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Response of Soybean (*Glycine max*) Genotypes to Plant Population and Planting Geometry in Northern India

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ABSTRACT

Optimum plant population and planting geometry are the important factors for obtaining high grain yields of soybean. The aim of the present study was to find out optimum plant population and planting geometry in soybean. Accordingly three field experiments were conducted. An experiment studied the effect of three plant populations (0.30, 0.45 and 0.60 million plants ha^{-1}) on the growth and yield of eight soybean genotypes. Plant populations of 0.45 and 0.60 million plants ha^{-1} with grain yield of 1474 and 1516 kg ha^{-1}, respectively, were on par and produced significantly higher grain yields than 0.30 million plants ha^{-1} (1285 kg ha^{-1}). Genotype SL 525 produced the highest grain yield (2432 kg ha^{-1}) followed by SL 517 (1802 kg ha^{-1}). Two experiments studied the effect of three planting geometries (row spacing of 22.5, 30 and 45 cm with constant plant population of 0.45 million plants ha^{-1}) on the growth and yield of eight genotypes in 2003 and six genotypes in 2004. Planting geometries differed neither in growth nor in yield. Genotype SL 525 was the highest yielder (3452 kg ha^{-1} in 2003 and 3264 kg ha^{-1} in 2004). Genotype JS 335- the most popular genotype in central and southern India- failed at Ludhiana i.e., in northern India (291 kg grain yield ha^{-1}) due to high infestation with mungbean yellow mosaic virus as Ludhiana is the hot spot for this disease. Plant population of 0.45 million plants ha^{-1} and row spacing of 45 cm were found optimum for soybean productivity.

Key words: Genotypes, plant population, planting geometry, row spacing, soybean, *Glycine max*, grain yield

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is an important oilseed crop globally. Optimum plant population is a pre-requisite to obtain higher productivity of soybean (Kang *et al*., 1998; Lee *et al*., 2008; Singh, 2009; Walker *et al*., 2010). Similarly planting density also influences the germination, vigour (Khan *et al*., 2007b) and productivity of soybean (De Bruin and Pedersen, 2009; Rahman *et al*., 2011). Development of high yielding and disease resistant genotypes is the continuous process. It has been reported that modern cultivars are more efficient at establishing, supporting and filling seeds on a per plant basis than older cultivars (Morrison *et al*., 2000; De Bruin and Pedersen, 2009). Genotypes may vary in seed development (Khan *et al*., 2007a), plant growth and therefore to yield optimally may require different plant populations (De Bruin and Pedersen, 2009; Walker *et al*., 2010) and planting densities. Thus, there was a need to study the optimum plant population as well as planting density for obtaining high grain yields of different genotypes of soybean.

The productivity of soybean in India is far below the world average (http://faostat.fao.org). Patil *et al.* (2002). discussed the different factors related to the poor yield of soybean, which included lack of research and development support for this crop, non-availability of region-specific soybean cultivars and poor plant population in field. Soybean genotypes are known to differ in productivity (Singh, 2010; Shegro *et al.*, 2010). Genotypes having low optimal plant population may reduce seeding costs and minimize lodging (Board, 2001; Rigsby and Board, 2003). So there was a dire need to find out genotypes of soybean which are suitable for northern Indian conditions along with the matching plant population and planting geometry to realize high grain yields. Therefore, various genotypes developed at different locations in India were tested to find out the most promising/suitable genotypes under northern Indian conditions.

MATERIALS AND METHODS

Site characterization: Three field experiments were conducted during Kharif (Rainy) season of 2002 to 2004 at the Punjab Agricultural University, Ludhiana, India. Ludhiana is situated at 36°56′ N, 75°52 E, altitude 247 m. The experiments were conducted on a loamy sand soil under irrigated conditions.

Treatments and crop husbandry: In 2002 to find out optimum plant population for different genotypes an experiment involving eight genotypes (SL 295, SL 517, SL 525, PK 416, PK 1042, PK 1283 Pusa 16 and DS 97-12) and three plant populations (0.30, 0.45 and 0.60 million plants ha^{-1}) was conducted in a split plot design. The genotypes were kept in the main plots and the plant population levels were assigned in the sub-plots. The experiment having three replications was sown on 10 June, 2002 in row to row spacing of 45 cm using 110 kg seed rate ha^{-1}. Different plant population levels, as per the treatments, were maintained by thinning the plants 15 days after sowing.

