Influence of reduced seed rate and sowing methods on growth parameters and seed yield of soybean (*Glycine max* L. Merr.)

Abstract

The field experiment was carried out during *Kharif*, 2018 and 2019with an objective to increase the productivity of soybean with reduced seed rate and varied sowing methods. The experiment comprising of two sowing methods *viz*., flatbed and raised bed, two varieties (JS-335 and JS-9560) and three seed rates (70, 60, and 50 kg ha^{-1}) was laid out in split plot design with four replications.The growth and yield parameters *viz.*, plant height (44.77 cm), canopy diameter (22.50 cm), pods per plant (37.72) and seed yield ha^{-1} (18.32 q) were maximum in raised bed method of planting. Use of lower seed rate *i.e.*,50 kg ha^{-1} produced maximum canopy diameter (23.97cm^2), pods plant^{-1} (39.86), seed yield plant^{-1} (15.12 g) and seed yield ha^{-1} (17.05q). Hence, there is a possibility of optimizing yield of soybean by adopting raised bed method of sowing at the seed rate of 50 kg ha^{-1}.

Keywords:*Raised bed method, seed rate, canopy diameter, flat bed method and optimization.*

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INTRODUCTION

Soybean designated as 'miracle bean' has established its potential as an industrially vital and viable oilseed crop in many areas of India. Soybean (*Glycine max* L.) Merrill is a legume that grows in tropical, sub-tropical and temperate climates. It is a multipurpose crop with many food and industrial values. It contains about 20-22% oil and 40-42 % high quality protein. It improves soil fertility by fixing atmospheric nitrogen at the rate of 65-115 kg ha^{-1} per year with the process of symbiosis through *Rhizobium Japonicum* micro-organisms. It also improves the structure and fertility of the soil by adding the leaves and straw having 9 per cent nitrogen, 12 per cent phosphorus and 8.9 per cent potash. Thus, it is soil fertility builder and eco-friendly. The area under soybean crop is increasing steadily and in India during 2018-19 the area covered was around 10.56 million ha with the production of 11.39 million tonnes. Soybean now has been established as one the most important oilseed crop in the world, accounting for more than 50 per cent of oilseed produced and 30 per cent of the total supply of all vegetable oils. There are many competitive factors that play an extremely important role in the production of soybean and its profitability to the producer. Seed quality, planting date, fertilizer, soil type, row spacing and seeding rate are just a few vital factors that producers must consider when planting soybean or any other production crop. It is important to plant the number of seeds that will achieve the desired number of plants per acre in a uniform stand of soybean. The seeding rate or plant population is one of the most important factors when it comes to profitability for the producer. Soybean seed costs have increased over the past few years, driven in part by soybean seed being priced similar to corn seed. Optimum plant population per unit area helps to maximum utilization of the available resource especially light, water and nutrient allowing the production of higher seed yield. Therefore, optimum seed rate is necessary for obtaining maximum seed yield. Uniform spacing generally gives better yield under favorable moisture condition. Farmers tend to plant 25 per cent more seed than needed. Some of it is just habit, but some producers feel that the high seeding rates are needed for better weed control. Most people can reduce seeding rate by 25 per cent without affecting either weed control or yield. Therefore, establishment of an optimum seed rate requirement is a non-monetary input factor for enhancing the production of soybean. The advantage of lower or the minimum seed rate is distribution of plant equidistantly which leads to increased canopy leaf area development (Weber *et al.*, 1966). These changes in canopy formation increase crop growth rate, dry matter accumulation and seed yield (Andrade *et al.*, 2002; Bullock *et al*., 1998).

Sowing method also plays an essential role in the emergence and establishment of seedlings. Amidst the sowing methods, raised bed method is a novel method for cultivation of soybean in India whereas; flatbed sowing is conventional sowing method. This raised bed planting method have numerous benefits like better plant establishment, root development and ability to use inter bed cultivation for weed control, proper irrigation management etc., over conventional flatbed sowing (Lakpale and Tripathi, 2012).

Seeding rate and methods of sowing are agronomic decisions that producers can use to maximize soybean seed yield. Risks are associated with reduced seeding rates, but as seed costs increase and since yield responses are small the focus must be placed on economic return rather than yield maximization. Hence, the present investigation was carried out to study the effect of soybean seeding rate and sowing methods on plant growth and seed yield.

MATERIALS AND METHOD

To evaluate the effect of differed sowing methods and seed rateson growth yield and quality of soybean,field experiment was carried out during *Kharif*, 2018 and 2019for two consecutive years at Seed Research Centre, UAS, GKVK, Bengaluru (12^o 15’ N Latitude and 77^o 35’ E longitude 930 m above Mean sea level).The annual rainfall ranges from 528 mm to 1374.4 mm with the mean of 915.8 mm. During *kharif* 2018 and 2019 the average rainfall received at Bangalore was 815 mm as against 78 rainy days. The experimental soil was sandy (46.3 %) with pH (7.5%), EC ($0.32 dsm^{-1}$), available nitrogen (143.5kg ha^{-1}), available P_2O_5(27.16 kg ha^{-1}) and K_2O (374.2 kg ha^{-1}). Seeds having initial germination of 90 per cent were dried to safe level of moisture (9.0 %), graded to uniform size and then used for the study to avoid variations. The experiment comprised of two sowing methods *viz*., S_1: Flat-bed sowing and S_2: Raised bed sowing;two varieties with different maturity days, V_1:JS-335 (medium duration) and V_2: JS-9560 (short duration) and three seed rates T_1:70 kg ha^{-1}, T_2:60 kg ha^{-1} and T_3:50 kg ha^{-1}. Experiment was laid out under split plot design with four replications. Seeds were sown with spacing of 30 × 10 cm. The land ploughed 3 times and prepared to fine tilth and crop was raised as per the recommended package of practices. Sowing was done in the second fort night of July at optimum soil conditions. The observation on growth and seed yield parameters were recorded. The data was pooled and data obtained from two years was statistically analyzed with suitable ANOVA.

