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Growth, Productivity and Economics of Soybean Genotypes under Varying Planting Densities

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Soybean [*Glycine max* (L.) Merrill] is an important oilseed crop widely grown as a valuable source of protein and oil for human nutrition. In Uttarakhand, it is cultivated over an area of 12 thousand hectares with production of 18 thousand tonnes and productivity of 1,500 kg per ha (DAC 2011-12). The unavailability of quality seed, poor or higher plant population, imbalanced fertilizer use and inadequate or non-use of plant protection measures are the major factors limiting soybean production in the region. Adjusting planting density is an important tool to optimize crop growth and the time required for canopy closure in addition to achieve maximum biomass and grain yield (Liu *et al*., 2008). Numerous studies have previously emphasized the significance of optimum plant population for better growth expression and productivity enhancement (Egli, 1988).

Selection of suitable genotypes plays a vital role in crop production, particularly in new areas of introduction. The choice of right genotypes of soybean helps to augment crop productivity by 20-25 per cent. Thus, the value of stable and high yielding genotypes has been universally recognized as an important non-monetary input for boosting the production of any crop. Therefore, present investigation was conducted to study the effect of planting density on growth, yield and economics of soybean genotypes under agro-climatic conditions of North Western Himalayas.

A field experiment was conducted during *kharif* 2012 at the experimental farm of the ICAR – Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora. The site is located at 29° 36′ N latitude and 79° 40′ E longitude at an elevation of 1,250 m above mean sea level. The soil of the experimental site was silty clay loam with pH 6.2, having low level of available nitrogen (172 kg N/ha), medium level of available phosphorus (21.3 kg P_2O_5/ha) and potash (183.5 kg K_2O/ha). The experiment was laid out in split plot design with three replications. The treatments consisted of three planting

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densities (0.30, 0.45 and 0.60 m plants/ha) as main plots while five soybean genotypes (VL Soya 47, VL Soya 59, VL Soya 63, VL Soya 65 and VL Soya 76) as sub-plots. The crop was sown in rows 45 cm apart by *kera* method using 125 kg seed per ha. Later on, when the plants were 3-4 leaf stage, the desired plant population was maintained by keeping plant to plant spacing at 7.5, 5.0 and 3.5 cm, respectively as per treatments. The other agronomic practices were followed as per recommendations. The crop was sown at the first shower of monsoon on 7 July, 2012 and harvested on 20 October, 2012. A total of 682.2 mm rainfall with 41 rainy days was received during the whole cropping season.

Representative plant samples were taken at 15 days interval starting from 30 DAS to 60 DAS to work out relative crop growth rate (RGR) and mean crop growth rate (CGR). The plant samples were first sun dried and thereafter, at 65^{o} C for 48 h in oven to achieve a constant weight before taking dry weight. Observations on component traits *viz*., plant height, yield attributes and yield were taken at the time of harvesting of the crop. Treatment wise monetary returns were worked out taking into consideration the market price of crop produce and inputs used. The rainwater use efficiency (RWUE) was computed as a ratio of yield and crop seasonal rainfall (Rockstrom *et al*., 2003). Statistical methods based on analysis of variance technique as described by Panse and Sukhatme (1985) were employed and the treatment differences were tested by least significant difference at 5 per cent of probability.

Effect of Plant Density

The total dry matter accumulation decreased with the increase in plant population (Table 1). Averaged across tested genotypes, significantly higher mean dry matter accumulation was recorded in treatments accommodating 0.30 million plants per ha closely followed by 0.45 million per ha planting density. Both these treatments were significantly superior to 0.60 m plants per ha. The mean crop growth rate (CGR) increased significantly with increasing levels of plant density and it was comparatively higher during periodic interval between 45-60 DAS than that of 30-45 DAS. However, relative crop growth rate (RGR) was not influenced significantly. Among other growth parameters, plant height increased, while number of branches per plant significantly decreased with increase in level of plant density. The CGR and plant height of soybean increased as plant density increased (Sekimura *et al*., 2000; Shamsi and Kobraee, 2009).