Two experiments were conducted in 2003 and 2004 to study the effect of three planting geometries (row spacings of 22.5, 30 and 45 cm with constant plant population of 0.45 million plants ha^{-1}) on the growth and yield of eight genotypes (SL 295, SL 518, SL 525, PK 416, PK 1042, Bragg, JS 335 and DS 98-14) in 2003 and six genotypes (SL 525, SL 633, SL 637, PK 1042, PK 1347 and Bragg) in 2004. The experiments were conducted in a split plot design by keeping genotypes in the main plots and planting geometries in the sub-plots. There were three replications in both the years. The sowing was done on 20 June 2003 and 9 June 2004 at different row spacings as per the treatments using 110 kg seed rate ha^{-1}. The desired plant population of 0.45 million plants ha^{-1} was maintained by thinning the plants 15 days after sowing.

In all the experiments a fertilizer dose of 30 kg N and 60 kg P_2O_5 ha^{-1} was applied at sowing. The crop was sprayed once with 625 mL ha^{-1} Rogor (dimethoate) to control whitefly (PAU, 2009). Weeds were controlled by two hand weedings at 30 and 45 days after sowing. Meteorological data recorded during the crop-growing season are presented in Table 1.

Statistical analysis: All data were subjected to analysis of variance in a split plot design as per the standard procedure. Wherever F ratio was found significant Critical Difference (CD) values were calculated at 5% level of significance.

Table 1: Meteorological data during crop season, 2002 to 2004

Year/month	Temp. (°C) Min.	Temp. (°C) Max.	Relative humidity (%)	Total rainfall (mm)	Departure from normal rainfall (mm)	Rainy days
2002						
June	27.2	37.8	60	36.7	-29.7	4
July	28.1	36.6	67	36.8	-195.3	3
August	27.2	34.9	74	24.5	-155.2	3
September	22.1	32.0	75	193.0	+92.2	7
October	17.8	31.9	62	2.2	-3.8	1
2003						
June	27.5	39.0	52	49.6	-16.8	5
July	26.3	33.5	78	180.6	-51.5	13
August	26.6	33.5	84	297.7	+118.0	9
September	24.3	33.2	78	52.8	-48.0	3
October	16.3	32.2	62	0.0	-6.0	0
2004						
June	25.1	35.9	58	55.4	-11.0	4
July	27.2	35.8	68	32.1	-200.0	2
August	26.0	32.9	81	225.4	+45.7	11
September	23.7	34.3	70	2.6	-98.2	2
October	17.1	29.7	72	33.0	+27.0	4

RESULTS

Effects of plant population: The varying plant populations exhibited significant differences in the grain yield of soybean (Table 2). Plant population of 0.60 million plants ha^{-1} recorded the highest grain yield (1516 kg ha^{-1}) which was significantly higher than that obtained with 0.30 million plants ha^{-1}. Plant populations of 0.60 and 0.45 million plants ha^{-1} were, however, on par in grain yield. The interaction between genotypes and plant population levels was found to be non-significant (data not presented) which indicates that the requirements of plant population were similar for all the genotypes. Plant population of 0.60 million plants ha^{-1} had significantly higher biological yield and plant height than 0.30 and 0.45 million plants ha^{-1}. Pods $plant^{-1}$ decreased with increase in plant population. Harvest index as well as 100-seed weight were not influenced significantly by plant population levels.

Effects of plant geometry: Plant geometries i.e. row spacing did not differ significantly in influencing the grain yield, biological yield and plant traits in both the years (Table 3, 4). The interaction between genotypes and row spacings was non-significant (data not presented) which shows that the same plant geometry could be used for different genotypes tested in these studies.

Performance of genotypes: Genotypes differed significantly in grain yield in all the three years of investigation (Table 2-4). In 2002 (Table 2) genotype SL 525 was the highest yielder (2432 kg ha^{-1}) followed by SL 517 (1802 kg ha^{-1}). Genotypes DS 97-12 and PK 1283 were significantly better than PK 1042 but were on par with Pusa 16. In 2003 (Table 3) SL 525 produced the highest grain yield (3452 kg ha^{-1}) which was, however, on par with SL 518, DS 98-14 and PK 416. Genotype JS 335 yielded the lowest as it was highly infested with mung bean yellow mosaic. In 2004 (Table 4) SL 525 was again the highest yielder (3246 kg ha^{-1}) which was however, on par with Bragg. Genotype PK 1042 yielded the lowest.

