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Avinash P Karjule
Junior Research Assistant, Seed Technology Research Unit, MPKV, Rahuri, Maharashtra, India

Uday G Kachole
Seed Production Officer, Seed Cell, Seed Technology Research Unit, MPKV, Rahuri, Maharashtra, India

Vijay R Shelar
Seed Research Officer, Seed Technology Research Unit, MPKV, Rahuri, Maharashtra, India

Narayan A Musmade
Seed Technology Research Unit, MPKV, Rahuri, Maharashtra, India

Corresponding Author:
Avinash P Karjule
Junior Research Assistant, Seed Technology Research Unit, MPKV, Rahuri, Maharashtra, India

Effect of varieties, seed rate and sowing methods on seed yield and quality of soybean (*Glycine max* L.)

Avinash P Karjule, Uday G Kachole, Vijay R Shelar and Narayan A Musmade

Abstract
Quality seed plays an important role to increase the production and productivity in soybean, however availability of quality seed is one of the major problem in soybean seed production. The field study was undertaken to investigate the effect of varieties, reduced seed rate and sowing methods on soybean seed quality and yield. It was observed that the seed yield (26.42 qt ha^{-1}) of soybean variety KDS 344 sown on Ridges and furrows was significantly higher at seed rate 70 kg ha^{-1} which was at par (25.03 qt) with the seed rate 60 kg $ha.^{-1}$ The cost benefit ratio was (1.53) and (1.49) for 70 kg and 60 kg ha^{-1} seed rates respectively. The plant population (52.45/m^2), plant height (69.17 cm) were also the highest at seed rate 70 kg ha^{-1} in the same variety. The seed quality parameters *viz.*, initial germination (93.25%), seed vigour index I (2683) and vigour index II (109.55) and plant growth parameters were significantly higher in the soybean variety KDS 344 sown on Ridges and furrows at reduced seed rate of 50 kg ha^{-1}.

Keywords: Variety, seed rate, ridges and furrow, seed yield, germination

Introduction
Soybean [*Glycine max* (L.) Merrill] is known as "golden bean" due to its various usages. Majority of the area under soybean –wheat based cropping system is in Central India and is covered under vertisols and associated soils (Bhatnagar and Joshi, 1999) [4]. As enrich in protein and accounts over half of the world's oilseed production it plays a key component for global food security (Ainsworth *et al.,* 2011) [1]. Soybean area is increasing probably due to higher returns with lower inputs and management practices. It gives stable cost effective yields in varied agro-climatic conditions (Kumar *et al.* 2008) [16]. For the sake of higher stabilize soybean yields, a revision is to be undertaken that includes both practical agronomic management and genetics. The cost of production of soybean could be minimized by introducing of new technology. In India there is huge gape between demand and supply of quality seeds of soybean to the stake holders. Higher yields with reduced seed rate will be one of the strategy for higher benefits and availability of quality seeds during shortage of soybean seeds. Increase in seed rate above optimum level may only enhance production cost without any increase in grain yield (Rafique *et al.,* 2010) [23]. Optimizing the seed production by reduced seed rates is possible by using proper management and responsive cultivars.
The management practice like land treatments (raised sunken bed system, ridges and furrows, broad bed and furrows) increased in situ soil moisture conservation, minimized runoff, and soil erosion (Singh *et al*, 1999) [31]. Water logging conditions creates excess moisture during monsoon season causes unfavourable conditions like reduced soil porosity, reduced soil aeration resulted in reduced root growth, nodulation and nutrient uptake which ultimately affects the physiology and biochemistry of a soybean plant ultimately reflects lower productivity. Land management practices plays an important role in minimizing soil erosion and improves water use efficiency. The seed production on ridges and furrows can save considerable amount of irrigation water and maximize water productivity (Dhindwal *et al.,* 2006) [9]. Ram and Kler, (2007) [28] reported that the raised bed planting reduces seed rate and provides favourable environment for the growth and development of the soybean. More studies were undertaken on the effect of seed rate on performance of genotypes on conventional planting methods in soybean. However, little work has been published on effect of seed rates on different varieties with ridges and furrow planting method.