Increase in planting density from 0.30 to 0.60 million per ha resulted into decreased values of all the yield attributes *viz*., number of pods per plant, pod length, number of seeds per pod and seed index (Table 2). The reduction in these yield attributes was comparatively higher from 0.45 to 0.60 than 0.30 to 0.45 m plants per ha. Increased plant competition under higher population for growth resources might have culminated in poor dry matter production, fewer pods and lesser branches, taller plants, and higher pod shedding than compared to when soybean was grown at low populations. Board and Harville (1996) and Shamsi and Kobraee (2009) have also indicated a decrease in number of pods per plant as plant density increased. Under higher plant densities, there is increased competition for resources suggesting low

Table 1. Effect of planting density on growth of different soybean genotypes

Treatment	Dry matter (g/plant)			Mean CGR ($g/m^2/day$)		Mean RGR (g/g/day)		Plant height (cm)	Branches (No/plant)
	30 DAS	45 DAS	60 DAS	30-45 DAS	45-60 DAS	30-45 DAS	45-60 DAS		
Plant density (m/ha)									
0.30	1.77	3.74	6.22	3.95	4.96	0.050	0.035	49.48	6.59
0.45	1.62	3.34	5.93	5.17	7.77	0.049	0.039	53.11	6.17
0.60	1.47	3.00	5.50	6.10	10.01	0.048	0.042	57.64	5.85
SEm (±)	0.05	0.10	0.10	0.13	0.35	0.001	0.002	1.04	0.04
CD (P=0.05)	**0.19**	**0.39**	**0.38**	**0.52**	**1.39**	**NS**	**NS**	**4.08**	**0.17**
Genotype									
VL Soya 65	2.01	4.13	6.19	6.22	6.21	0.048	0.027	54.98	4.53
VL Soya 76	2.01	4.02	6.34	5.85	6.87	0.046	0.031	58.49	7.36
VL Soya 47	1.45	3.07	5.49	4.70	7.26	0.050	0.039	55.53	6.93
VL Soya 59	1.29	2.72	5.59	4.18	8.64	0.050	0.048	49.36	6.11
VL Soya 63	1.34	2.87	5.82	4.42	8.92	0.051	0.048	48.69	6.09
SEm (±)	0.05	0.09	0.16	0.17	0.61	0.001	0.003	1.01	0.19
CD (P=0.05)	**0.13**	**0.28**	**0.47**	**0.50**	**1.79**	**0.002**	**0.008**	**2.96**	**0.56**

dry matter assimilation in seeds leading to less seed weight

Consistent and significant increase in seed yield was observed with the increase in planting density up to 0.45 million per ha; however, further increase in plant population exhibited adverse impact on soybean yield. Significantly higher seed yield (2,242 kg/ha) was recorded with 0.45 million per ha planting density elucidating 5.6 and 10.2 per cent higher yield advantage over treatments involving 0.30 and 0.60 million plants per ha, respectively. Significant improvement in harvest index was noticed with the reduction in plant density. Ball *et al.* (2000) reported that increasing plants population reduced yield of individual plants but increased yield per unit of area. The results are in close conformity with that of Rahman *et al.* (2004) who reported that plant density up to 0.40 million per ha gave the highest yield but above this plant density no yield advancement was achieved.

The cost of cultivation increased with increasing levels of planting density and was highest in 0.60 million per ha (Table 3). Highest gross returns, net returns and B:C ratio was recorded under 0.45 million per ha followed by 0.30 million per ha. The net returns and B:C ratio under 0.45 million per ha were at par with 0.30 million per ha while significantly superior than 0.60 million per ha. Higher gross returns, net returns and B:C ratio under 0.45 m plants per ha might be due to the reason that there was

Table 2. Effect of planting density on yield attributes and yields of different soybean genotypes

Treatment	Pods (No/ plant)	Pod length (cm)	Seeds (No/ pod)	Seed index (g/100 seeds)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
Plant density (m/ha)							
0.30	63.83	3.76	2.56	17.10	2117	2045	50.72
0.45	59.63	3.70	2.49	16.86	2242	2295	49.29
0.60	54.52	3.58	2.41	16.52	2013	2178	47.84
SEm (±)	0.24	0.03	0.02	0.10	43	66	0.35
CD (P=0.05)	**0.95**	**0.12**	**0.10**	**0.40**	**169**	**NS**	**1.37**
Genotype							
VL Soya 65	44.47	3.50	2.26	18.38	1479	1696	46.59
VL Soya 76	66.49	3.83	2.69	16.01	2431	2426	50.08
VL Soya 47	69.38	3.73	2.57	16.37	2336	2283	50.61
VL Soya 59	57.02	3.64	2.42	15.81	2167	2090	50.92
VL Soya 63	59.27	3.68	2.50	17.56	2206	2369	48.23
SEm (±)	1.20	0.02	0.04	0.19	48	54	0.17
CD (P=0.05)	**3.49**	**0.07**	**0.11**	**0.56**	**140**	**158**	**0.49**

proportionately less increase in cost of 0.45 m plants per ha compared to more increase in seed and straw yields. The highest rain water use efficiency (3.29 kg/ha/mm) was recorded under 0.45 m plants per ha and it followed by 0.30 m plants per ha (3.10 kg/ha/mm) and 0.60 m plants per ha (2.95 kg/ha/mm).

