenum) are also reported in soils of the IGP and are becoming more prevalent as cropping intensity increases. Low soil organic matter and little return of crop residues or other organic materials to soils exacerbate the deficiencies.

Decline in organic matter content of soils: Inadequate use of organic manures, crop residues, and human wastes is another matter of great concern as hardly less than one ton organic manure per ha is being added to the soil in spite of great potential of legumes as green manure. This is leading to fast decline in organic matter content of soils (0.2% carbon content in intensive rice growing areas in Punjab).

Groundwater depletion: Planting of rice two months before the onset of monsoon in Punjab and parts of Haryana has dangerously lowered the water table. On an average, ground water is depleting at the rate of 300 mm per year in Punjab and Haryana.

Increasing problems of salinity-alkalinity: In the command areas, salinity is building up due to excessive and indiscriminate use of irrigation water.

Increasing disease and insect pest pressure: Genetic heterogeneity, a distinct feature of earlier systems of agriculture, is replaced by genetic homogeneity both at varietal and crop levels which enhances genetic vulnerability to biotic stresses. Frequent outbreak of stem borer, white backed plant hopper, and leaf folder in rice are some recent examples of increasing disease and insect pressure.

Menace of weeds: Incidence of *Phalaris minor*, the notorious weed with enhanced level of resistance to herbicides in wheat, has increased substantially.

Environmental pollution: Indiscriminate use of chemical fertilizers, coupled with plant protection chemicals, has led to environmental pollution. For example, nitrate content in ponds and ground water in Punjab has increased to an alarming level.

Present Status of Mungbean

Mungbean is grown under four situations in about 3.08 million ha area in the country. It is predominantly cultivated either as an inter-crop with sorghum, cotton, maize, millets, pigeonpea, sunflower, and sugarcane or as a monocrop in *Kharif* season. This crop is also grown as a *Rabi* crop in rice fallows or rice-rice systems in southern and eastern regions. It is also grown as spring and summer crop in the IGP. Spring crop is sown in March after the harvest of crops like mustard, potato, and sugarcane. Summer crop is sown after the harvest of wheat in mid April. Summer mungbean needs to complete its maturity within 60 days while spring-sown mungbean takes about 70 days. Spring/summer mungbean is grown in rice-mustard/potato-mungbean in western IGP and rice-mustard-mungbean in eastern IGP. The area under cultivation with mungbean in rice-wheat cropping system is very small at present.

In the IGP, mungbean is grown in about 319,000 ha area covering almost all the states of the region, i.e. Punjab, Haryana, Uttar Pradesh, Bihar, and West Bengal. It accounts for 10.36% of the national mungbean acreage with 16.46% share in the production. Both area and production under mungbean experienced positive trend during the past three decades. While area under mungbean in IGP has almost doubled from163,000 ha in 1970-71 to the present level of 319,000 ha (Table 2), the production has increased threefold from 61,000 tons to 167,900 tons during the period (Table 3). Among the states, Bihar accounts for 59% of IGP area and 65% of the production. Next in order is Uttar Pradesh with 25.6% area and 19.4% production followed by Punjab (9.3% and 11%), West Bengal (3.5% and 3.9%) and Haryana (3.1% and 1.1%). Bihar and Uttar Pradesh together contribute about 84% of IGP mungbean production and 14% of total production in India. Mungbean area in Bihar, Uttar Pradesh, and Punjab has increased during the past thirty years while it has fallen in Haryana and West Bengal. Yield of mungbean has increased in all states of IGP with the exception of Haryana. Yield levels are much higher in Punjab (623 kg ha^{-1}), Bihar (581 kg ha^{-1}) and West Bengal (580 kg ha^{-1}) than in Uttar Pradesh (400 kg ha^{-1}) and Haryana (184 kg ha^{-1}). The average productivity of mungbean in IGP has gone up to 526 kg ha^{-1} at present from 374 kg ha^{-1} in 1970-71 and 450 kg ha^{-1} in 1980-81.

