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Effect of Plant Density on the Growth and Yield of Mungbean [*Vigna radiata* (L.) Wilczek] Genotypes under Different Environments in India and Taiwan

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ABSTRACT

Optimum plant population is a prerequisite for obtaining high yields of any crop. The aim of the study was to find out the optimum plant density of mungbean for obtaining high grain yield. Field investigations were undertaken at Punjab Agricultural University (PAU), Ludhiana, India on a loamy sand soil and at Asian Vegetable Research and Development Center (AVRDC), Taiwan on a sandy loam soil. At PAU, 40 plants m^{-2} at 25×10 cm spacing gave significantly higher grain yield than 33 plants m^{-2} at 30×10 cm spacing. Genotypes Pusa Vishal (selection from AVRDC material NM 92), SML 668 (selection from NM 94) and Pusa 9531 were on par in the grain yield and were better than UPM 98-1 and MH 96-1. Pusa Vishal and SML 668 had significantly larger seed size compared to Pusa 9531 and MH 96-1. At AVRDC, 20 plants m^{-2} sown at 50×10 cm spacing was the optimum for achieving higher grain yield and at higher plant densities, the yield tended to decrease. Lodging score was higher under higher plant densities. Genotypes NM 92 and VC 3890-A were superior to NM 94 and SML 134 in grain yield. Interaction between genotypes and plant density was non-significant for grain yield and other characters at both the locations.

Key words: Days to flowering, days to maturity, plant population, spacing, climatic conditions

INTRODUCTION

Mungbean [*Vigna radiata* (L.) Wilczek] is an important grain legume in South Asia. It not only provides protein-rich diet but also plays a significant role in sustaining crop productivity by adding nitrogen through rhizobial symbiosis and crop residues (Sharma and Behera, 2009a, b).

The optimum plant density is a pre-requisite for obtaining higher productivity (Rafiei, 2009). Plant density affects the plant growth (Jahan and Hamid, 2005) as well as grain yield in mungbean (Jahan and Hamid, 2004). Plant density may vary with genotype, time of sowing, growing conditions, etc. (Sekhon *et al.*, 1996, 2002). Plant population may not only be defined in terms of number of plants per unit area (plant density) but also in terms of arrangement of plants on the ground (spatial arrangement or plant geometry) (Kaul and Singh, 2002). The optimum plant population can be maintained by using adequate seed rate. Regan *et al.* (2003) reported that economic plant density helps in estimating the most profitable seed rate.

For obtaining high yields, optimum seed rate should be used for planting in an appropriate planting geometry. Extensive studies in India showed that 20×10 cm spacing was superior to 30×10 cm in summer season while in kharif (rainy season) 30×10 cm spacing was optimum for obtaining higher grain yields of mungbean (PAU, 1998; Ahlawat and Rana, 2002). In Bangladesh, planting density of 30×10 cm gave higher yield of mungbean than 20×20 cm or 40×30 cm planting density (Sarkar *et al.*, 2004). High variation has been reported in mungbean with respect to growth, phenology, yield attributes and grain yield (Yimram *et al.*, 2009). The data on optimum plant population density were available for medium or small seed size and long-duration genotypes. However, recently large seed size genotypes have been developed and released for cultivation at farmers' fields. These genotypes are very quick growing, have broader leaves, shorter duration than the medium- or small-seeded genotypes (Singh *et al.*, 2007). Since the new genotypes were morphologically different, experiments were conducted on variable plant densities at PAU and AVRDC under the DFID-Mungbean project 2002-4 on 'Improving income and nutrition by incorporating mungbean in cereal-fallows in the Indo-Gangetic Plains of South Asia'. The major objective was to evaluate the response of new promising large seeded mungbean genotypes to variable planting density under different environments.