Table 2: Grain yield, biological yield and plant characters of soybean as influenced by genotypes and plant populations in 2002

Treatment	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Plant height (cm)	Pods plant^{-1}	100-seed weight (g)
Genotypes						
SL295	1540	5461	28.1	69.9	53.6	8.69
SL 517	1802	6301	28.5	66.7	68.5	7.89
SL 525	2432	8286	29.3	88.3	68.6	8.35
PK 416	1506	5777	26.0	79.7	69.0	8.48
PK 1042	414	2834	14.6	60.5	35.9	6.98
PK 1283	1550	5392	28.7	79.3	64.3	7.51
Pusa 16	898	3980	22.5	67.5	55.6	8.13
DS 97-12	1254	5412	23.1	63.5	66.6	7.37
CD 5%	699	1739		8.4	13.7	0.85
Plant populations (million plants ha^{-1})						
0.30	1285	4777	26.8	68.6	65.1	7.79
0.45	1474	5496	26.8	71.3	59.0	7.93
0.60	1516	6018	25.1	75.8	56.7	8.05
CD 5%	135	416		4.2	4.4	NS

Table 3: Grain yield, biological yield and plant characters of soybean as influenced by genotypes and row spacings in 2003

Treatment	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Plant height (cm)	Pods plant^{-1}	100-seed weight (g)	Days to 50% flowering	Days to maturity
Genotypes								
SL 295	2998	8727	34.3	87.0	56.8	12.01	55	128
SL 518	3245	10496	30.9	77.6	74.4	9.08	59	130
SL 525	3452	10487	32.9	82.7	67.0	10.83	59	130
PK 416	3070	8404	36.5	82.6	60.4	10.88	54	130
PK 1042	2846	8053	35.3	77.2	64.5	10.95	55	129
Bragg	2540	7829	32.4	79.4	63.5	9.52	56	130
JS 335	291	3340	8.7	46.6	12.1	7.86	57	130
DS 98-14	3102	8242	37.6	62.3	61.3	12.55	61	135
CD 5%	421	1198		8.9	8.4	0.55		
Row spacings (cm)								
22.5	2614	8202	31.8	75.5	57.4	10.44		
30	2670	7962	33.5	74.2	56.6	10.47		
45	2796	8427	33.1	73.6	58.5	10.47		
CD 5%	NS	NS		NS	NS	NS		

In all the three years, similar trend to grain yield was observed in case of biological yield (Table 2-4). The high-yielding genotypes had better plant growth and more number of pods plant^{-1} (Table 2-4).

DISCUSSION

Inadequate plant population results in low yields of soybean (Singh, 2009). Plant populations of 0.45 and 0.60 million plants ha^{-1} were on par in the grain yield and both were significantly superior to plant population of 0.30 million plants ha^{-1} (Table 2). It has been reported that grain yields of soybean were similar with 0.40 and 0.60 million plants ha^{-1} and were higher than those with 0.20 million plants ha^{-1} (Joshi and Billore, 1996; Kang *et al*., 1998). Almost similar results have been found in the present study. Similarly in earlier studies Singh (2010) reported

Table 4: Grain yield, biological yield and plant characters of soybean as influenced by genotypes and row spacings in 2004

Treatment	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Plant height (cm)	Pods $plant^{-1}$	100-seed weight (g)	Days to 50% flowering	Days to maturity
Genotypes								
SL 525	3246	7508	43.2	90.8	73.9	11.84	65	148
SL 633	2514	7224	34.8	85.1	71.6	10.75	63	146
SL 637	2057	5971	34.4	78.2	68.6	9.70	64	146
PK 1042	1947	5432	35.8	70.0	50.8	10.81	62	147
PK 1347	2341	5276	44.3	62.7	50.0	10.75	80	148
Bragg	2770	7096	39.0	83.3	64.0	10.80	66	147
CD 5%	541	855		8.1	10.4	0.95		
Row spacings (cm)								
22.5	2446	6232	39.2	77.0	62.8	10.61		
30	2487	6428	38.6	79.3	62.7	10.81		
45	2505	6593	37.9	78.8	64.0	10.91		
CD 5%	NS	NS		NS	NS	NS		