Effect of genotypes

Genotypes exhibited significant differences for dry matter accumulation, CGR and RGR with respect to the observations taken at fortnightly interval from 30 to 60 DAS (Table 1). VL Soya 76 and VL Soya 65 being at par recorded significantly higher dry matter accumulation than VL Soya 47, 59 and 63 at 30 and 45 DAS, however, at 60 DAS, only VL Soya 65 was at par with these genotypes. During 30-45 DAS, CGR was relatively higher under VL Soya 76 and 65 while it was comparatively more under genotypes VL Soya 47, 59 and 63 during 45-60 DAS. Higher values of CGR were observed during 45-60 DAS as compared to 30-45 DAS, which might be attributed to better source: sink ratio through better translocation of metabolites and utilization of growth resources. Saxena *et al.* (2013) reported more stage based energy utilization/exploitation referring towards production (earlier half) and expansion of primary plant parts (leaves, stem, primary branches, *etc.*). He further stressed that with the passage of time, the value of RGR decreased due to increase in

Table 3. Effect of planting density on economics and rain water use efficiency of different soybean genotypes

Treatment	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio	Rainwater use efficiency (kg/ha/mm)
Plant density (m/ha)					
0.30	27269	50971	23702	1.86	3.10
0.45	28643	54217	25574	1.89	3.29
0.60	29433	48907	19474	1.66	2.95
SEm (±)	-	1071	1072	0.04	-
CD (P=0.05)	**-**	**NS**	**4207**	**0.15**	**-**
Genotype					
VL Soya 65	27343	35591	8248	1.30	2.17
VL Soya 76	28967	58826	29859	2.03	3.56
VL Soya 47	28810	56440	27631	1.96	3.42
VL Soya 59	28528	52292	23764	1.83	3.18
VL Soya 63	28593	53674	25081	1.88	3.26
SEm (±)	-	1170	1170	0.04	-
CD (P=0.05)	**-**	**3416**	**3416**	**0.12**	**-**

relative dry matter of the plants. VL Soya 76 produced significantly taller plants (58.49 cm) with more number of branches per plant (7.36) and was at par with VL Soya 47. VL Soya 65 recorded lowest number of branches per plant (4.53). Differential behaviour in growth habit of soybean genotypes may be attributed to their genetic makeup (Singh *et al.*, 2013)

Across varying planting densities, yield, yield attributes and harvest index of soybean were significantly influenced by genotypes under study (Table 2). The genotype VL Soya 76 recorded highest number of pods per plant (69.38), pod length (3.83 cm) and number of seeds per pod (2.69) and was significantly superior to rest of the genotypes. Though VL Soya 65 recorded highest seed index (18.38 g/100 seed) but was worst in terms of pods per plant, pod length and number of seeds per pod. Among all the genotypes, VL Soya 76 was found superior with respect to seed (2,431 kg/ha) and straw (2,426 kg/ha) yields indicating 4.0, 9.4, 11.4 and 39.2 per cent yield superiority over VL Soya 47, 63, 59 and 65, respectively. Harvest index was highest with genotype VL Soya 59 (50.92 %) and minimum in VL Soya 65 (46.59 %). Better expressions of growth and yield attributes finally culminated in higher yield in genotypes VL Soya 76 and 47. Saxena *et al.* (2013) have also reported genotypic difference in seed yield of soybean.

There was not much difference in the cost of cultivation for different genotypes, however, gross returns, net returns and B: C ratio differed significantly across the genotypes (Table 3). The highest gross returns (Rs 58,826/ha), net returns (Rs 29,859/ha) and B:C ratio (2.03) were recorded with VL Soya 76 attributing its statistically higher economic and biological yields.

The genotype VL Soya 65 resulted in lowest monetary returns. VL Soya 76 was found to be the most efficient genotypes with respect to rain water use efficiency (3.56 kg/ha/mm) among all the tested genotypes.

From the study, it could be concluded that among soybean genotypes, VL Soya 76 produced highest seed yield (2,431 kg/ha) with B:C ratio of 2.03 while among planting densities, 0.45 million/ha resulted into maximum seed yield (2,242 kg/ha) with B:C ratio of 1.89.

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