MATERIALS AND METHODS

Field experiments were undertaken at PAU, Ludhiana (30°56' N, 75°52' E, altitude 247 m), India on a loamy sand soil and at the AVRDC, Taiwan (120°17' N, 23°7' E, altitude 9 m) on a sandy loam soil in summer 2002 and 2003. The information on soil chemical analysis and the weather conditions experienced by the crop at these two sites have been given in Table 1. At PAU, during summer 2002, experiment consisting of four genotypes [Pusa Vishal (selection from AVRDC material NM 92), SML 668 (selection from AVRDC material NM 94), Pusa 9531 and UPM 98-1] and three plant densities (33, 40 and 50 plants m^{-2} sown at 30×10 cm, 25×10 cm and 20×10 cm, respectively) was arranged in a split plot design with three replications. Genotypes were allocated in the main-plots and plant densities in the sub-plots. In 2003, genotype MH 96-1 was sown instead of UPM 98-1 as the performance of the latter was poor in 2002. The sowing was done on 26 and 28 March on flat beds. In the first year 4 irrigations were applied whereas in the second year 5 irrigations were applied to the crop.

Table 1: Soil and weather conditions at experimental sites at PAU and AVRDC

Particulars	PAU	AVRDC
Soil chemical analysis		
Organic carbon	0.29%	0.85%
Available N	98 kg ha^{-1}	0.9%
Available P	15.7 kg ha^{-1}	62 ppm
Available K	288 kg ha^{-1}	55 ppm
pH	8.2	7.8
Weather data during crop season		
Maximum temperature	28.6 to 47.2°C	31.9 to 33.5°C
Minimum temperature	12.0 to 29.5°C	16.1 to 26.7°C
Relative humidity	38 to 69%	68.7 to 78.8%
Total rainfall	123.5 mm and 93.2 mm during 2002 and 2003, respectively	721.5 mm and 315 mm during 2002 and 2003, respectively

At AVRDC, in 2002 and 2003, the experiment consisting of 4 genotypes (NM 92, NM 94, VC 3890-A and SML 134) and four plant densities (20, 30, 40 and 50 plants m^{-2} sown at 50×10 cm, 50×6.67, 50×5 and 50×4 cm, respectively) was arranged in a split plot design, keeping genotypes in the main-plots and plant density in the sub-plots. Each treatment was replicated thrice. The sowing was done on 16 August and 17 July in 2002 and 2003, respectively on raised beds with 2 rows at 50 cm apart. In the first year, the crop was raised without irrigation as there was well-distributed rainfall while in the second year, 2 irrigations were given.

At both the locations, 20 kg N and 40 kg P_2O_5 ha^{-1} was drilled as a basal dressing. Weeds were controlled using pendimethalin (Stomp 30 EC) at 0.75 kg ha^{-1} as pre-emergence. Data were recorded on days to flowering, days to maturity, plant height, number of pods $plant^{-1}$, number of seeds pod^{-1}, 100-seed weight and grain yield. Lodging and powdery mildew score on a 1-9 scale (1 = no lodging; 9 = maximum lodging) was recorded at AVRDC only since at PAU, lodging and powdery mildew were not a problem in mungbean during summer season.

Statistical analysis: Data were subjected to statistical analysis using CPCS 1 program for PAU data and SAS program for AVRDC data.

RESULTS

Performance of genotypes at PAU, Ludhiana: Genotypes differed significantly in plant height in both the years (Table 2). Pusa Vishal and Pusa 9531 were on par in plant height and were taller than SML 668. UPM 98-1 (tried in the first year) was significantly shorter than the other genotypes whereas MH 96-1 (tried in the second year) was significantly taller than the rest.