In view of this, present study was planned to evaluate the effect of reduced seed rates on varietal performance with conventional and ridges and furrow planting methods on productivity, insect and disease infestation economic viability of low seed rate and seed yield and quality of soybean

Materials and Methods

The field study was undertaken with the soybean varieties KDS 344 (Phule Agrani) (V_1) and JS-9305 (V_2) sown with reduced seed rates *i.e.* @ 60kg/ha (T_1) and @ 50kg/ha (T_2) along with recommended seed rate @ 70 kg/ha (T_0) along with reduced seed rates with two types of planting method *viz.*, Ridge & furrow (S_1) and Flat bed (S_2) in four replications. The plant to plant spacing was adjusted according to seed rates and 100 seed weights of the selected varieties. The 100 seed weight of var. JS-9305 is 14 g and plant to plant distance is 4.4 cm, 5.2 cm and 6.2 cm for 70 kg, 60 kg and 50 kg seed rate respectively whereas 100 seed weight of var. KDS 344 (Phule Agrani) is 12 g and plant to plant distance is 3.8 cm, 4.5 cm and 5.3 cm for 70 kg, 60 kg and 50 kg seed rate respectively. The seed yield and quality attributes were recorded during the crop growth and after harvest. The data obtained were analysed through analysis of variance (ANOVA) technique for factorial controlled randomized design and presented at 5% level of significance (P = 0.05) suggested by Panse and Sukhatme (1967) [22].

Results and Discussion

The data on influence of varieties, sowing methods and sowing rates on seed yield, yield contributing traits and quality are presented in Table 1 and 2. From the data it is revealed that the seed yield and seed quality of soybean influenced significantly due to varieties, sowing types and seed rates.

Table 1: Effect of variety, sowing method and seed rate on seed yield and quality parameters of soybean

Treatments	Plant population /m^2	Plant height (cm)	Plant canopy diameter (cm)	No. of branches/plant	No. of pods /plant	Seed yield (g)/plant
Sowing method						
S_1-Flat bed	41.53	57.14	38.61	6.43	69.26	17.35
S_2-Ridge & furrow	42.28	59.56	43.35	6.73	72.32	18.97
SE ±	0.271	0.785	0.160	0.046	1.046	0.311
CD at 5%	NS	2.261	0.461	0.131	3.013	0.894
Seed rate						
T_0 - Recommended seed rate @ 70 kg/ha	48.48	61.14	38.32	6.04	68.26	16.80
T_1 - Reduced seed rate @ 60kg/ha	42.00	58.02	41.26	6.59	71.14	18.23
T_2 - Reduced seed rate @ 50kg/ha	35.23	55.89	43.35	7.11	72.96	19.45
SE ±	0.332	0.962	0.196	0.056	1.282	0.380
CD at 5%	0.955	2.769	0.565	0.161	3.690	1.095
Variety						
V_1: Phule Agrani (KDS 344)	45.81	64.73	44.70	6.95	75.13	19.83
V_2: JS 9305	37.99	51.96	37.26	6.21	66.45	16.49
SE ±	0.271	0.785	0.160	0.046	1.046	0.311
CD at 5%	0.780	2.261	0.461	0.131	3.013	0.894

Table 1: Continue….