Scope for Mungbean

After the harvest of wheat and before the planting of rice, the land remains fallow for 65-70 days (late March/April to Early July) in the IGP of India. This could be utilized for raising a catch crop of summer pulses. Mungbean being a short duration high value cash crop fits very well between wheat and rice in the IGP and tremendous potential exists for its expansion. This, however, requires development of short duration mungbean varieties which are photoperiod insensitive and high-yielding besides being resistant to key diseases. This system has the potential to increase farm income besides improving soil productivity and long-term sustainability of agriculture.

Varietal Development

Past efforts made by National Agricultural Research System have resulted in the release of short duration varieties like Type 44 and Pusa Baisakhi in early seventies, and PDM 11 and PDM 54 during the eighties. In recent years large number of MYMV resistant and high yielding varieties of mungbean (Samrat, SML 267, Pusa 9531, etc.) with synchronous maturity have been developed and have received wider acceptance of farmers during spring/summer seasons.

South Asia Vegetable Research Network (SAVERNET) has also initiated a project on improving the income and nutrition by incorporating mungbean in cereal fallows in the Indo-Gangetic Plains of South Asia specifically India, Bangladesh, and Nepal. Based on multilocation and multi-season trials, three mungbean varieties namely SML 668 (NM 94), Pusa Vishal (NM 92), and Pant Mung 5 (VC 6368) have been released in India using AVRDC material. These cultivars are appropriate for the IGP region as they fulfill most of the varietal needs of this particular niche such as high yield potential, large seeds, short duration (60-70 days), and MYMV resistance.

Refinement of Agro-technologies

Introduction of new cultivars as catch crop in rice-wheat system has led to refinement of agro-technologies such as planting time, seed rate, seed priming, plant population density, tillage versus non-tillage, weed control, fertilizer requirement, irrigation requirement, and stress management. Agronomic studies in Punjab have shown that the best time of planting mungbean in rice-wheat system is March 20 to April 20. SML 668 and Pusa Vishal are large-seeded varieties and hence the seed rate needs to be enhanced to 38 kg ha^{-1} as compared to 25 kg ha^{-1} for traditional cultivars such as SML 267 and Pusa 9531. It was found out that no tillage was as good as tillage when planting after wheat. Therefore, no tillage option is suggested in order to save time, labor and cost of planting and weeding. Weed Control in general is essential to have good plant stand, growth, and yield of the crop. Irrigations after sowing, at flowering, and at seed filling stages are essential to produce high yield. The large-seeded determinate cultivars such as Pusa Vishal and SML 668 can give higher yield at higher plant population density (AVRDC 2002).

Sowing Time: During spring/summer season, sowing of mungbean should be taken up as soon as the field is vacated by preceding crops. The ideal times of planting are the first fortnight of March for spring mungbean and the first fortnight of April for summer mungbean. Ali and Meena (1986) found that the ideal time of planting for summer mungbean was the first week of April at Kanpur. The late-planted crop may suffer heavy loss due to pre-monsoon rains coinciding with the maturity of the crop.

Seed Rate: Growing season, cropping system, and seed size are the major factors deciding seed rate of mungbean. As a sole crop during *Kharif* season 20-25 kg seed ha^{-1} for mungbean is required to maintain the desired plant stand. But during summer season, the seed rate should be increased to about 35-38 kg ha^{-1} as the plant does not put up much vegetative growth.

Plant Population Density: A row spacing of 45 cm during *Kharif* season and 20 cm during spring season/summer season is ideal for mungbean. Four cultivars (Pusa Vishal, UPM 98-1, Pusa 9531, and SML 668) tested at different plant population densities at PAU in 2002 revealed that plant population density of 500,000 plants ha^{-1} (20 x 10 cm) produced significantly higher yields than the density of 330,000 plants ha^{-1} (30 x 10 cm) (AVRDC 2002).