Pusa 9531 produced significantly more number of pods $plant^{-1}$ than UPM 98-1 in the first year and MH 96-1 in the second year while no differences were recorded among SML 668, Pusa Vishal and Pusa 9531. In 2002, UPM 98-1 and in 2003 MH 96-1 were significantly inferior to others in pods production. Number of seeds pod^{-1} remained unaffected in the genotypes during both the years of study. Seed size differed significantly among the genotypes. During both the years SML 668 had significantly higher seed weight than Pusa 9531 but was statistically on par with Pusa Vishal. UPM 98-1 (tried in the first year) also had significantly large seed size than Pusa 9531

Table 2: Influence of plant density on growth and the grain yield of mungbean genotypes at PAU

	Plant height (cm)			Pods $plant^{-1}$			Seeds pod^{-1}			100-seed weight (g)		
Treatment	2002	2003	Mean	2002	2003	Mean	2002	2003	Mean	2002	2003	Mean
Genotypes												
Pusa Vishal	49.7	47.1	48.4	26.6	22.6	24.6	10.12	9.95	10.03	4.47	5.06	4.76
SML 668	41.5	36.2	38.8	27.1	22.4	24.7	10.08	9.33	9.72	5.71	5.74	5.72
Pusa 9531	50.7	47.7	47.7	29.4	23.4	26.4	9.02	8.77	8.89	3.83	4.22	4.02
UPM 98-1	37.3	-	-	21.7	-	-	9.48	-	-	5.25	-	-
MH 96-1	-	58.2	-	-	18.8	-	-	9.35	-	-	3.75	-
SE (DF = 6)	1.76	1.43		1.31	0.81		0.424	0.487		0.081	0.065	
Plant density (plants m^{-2})												
33	46.1	47.9	46.0	28.8	23.8	26.3	10.18	9.53	9.86	4.83	4.77	4.79
40	44.9	46.6	45.7	26.0	21.6	23.8	10.01	9.43	9.71	4.83	4.71	4.77
50	45.1	47.9	46.5	25.7	20.0	22.8	9.51	9.09	9.30	4.79	4.60	4.69
SE (DF = 16)	1.29	1.02		0.97	0.59		0.272	0.314		0.031	0.033	

while MH 96-1 had the significantly smallest seed size. SML 668 showed average seed weight of 5.72 g per 100 seeds and Pusa Vishal 4.76 g per 100 seeds. On an average, Pusa 9531 had 4.02 g per 100 seeds while UPM 98-1 and MH 96-1 had 5.25 g and 3.75 g per 100 seeds, respectively (Table 2).

In 2002, the differences in flower initiation and maturity were non-significant while in 2003 these traits differed significantly. During the two years, flowering in SML 668 and Pusa Vishal occurred 35-38.1 Days After Sowing (DAS) whereas in Pusa 9531 and UPM 98-1 flowering took place 40.1 and 41.5 DAS, respectively. MH 96-1 was late and flowered 48.2 DAS. SML 668 and Pusa Vishal matured in 65-68.1 days, Pusa 9531 and UPM 98-1 in 69-70.2 days while MH 96-1 in 75.4 days (Table 3).

In both years, Pusa Vishal, SML 668 and Pusa 9531 were on par in the grain yield and were significantly superior to UPM 98-1 or MH 96-1 (Table 4).

Effect of plant density at PAU, Ludhiana: Various plant densities (Table 2) did not influence plant height. It was around 46 cm under different plant densities in both years. The number of

Table 3: Effect of plant density on days taken to flower initiation and maturity of mungbean genotypes at PAU

	Days taken to flower initiation			Days taken to maturity		
Treatment	2002	2003	Mean	2002	2003	Mean
Genotypes						
Pusa Vishal	38.0	38.10	38.0	66.1	68.00	67.0
SML 668	36.1	35.00	35.5	65.0	68.10	66.5
Pusa 9531	40.1	41.00	40.5	69.0	69.00	69.0
UPM 98-1	41.5	-	-	70.2	-	-
MH 96-1	-	48.20	-	-	75.40	-
SE (DF = 6)	1.94	1.71		2.23	1.36	
Plant density (plants m^{-2})						
33	38.1	39.10	38.5	67.2	69.30	68.2
40	39.0	40.20	39.5	67.4	69.00	68.2
50	39.0	40.00	39.5	68.0	70.10	69.0
SE (DF = 16)	1.12	1.34		1.40	0.93	

Table 4: Influence of plant density on the grain yield of mungbean genotypes at PAU