high grain yields of soybean with plant population of 0.45 and 0.60 million plants ha^{-1}. Rahman *et al.* (2011) reported increase in soybean yields up to plant population of 0.8-1.0 million plants ha^{-1} and then decreasing trend at 1.2 million plants ha^{-1}. Higher grain yield at the highest plant population level was due to better plant growth, more pods per unit area and higher biological yield. Grain yield is positively related to Photosynthetically Active Radiation (PAR) interception (Wells *et al.*, 1993; De Bruin and Pedersen, 2009). Therefore, at higher plant population more interception of PAR is expected to increase grain yields and this could be the reason for higher yields at higher plant population in the present study. Ball *et al.* (2000) also opined that for short-season production high populations of soybean canopy ensure early canopy coverage and maximize light interception, crop growth rate and crop biomass, resulting in increased yield potential. Considering the lower cost involved with the use of less seed rate for maintaining a plant population of 0.45 million plants ha^{-1} than 0.60 million plants ha^{-1} the former is recommended. Similar are the views of Lee *et al.* (2008).

With an increase in plant population an increasing trend was observed in case of biological yield and plant height (Table 2). Taller plants at 0.60 million plants over 0.30 and 0.45 million plants ha^{-1} could be due to competition amongst plants for sunlight. Plant height of soybean has been reported to increase with increasing plant density (Kang *et al.*, 1998) thus supporting the present study. As the plant population increased from 0.30 million plants to 0.60 million plants ha^{-1} the number of pods $plant^{-1}$ decreased (Table 2) possibly due to more competition amongst plants for nutrients, moisture, sunlight and space. Though the number of pods $plant^{-1}$ decreased with increase in plant population yet the number of pods per unit land area increased thus resulting in higher grain yield at higher plant population level. In soybean as the plant density increases pods $plant^{-1}$ decrease (Kang *et al.*, 1998; Ram *et al.*, 1999), whereas pods m^{-2} increase (Kang *et al.*, 1998). The results are in agreement with the finding of these researchers. Harvest index remained unaffected under different plant population levels (Table 2). Other researchers (Billore and Joshi, 1997; Ball *et al.*, 2000) also reported that harvest index remains relatively constant under different plant populations.

Different planting geometries at uniform plant population of 0.45 million plants ha^{-1} did not differ significantly in grain yield and yield attributes (Table 3, 4). This shows that optimum plant population is more important than planting geometry for obtaining high grain yields of soybean.

Intercropping systems generally have higher yield advantage usually due to greater radiation use efficiency (Gao *et al*., 2010).

Genotypes differed significantly in grain yields (Table 2-4). It has been reported that genotypes of soybean do differ in grain yields (Joshi and Billore, 1996; Billore and Joshi, 1997; El Douby *et al*., 2002; Siddiqui *et al*., 2007; Shegro *et al*., 2010), which could possibly be due to differences in growth, yield attributes, crop duration, tolerance to diseases and insect pests etc. In the present study the high yielding genotypes produced high yields due to better plant growth (plant height) and more number of pods plant^{-1} (Table 2-4).

Soybean genotypes are known to vary in maturity duration (Muhammad *et al*., 2003; Shegro *et al*., 2010). In the present study different genotypes took 54-61 days and 62-80 days for 50% flowering and 128-135 days and 146-148 days for maturity in 2003 (Table 3) and 2004 (Table 4) respectively. Shorter 50% flowering and maturity periods in 2003 than in 2004 could be due to delayed sowing (20 June in 2003 vs 9 June in 2004) and variation in weather conditions such as temperature and rainfall during the two years of the investigation (Table 1).

Some of the genotypes were very good yielders whereas some were very poor yielder, the poor yields were mainly due to their susceptibility to Mungbean Yellow Mosaic Virus (MYMV). Ludhiana is the hot spot for MYMV. JS 335 is the leading genotype in central and southern India, occupying most of the soybean area. However, this genotype failed miserably in northern India i.e., at Ludhiana solely due to high susceptibility to MYMV. Another serious disease of soybean in many parts of the world is soybean mosaic, which has been reported to decrease carbohydrate content in the nodules (Gupta *et al*., 2010) which may consequently affect nitrogen-fixing ability of the plant. Though nodulation data were not recorded in the present study low yields in some of the genotypes could be due to the reason reported by Gupta *et al*. (2010).

CONCLUSION

The results show that not the planting geometry but optimum plant population is more important for realizing high grain yields of soybean under northern Indian conditions.

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