Fertilizer and Irrigation Requirements: Application of recommended dose of fertilizer (12.5 kg N and 25 kg P) was found to be appropriate. Four irrigations given at 15, 25, 35, and 45 days after sowing resulted in significantly higher grain yield of mungbean under Punjab conditions. Mishra and Ali (1998) observed that the plant population at harvest was significantly influenced by phosphorus application. Application of 50 kg P_2O_5 ha^{-1} recorded 16.3% higher plant populations than that of unfertilized control with consequent increase in grain yield (27.6%). Similarly, the application of molybdenum up to 4 g kg^{-1} of seeds also resulted in higher grain yield (25.5%).

Table 1. Share of rice and wheat in total area under food grains in Northern states during 2001-02

State	Total area (m ha) under				Share of rice and wheat in total area (%)
	Food grains	Rice	Wheat	Wheat and rice	
Punjab	6.16	2.49	3.42	5.91	96
Haryana	4.25	1.03	2.30	3.33	78
Uttar Pradesh	20.02	5.88	9.08	14.96	75
Bihar	7.06	3.57	2.13	5.70	81
West Bengal	6.81	6.07	0.43	6.50	95
IGP total	44.30	19.04	17.36	36.40	82
National status	121.91	44.62	25.92	70.54	58

Table 2. Area under mungbean cultivation in the IGP of India

State	Area ('000 ha)			
	1970-71	1980-81	1990-91	2000-01
Punjab	6.90	13.90	50.00	29.50
Haryana	22.50	4.20	9.40	9.80
Uttar Pradesh	13.20	139.90	110.70	81.50
Bihar	103.00	149.30	222.00	187.00
West Bengal	17.40	29.20	15.50	11.20
Total IGP	163.00	336.50	407.60	319.00
India	2070.00	2830.00	3360.00	3080.00
Contribution (%) of IGP in national acreage	7.90	11.89	12.13	10.36

Table 3. Mungbean production in IGP of India

State	Production ('000 tons)			
	1970-71	1980-81	1990-91	2000-01
Punjab	3.90	10.30	37.50	18.40
Haryana	9.40	3.20	5.00	1.80
Uttar Pradesh	3.80	53.70	45.80	32.60
Bihar	36.20	69.50	123.50	108.60
West Bengal	7.70	14.80	7.20	6.50
Total IGP	96.10	151.50	219.00	167.90
India	700.00	980.00	1380.00	1020.00
Contribution (%) of IGP in national production	13.73	15.46	15.87	16.46

Plant Protection Measures: Only healthy and pure seeds treated with fungicides and rhizobial culture should be used for planting mungbean. During spring season, soil application of granular insecticides such as aldicarb, phorate, and carbofuran at 10 kg ha^{-1} has proved to be highly effective against whitefly and other sucking pests. As a general principle, two hand weeding during the first 35 days of sowing provides effective control of weeds.

Conclusion

To make cereal-based cropping system an everlasting proposition, scope of mungbean in rice-wheat system has to be increased tremendously. Keeping this in mind, research efforts need to be directed towards development of short duration varieties of mungbean insulated against major biotic stresses especially MYMV and *Cercospora* leaf spot. Availability of short duration varieties coupled with matching agro-technologies has resulted in the identification of several remunerative and more productive cropping systems, which have either already shown its promise or have tremendous potential for expansion in new niches and diversification in the existing cropping systems (Table 4).

Table 4. Possible new niches for mungbean

Cropping system	Possible niches	Suitable varieties
Maize-Potato/ Mustard - Mungbean	Punjab, Haryana, Western Uttar Pradesh	Pant Mung 2 PDM 11 HUM 2 Samrat SML 668 Pusa Vishal Pant Mung 5
Spring sugarcane + Mungbean	Eastern Uttar Pradesh, Bihar, West Bengal	Pant Mung 2 PDM 11 Narendra Mung 1
Rice-Wheat-Mungbean	Punjab, Haryana, Western Uttar Pradesh	Pant Mung 2 Narendra Mung 1 Samrat HUM 2 SML 668 Pusa Vishal, Pant Mung 5
Maize-*Rajmash*-Mungbean	Eastern Uttar Pradesh, Bihar	Pant Mung 2 PDM 11 HUM 2

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