	Grain yield (kg ha^{-1})		
Treatment	2002	2003	Mean
Genotypes			
Pusa Vishal	2366	2007	2186
SML 668	2424	2069	2296
Pusa 9531	2376	2006	2191
UPM 98-1	1844	-	-
MH 96-1	-	1151	-
SE (DF = 6)	128.7	52.4	
Plant density (plants m^{-2})			
33	2114	1758	1936
40	2305	1849	2077
50	2339	1864	2101
SE (DF = 16)	58.60	34.2	

pods plant^{-1} were significantly higher in the case of 33 plants m^{-2} than 40 and 50 plants m^{-2}. However, there was no significant difference in the number of pods plant^{-1} in 40 and 50 plants m^{-2}. The number of seeds pod^{-1} and seed size did not vary under different plant densities. Flowering and crop maturity remained unaffected by plant densities (Table 3). In 2002, 40 plants m^{-2} gave significantly higher grain yield over 33 plants m^{-2} (Table 4). However, in 2003 the grain yield was significantly different in 33 and 50 plants m^{-2} but 40 and 50 plants m^{-2} treatments were on par. On an average, there was 8.9 and 5.1% increase in the grain yield of 40 plants over 33 plants m^{-2} in the two consecutive years.

Performance of genotypes at AVRDC, Taiwan: Plant height data recorded in 2003 showed that genotype SML 134 was the tallest while NM 92 had significantly higher plant height than NM 94 (Table 5). VC 3890-A was significantly shorter than SML 134 in plant height. Genotypes NM 92 and NM 94 were shorter than VC 3890-A. Average number of pods plant^{-1} was the highest in SML 134 and were significantly higher than the other genotypes for both years. In 2002, NM 92, NM 94 and VC 3890-A and VC 3890-A were statistically on par in the number of pods plant^{-1} whereas in 2003, NM 92 was superior to NM 94 and VC 3890-A. Genotypes did not differ significantly in the number of seeds pod^{-1}. However, the seed size recorded significant differences. On an average, VC 3890-A had the largest seed size i.e., 5.89 g per 100 seeds, followed by NM 94 (5.18 g) and NM 92 (4.75 g per 100 seeds). The seed size of SML 134 was only 3.25 g per 100 seeds which was significantly lower than the other genotypes.

NM 92 and NM 94 were earlier in flowering by about 4 days than VC 3890-A and 2.5 days than SML 134 (Table 5). The maturity period of NM 92 and NM 94 was around 64 days while of SML 134 and VC 3890-A was 68.6 days in the first year. In the second year NM 92, NM 94 and VC 3890-A matured between 60.4 and 61.3 days while SML 134 in 62.5 days.

In 2002, genotype VC 3890-A yielded the maximum (1710 kg ha^{-1}) while NM 94 the minimum (746 kg ha^{-1}) grain yield (Table 7). VC 3890-A was significantly superior to other genotypes in terms of grain yield and seemed to be the most stable, having the smallest yield difference between years. Genotype SML 134 was inferior to NM 92 and VC 3890-A but superior to NM 94. In 2003, NM 92 and VC 3890-A were on par in the grain yield and both were significantly better than NM

Table 5: Effect of plant density on various traits of summer mungbean genotypes at AVRDC

Treatment	Plant height (cm)	Pods plant^{-1}			Seeds pod^{-1}			100-seed weight (g)		
	2003	2002	2003	Mean	2002	2003	Mean	2002	2003	Mean
Genotypes										
NM 92	84.9	17.0	25.1	21.0	11.6	12.1	11.8	5.1	4.4	4.75
NM 94	75.4	14.5	18.4	16.4	12.2	12.2	12.2	5.5	4.8	5.18
VC 3890-A	91.8	16.0	15.1	15.5	12.1	12.6	12.3	6.6	5.1	5.89
SML 134	98.3	32.0	30.4	31.2	11.7	12.4	12.0	3.5	3.0	3.25
SE (DF=6)	1.26	1.43	1.78		0.81	0.12		0.27	0.21	
Plant density (plants m^{-2})										
20	85.7	22.9	26.8	24.8	12.2	12.5	12.2	5.1	4.4	4.75
30	88.2	22.0	21.7	21.8	11.9	12.5	12.3	5.1	4.4	4.75
40	90.0	20.0	21.3	20.6	11.6	12.0	11.8	5.2	4.3	4.75
50	86.5	14.0	19.2	16.6	12.1	12.3	12.1	5.2	4.2	4.70
SE (DF=24)	0.86	1.40	0.45		0.68	0.09		0.13	0.10	