Treatments	Seed yield Kg/plot	Seed yield qt/ha	100 seed weight (g)	Germination (%)	Root shoot length (cm)	Dry matter content (g)	Vigour index I	Vigour index II
Sowing method								
S_1-Flat bed	4.01	20.70	13.15	91.46 (73.03)	26.89	1.15	2460	104.92
S_2-Ridge & furrow	4.43	22.86	13.22	92.33 (73.96)	27.51	1.16	2540	106.97
SE ±	0.063	0.326	0.059	0.109	0.204	0.002	19.58	0.277
CD at 5%	0.182	0.939	NS	0.314	0.588	0.007	56.37	0.768
Seed rate								
T_0 - Recommended seed rate @ 70 kg/ha	4.44	22.91	13.05	91.06 (72.62)	26.26	1.14	2392	104.16
T_1 - Reduced seed rate @ 60kg/ha	4.24	21.86	13.21	91.88 (73.47)	27.13	1.15	2493	105.84
T_2 - Reduced seed rate @ 50kg/ha	3.99	20.57	13.29	92.75 (74.39)	28.20	1.16	2616	107.83
SE ±	0.077	0.399	0.072	0.133	0.250	0.003	23.98	0.339
CD at 5%	0.223	1.150	NS	0.384	0.720	0.008	69.04	0.977
Variety								
V_1: Phule Agrani (KDS 344)	4.50	23.20	12.18	92.21 (73.83)	27.64	1.17	2549	107.44
V_2: JS 9305	3.95	20.36	14.19	91.58 (73.16)	26.76	1.14	2451	104.45
SE ±	0.063	0.326	0.059	0.109	0.204	0.002	19.58	0.277
CD at 5%	0.182	0.939	0.169	0.314	0.588	0.007	56.37	0.768

*Figures in parenthesis are Arc sin transformed values

Table 2: Interaction effects of variety, sowing method and seed rate on seed yield and quality parameters of soybean

Treatments	Plant population/m^2			Plant height (cm)			Plant canopy (cm^2)			No. of branches/plant			No. of pods /plant			Seed yield/ plant (g)		
$V_1S_1T_0$	50.40			65.42			39.61			6.35			70.90			17.90		
$V_1S_1T_1$	47.25			62.68			42.79			6.80			74.15			19.48		
$V_1S_1T_2$	38.05			61.20			44.66			7.20			76.30			20.57		
$V_1S_2T_0$	52.45			69.17			45.18			6.70			74.10			18.85		
$V_1S_2T_1$	48.10			66.00			47.19			7.05			76.80			20.19		
$V_1S_2T_2$	38.60			63.93			48.77			7.60			78.50			21.97		
$V_2S_1T_0$	46.45			54.35			32.58			5.35			61.95			14.45		
$V_2S_1T_1$	34.45			51.41			34.60			6.15			65.50			15.22		
$V_2S_1T_2$	32.55			47.76			37.44			6.70			66.75			16.50		
$V_2S_2T_0$	44.60			55.61			35.93			5.75			66.10			16.01		
$V_2S_2T_1$	38.20			52.01			40.49			6.35			68.10			18.02		
$V_2S_2T_2$	31.70			50.66			42.54			6.95			70.30			18.76		
SE ±	0.664			0.439			0.392			0.112			2.563			0.761		
CD at 5%	1.911			NS			1.130			NS			NS			NS		
CV	3.17			7.59			1.92			3.40			7.24			8.38		
	V X S	V X T	S X T	V X S	V X T	S X T	V X S	V X T	S X T	V X S	V X T	S X T	V X S	V X T	S X T	V X S	V X T	S X T
SE ±	0.383	0.469	0.469	0.111	1.360	1.360	0.227	0.277	0.277	0.065	0.079	0.079	1.480	1.812	1.812	0.439	0.538	0.538
CD at 5%	NS	1.351	1.351	NS	NS	NS	NS	NS	NS	NS	0.227	NS	NS	NS	NS	NS	NS	NS