94 and SML 134. The powdery mildew incidence was the maximum in the case of NM 94 and minimum in the case of VC 3890-A (Table 8). The lodging score for NM 94 was significantly higher than the other genotypes. VC 3890-A seemed to be lodging resistant. Genotype NM 92 showed less lodging than SML 134 in the second year.

Effects of plant density at AVRDC, Taiwan: Plant height did not differ significantly due to various plant densities (Table 5). In 2002, the plant density of 20, 30 and 40 plants m^{-2} showed no significant differences in the number of pods $plant^{-1}$ while a marked decline was noticed in the case of 50 plants m^{-2} (Table 5). In 2003, 20 plants m^{-2} produced significantly higher number of pods $plant^{-1}$ than 30, 40 or 50 plants m^{-2}. The number of seeds pod^{-1} and 100-seed weight remained unaffected with various plant densities in both years. There was no marked difference in days to flowering and crop maturity with variable plant densities (Table 6).

Table 6: Effect of plant density on days taken to flower initiation and maturity of mungbean genotypes at AVRDC

	Days to flower initiation			Days take to maturity		
Treatment	2002	2003	Mean	2002	2003	Mean
Genotypes						
NM 92	29.8	33.10	30.0	64.0	60.40	62.2
NM 94	28.7	32.60	30.0	64.3	61.00	62.7
VC 3890-A	32.3	36.50	34.0	69.1	61.30	65.2
SML 134	31.5	34.20	32.5	68.2	62.50	65.4
SE (DF = 6)	0.41	0.20		0.72	0.35	
Plant density (plants m^{-2})						
20	30.0	34.00	32.0	61.1	60.20	64.8
30	30.0	34.00	32.0	60.3	60.00	65.3
40	30.0	34.20	32.0	60.2	60.30	62.7
50	28.0	34.20	31.0	59.4	59.50	62.8
SE (DF = 24)	0.49	0.24		0.87	0.37	

Table 7: Influence of plant density on the grain yield of mungbean genotypes at AVRDC

	Grain yield (kg ha^{-1})		
Treatment	2002	2003	Mean
Genotypes			
NM 92	1419	1638	1528
NM 94	746	1105	925
VC 3890-A	1710	1649	1679
SML 134	1242	1150	1196
SE (DF = 6)	52.3	44.7	
Plant density (plants m^{-2})			
20	1378	1493	1435
30	1348	1472	1410
40	1226	1355	1290
50	1164	1221	1192
SE (DF = 24)	49.2	87.3	

Table 8: Effect of plant density on the lodging score and powdery mildew score of summer mungbean genotypes at AVRDC

	Lodging score			Powdery mildew score		
Treatment	2002	2003	Mean	2002	2003	Mean
Genotypes						
NM 92	3.3	1.0	2.1	5.5	3.8	4.6
NM 94	6.6	3.7	5.2	6.1	4.8	5.5
VC 3890A	1.0	1.5	1.3	2.5	1.1	1.8
SML 134	4.2	2.7	3.5	3.5	3.7	3.6
SE (DF = 6)	0.99	0.14		0.96	0.37	
Plant density (plants m^{-2})						
20	3.1	1.7	2.4	4.0	3.1	3.5
30	3.1	1.9	2.5	4.5	3.1	3.8
40	4.4	2.5	3.5	4.5	3.3	3.9
50	4.5	2.8	3.7	4.7	3.8	4.2
SE (DF = 24)	0.72	0.12		0.23	0.19	