Table 2: Continue…

Treatments	Seed yield /plot (kg)			Seed yield /ha (kg)			B:C ratio	100 seed weight(g)			Initial Germination (%)			RS length (cm)			Dry matter content (g)			Vigour index I			Vigour index II		
$V_1S_1T_0$	4.39			22.63			1.38	12.03			90.50 (72.05)			26.52			1.148			2400			103.85		
$V_1S_1T_1$	4.27			22.05			1.35	12.19			91.25 (72.80)			27.14			1.155			2476			105.40		
$V_1S_1T_2$	4.12			21.24			1.32	12.20			92.75 (74.39)			28.19			1.168			2614			108.29		
$V_1S_2T_0$	5.12			26.42			1.53	12.07			92.25 (73.84)			26.78			1.160			2497			108.17		
$V_1S_2T_1$	4.85			25.03			1.49	12.27			93.25 (74.95)			28.12			1.173			2622			109.34		
$V_1S_2T_2$	4.23			21.84			1.31	12.34			93.25 (74.95)			29.09			1.188			2683			109.55		
$V_2S_1T_0$	4.05			20.90			1.27	14.04			90.75 (72.30)			25.57			1.130			2320			102.55		
$V_2S_1T_1$	3.76			19.39			1.19	14.14			91.25 (72.80)			26.46			1.138			2414			103.80		
$V_2S_1T_2$	3.49			17.99			1.12	14.30			92.25 (73.84)			27.50			1.145			2536			105.63		
$V_2S_2T_0$	4.21			21.70			1.26	14.08			90.75 (72.30)			26.19			1.138			2376			103.23		
$V_2S_2T_1$	4.06			20.96			1.25	14.25			91.75 (73.31)			26.83			1.143			2462			104.83		
$V_2S_2T_2$	4.11			21.22			1.27	14.32			92.75 (74.39)			28.04			1.150			2600			106.66		
SE ±	0.155			0.799				0.144			0.267			0.500			0.006			47.95			0.679		
CD at 5%	0.446			2.299				NS			0.769			NS			NS			NS			NS		
CV	8.33			8.33				2.19			1.55			3.68			2.02			3.84			1.28		
	V X S	V X T	S X T	V X S	V X T	S X T		V X S	V X T	S X T	V X S	V X T	S X T	V X S	V X T	S X T	V X S	V X T	S X T	V X S	V X T	S X T	V X S	V X T	S X T
SE ±	0.089	0.109	0.109	0.461	0.565	0.565		0.083	0.102	0.102	0.154	0.189	0.189	0.289	0.354	0.354	0.003	0.004	0.004	27.686	33.908	33.908	0.392	0.480	0.480
CD at 5%	NS	NS	NS	NS	NS	NS		NS	NS	NS	0.444	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.128	NS	NS

Figures in parenthesis are Arc sin transformed values

A. Effect of seed rates

It was observed that the seed yield per hector (22.91 qt) were significantly higher at seed rate 70 kg ha^{-1} which was at par with the seed rate 60 kg ha^{-1}. The plant population (48.48/m^2), plant height (61.14 cm) were also the highest at seed rate 70 kg ha.$^{-1}$ Lone *et al.* (2010) [10] also recorded higher soybean plant height in higher seed rate treatments. The seed quality parameters *viz.*, initial germination (92.75%), seed vigour index I (2616) and vigour index II (107.83) and plant growth parameters were significantly higher at seed rate 50 kg ha^{-1}. The higher plant density per unit area resulted in increased plant height and there is more competition between the plants for solar energy utilization in higher seed rates. Similar results were reported by Cox and Cherney (2011) [5], Rahman and Hossain (2011) [24] and Akond *et al.*, (2013) [2]. Reduction in seed rates contributed to yield changes but not to changes in profitability with the seed rates of 70 and 60 kg ha^{-1}. Adopting narrow row spacing and reduced seed rates as compared to current production recommendations could be used to reduce production costs and increase yield and profitability. Increased plant growth and yield attributes was associated with plant population. Higher yields might be due to higher plant populations however, in case of reduced seed rate plants get more space for growth ultimately resulted in higher yield attributes and could achieve the yield up to yield levels of higher seed rates. The results were obtained by Jason *et. al.* (2008) [13], Naoki in soybean, Kilic and Gursoy (2010) [15] in wheat.