In 2002, the grain yield showed significant differences due to various plant densities (Table 7). The plant densities of 20, 30 and 40 plants m^{-2} were on par in grain yield and the treatment of 50 plants m^{-2} produced significantly less grain yield than 20 and 30 plants m^{-2}. Similar results on the grain yield were observed in 2003. In the first year the lodging score did not differ significantly with increase in plant density but in the second year it was significantly higher in the case of 40 and 50 plants m^{-2} than 20 and 30 plants m^{-2} (Table 8). Plant densities did not influence the powdery mildew incidence significantly in both years.

DISCUSSION

Performance of genotypes: At PAU, Ludhiana, the genotypes attained plant height between 36.2 and 58.2 cm (Table 2). The experimental soil of Ludhiana was loamy sand (light textured), poor in organic carbon (0.29%) and climate was harsh. The maximum temperature ranged between 28.6 and 47.2°C and relative humidity varied between 38 and 69% during the crop growth (Table 1). On the other hand at AVRDC, Taiwan the height of genotypes was between 75.4 and 98.3 cm (Table 5). The soil of AVRDC was sandy loam, having organic carbon 0.85%, maximum temperature during the crop season remained 31.9 to 33.5°C and due to more rainfall (721.5 and 315 mm in the two years) relative humidity varied between 68.7 and 78.8%. The different climatic conditions at two locations could be responsible for variable crop growth.

At PAU, flowering occurred about a week later than at AVRDC (Table 3, 6). This was possibly due to the reason that at PAU during the initial stages of crop growth the minimum temperatures were around 12°C while at AVRDC these were above 16°C (Table 1). Because of higher minimum temperature at AVRDC crop initiated flowering earlier than at PAU and crop maturity was also earlier at the former location. Such variations in the initiation of flowering due to environmental (photoperiod and temperature) variations have also been observed by other researchers (Sinha, 1977; Khanna-Chopra and Sinha, 1989; Summerfield and Lawn, 1988; Tickoo *et al.*, 1996; Singh *et al.*, 2004).

At AVRDC, in 2002, NM 92 and NM 94 started flowering about 29 DAS while VC 3890-A and SML 134 about 32 DAS. In 2003, in all the genotypes flower initiation was delayed by 3-4 days than 2002 which may be due to the difference in sowing dates. However, in the first year genotypes matured 4-7 days later than the second year. Heavy rainfall in the first year may be the reason for delayed crop maturity.

At PAU, SML 668 and UPM 98-1 were short-statured (around 39 cm) whereas MH 96-1, Pusa Vishal and Pusa 9531 were taller. Pusa 9531 had more number of pods plant^{-1} than SML 668 and Pusa Vishal. However, for mean grain yield all these three genotypes were on par due to the small seed size of Pusa 9531 which is 15.5 and 29.7% smaller than Pusa Vishal and SML 668, respectively. Similar results have been reported by Tickoo *et al.* (1996) in mungbean. The number of seeds pod^{-1} in the case of Pusa 9531 were also less by 11.4 and 8.7% than Pusa Vishal and SML 668, respectively. Mungbean genotypes are known to differ in productivity (Sarkar *et al.*, 2004). Seed yield is positively correlated with pods/plant, seeds/pod and mean seed weight (Sriphadet *et al.*, 2010), as was also observed in the present study.

At PAU, the grain yield of Pusa Vishal, SML 668 and Pusa 9531 were higher in the first year (Table 4) as the total rainfall during the crop growth in 2002 was higher. The higher total rainfall during the crop growth caused better growth of the crop than the second year. Number of pods plant^{-1} and number of seeds pod^{-1} were also numerically higher in 2002 than in 2003 while 100-seed weight remained unaffected. Hamid (1996) reported that seed size is a genetically controlled character and is not influenced much by management or environmental factors.

At AVRDC, among the genotypes, VC 3890-A produced significantly higher grain yield during both the years (Table 7). The higher grain yield in the case of VC 3890-A was possibly due to large seed size (Table 5), resistance to lodging and less powdery mildew attack (Table 8). NM 94 though also had relatively large seed size yet it was susceptible to lodging and powdery mildew and produced less grain yield. SML 134 had more number of pods plant^{-1} but due to small seed size it yielded low. Moreover, it was susceptible to lodging as well as powdery mildew. Mungbean genotypes do differ in productivity due to their differences in plant growth and yield attributes (Khan *et al.*, 2003). Furthermore, some genotypes are not only superior to others in terms of grain yield but also in disease resistance (Kumar and Reena, 2007).

Effects of plant density: In the present study, at PAU higher grain yields were obtained at 40 plants m^{-2} (planted at 25×10 cm) on light-textured and low fertility soil and under harsh temperatures while at AVRDC, 20 plants m^{-2} (planted at 50×10 cm) were optimum on high fertility soil and under mild climatic conditions with high relative humidity. Row and plant spacings influence plant yield, yield attributes and yields of mungbean (Ihsanullah *et al.*, 2002). Under the two situations plant height was markedly different. At PAU, grain yields were higher in 2002 than 2003 as there was good rainfall and temperatures were mild during crop growth which favored better crop growth. However, at AVRDC in 2002 the low yields were due to late sowing.

At PAU, the treatment of 33 plants m^{-2} was significantly inferior to both 40 and 50 plants m^{-2} in grain yield during both the years of study (Table 4). The increase in grain yield at higher plant densities was mainly due to the increased number of plants per unit area, which were able to compensate for the reduction in the number of pods plant^{-1} at greater plant densities. The grain yield did not differ significantly in 40 and 50 plants m^{-2}. On the other hand at AVRDC, 20 plants m^{-2} gave higher grain yield and the yield tended to decrease with increase in the plant density. Rowden *et al.* (1981), Pandey and Ngarm (1985) and Hamid (1996) reported that over-crowding depressed grain yield due to competition for resources and mutual shading and lower yields observed in the present study at AVRDC with higher plant population could be due to the reasons stated by these authors. There was marked decline in the number of pods plant^{-1} at 50 plants m^{-2} at AVRDC. Hamid (1996) reported that plant competition is more severe at the reproductive stage than the vegetative stage. In this study lodging score was higher at higher plant densities i.e., 40 and 50 plants m^{-2} over the 20 and 30 plants m^{-2}. Other researchers (Gifford *et al.*, 1984; Hashem and Hamid, 1996; Hamid *et al.*, 1990) revealed that less interception of solar radiation in the crop foliage of lodged crop resulted in poor conversion of intercepted light to photosynthates of assimilates and partitioning of photosynthates to organs of economic importance and the same could be reason for lower yield and higher lodging with high plant density in the present study at AVRDC.

At AVRDC, variable plant densities did not affect powdery mildew score significantly. Powdery mildew score was higher in the first year than the second year as in the first year the crop was sown late and there was more rainfall. Powdery mildew incidence is expected higher under late sowings and due to more rainfall. At PAU, because of high temperature and low rainfall during the crop growth powdery mildew was not a problem.

CONCLUSIONS

On the basis of two-year data of two different locations, it can be concluded that for summer mungbean sowing under loamy sand (light-textured) soils at PAU the medium statured genotypes Pusa Vishal, SML 668 and Pusa 9531 were superior to UPM 98-1 (short statured) and MH 96-1 (tall statured). Plant density of 40 plants m^{-2} at 25×10 cm planting was the optimum for achieving higher productivity. At AVRDC, where soil was fertile, sandy loam and rainfall was high the genotypes NM 92 and VC 3890-A which were resistant to lodging and powdery mildew, performed better than NM 94 and SML 134. Under such conditions the planting of 20 plants m^{-2} (two rows on raised beds at 50 cm apart with plant to plant spacing of 10 cm) was found to be the optimum.

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