B. Effect of sowing method

The sowing method also affected the seed yield and quality attributes. The yield contributing parameters *viz.*, number of

branches (6.73), number of pods (72.32 plant^{-1}), seed yield (18.97 g plant^{-1}), seed yield (4.43 kg plot^{-1}), seed yield (22.86 qt ha^{-1}) as well as the seed quality parameters *viz.*, initial germination (92.33%) and vigour index I (2540) and vigour index II (106.97) were significantly higher in the sowing method of ridges and furrows over the flat bed sowing. Higher seed yield and quality might be due to better growing environment and proper drainage of lodged water in ridge planting than flat sowing which ultimately beneficial for better crop growth. Dhakad *et al*. (2014) [8] found higher growth and yield attributes of soybean in ridge and furrow system compared to the flat bed sowing which subsequently resulted in yield enhancement to the extent of 27.2 percent. Ralli and Dingra (2003) [27] reported higher growth rates of soybean in case of ridge and furrow because of less stagnation of water due to furrow and proper aeration due to ridges leading to satisfactory physical environment for plant growth. Devrat *et al.* (2012) [6] also reported significantly higher plant population on furrow irrigated raised bed than on normally adopted flat bed. The results are in accordance to Nagavallemma *et al.* (2005) [18], Verma *et al.* (2018) [34].

C. Effect of varieties

The plant height (64.73 cm), plant canopy diameter (44.70 cm), number of branches (6.95), number of pods (75.13 plant^{-1}), seed yield (19.83 g plant^{-1}), seed yield (4.50 kg plot^{-1}), seed yield (23.20 qt ha^{-1}) as well as the seed quality parameters *viz.*, initial germination (92.21%) and vigour index I (2549) and vigour index II (107.44). The plant growth and yield contributing parameters were significantly higher in soybean variety Phule Agrani (KDS 344) over JS 9305. Newer variety development is a regular phenomenon as per the requirements of farmers. Different soybean varieties gave varied response to environmental changes and land management practices. It was found that soybean genotype Phule Agrani (KDS 344) possessed relatively better growth attributes and responding more positively to land management practices and seed rates as compared to other genotypes JS 9305. These results are in accordance to Negi *et. al.* (2018) [20] who reported varied response of different cultivars of soybean under changing environmental conditions. There are development different types of micro climate in dense population in higher seed rates and plants with more space for growth due to reduced seed rates. Similar varietal responses for varied ecological conditions were reported by findings were reported by Ashard *et al*., (2006) [3], Rajanna *et al.*, (2000) [25].

D. Interaction effect

The interaction effect of varieties, sowing type and seed rates showed significant effect on yield parameters. The seed yield (5.12 kg plant^{-1} and 26.42 qt ha^{-1}) were significantly higher in the ridges and furrow sowing method of soybean variety Phule Agrani (KDS 344) with the seed rate 70 kg ha^{-1}. The same variety sown with ridges method and with the seed rate 60 kg ha^{-1} showed at par values for yield and quality parameters. The seed quality parameters *viz.*, initial germination (93.25%) was higher in the same treatment combination with seed rate 50 kg ha.$^{-1}$ Ram *et. al.* (2012) [29] advocated that raised bed, raised broad bed and ridge furrow sowing of soybean should followed over flat bed sowing mainly due to their ability to save irrigation water and better root development resulting higher benefits. At low plant density in reduced seed rates favoures better plants developed and more branching in soybean due to reduced competition for light. Lower number of lateral branches was observed in case of higher seed rates and more density. These results are in agreement with the findings of Hosseini *et al.* (2001) [12]; Dapaah *et al.* (2005) [7]; Worku and Astatkie (2011) [35] and Shamsi and Kobraee (2011) [30].

E. Cost benefit ratio

The highest cost benefit ratio (1.53) was observed in the raised bed sowing of the soybean variety Phule Agrani with 70 kg seed rate and was (1.49) in the raised bed with seed rate of 60 kg/ha. The cost benefit ratio was found the lowest (1.12) in the flat bed sowing of the soybean variety JS 9305 with 50 kg/ha seed rate.

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