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Since the experiment has multiple response, therefore Multivariate Analysis of Variance (MANOVA) is recommended with its table for a reader to see reasons some factors are significant or not.

RESULTS AND DISCUSSION

Plant population per unit area is the key factor of production. Plant population significantly differed among the sowing methods, varieties and seed rates (Table 1). The highest plant population was noted in raised bed method of sowing (28.54 $/m^2$) as compared to flat-bed method (17.41$/m^2$). This might be due to appropriate drainage of water, more aeration of soil and root proliferation (Chaurasiya, 2013). These results are in accordance with Singh (2009) in soybean. Among the varieties, JS-335 (V_1) was having more plant population (24.37$/m^2$) as compared to V_2-JS-9560 (17.42$/m^2$). The seed rate at 70 kg ha^{-1}had significantly highest plant population (25.12$/m^2$).Minimum number of plants$/m^2$was noted in case of seed rate 50kg ha^{-1} (19.68$/m^2$). These results are also in line with the observations recorded by Achakzai and Taran (2011) who reported that plant population ranged from 5-11 plants / m^2 by changing seed rates (Ganesh Shankar, 2017).

The plant height recorded wassignificantly highest in raised bed method of sowing S_1 (44.77 cm) as against flatbed sowing S_2 (30.56 cm). The better expression of plant height with raised bed method might be due to favourable conditions available for growth of plant with this method (Hariram *et al.*, 2012). The results are in accordance with Kumar *et al.*, (2015), Patel *et al.*, *(*2016) in groundnut. However, no significant variation in plant height was noticed among varieties and seed rates.

Plant performance is strongly associated with plant development and growth. Several developmental features of plants, such as overall plant architecture and leaf features are major traits that determine the overall performance of crop plants. Plant canopy structureis one such parameter which is directly related to the yield. The maximum diameter was noticed in raised bed method of sowing S_1 (22.50cm^2) as compared to flatbed method S_2 (20.04cm^2). This might be due to good water uptake and nutrient availability in raised bed method. Among the varieties, the variety JS-335 (27.33cm^2) recorded significant highest canopy diameter.This might the varietal characters. In case of seed rate, the canopy diameter was noted significantly highest among the reduced seed rate 50kg ha^{-1}(23.97 cm^2) as against the recommended seed rate of 70 kg ha^{-1}(19.50cm^2). Hence, optimizing crop canopy structure can improve canopy photosynthetic productivity and thereby crop yield potential.

Like plant height and plant canopy, seed rate significantly influenced the number of branches/plant. Highest number of branches were noticed in raised bed method of sowing S_1 (4.80) as against the flat bed method S_2 (3.10). Among varieties, the highest number of branches per plant was recorded in JS-335 (4.50). Among the seed rates,50kg ha^{-1} recorded more number of branches per plant(4.6) while, less number of branches per plant was recorded in70 kg ha^{-1} (3.5). Higher interception of solar radiation under lower seed rates might be the results of higher plant branches. These findings are in agreement with Saitoh (2011), and Worku&Astatkie (2011)**.**

The pod and seed number per plantare most important yield contributing traits which change in response of sowing methods and seed rate (Table 2). Highest number of pods per plant(37.72) and seeds per plant (86.4) was noted in raised bed method of sowing S_1 compared to flatbed method S_2 (34.67 and 72.7respectively). The better growth of plant under raised bed method of sowing might have resulted in higher photosynthetic activity and better translocation of food reserves to the sink. With respect to seed rates, highest number of pods per plant (39.86) and seeds per plant (90.9) was recorded in seed rate 50 kg ha $^{-1}$. While, lowest number of pods per plant(34.35) and seeds per plant (77.4) was noted in seed rate of 70 kg ha $^{-1}$. Ohyama *et al.* (2013)reported that soybean productivity mainly depends on podsand seedsper plant. The decreasing trend of pods and seeds number per plant with increasing seed rate could be attributed to the competition existing between the populated crops for water, nutrients and light. The results are in resemblance with Bahr (2007) in chickpea and Begum *et al.* (2009) in mung bean.

The sowing method and seed rate significantly influenced the per plant yield of soybean (Table 1).Raised bed method of sowing (14.07 g) recorded highest seed yield per plant as compared to flatbed method (11.42 g). Among the seed rates, highest seed yield per plant was obtained from the seed rate of 50 kg ha $^{-1}$ (15.12 g), while lowest was noted in 70 kg ha $^{-1}$ (13.15 g). Similar results were also reported by Singh and Singh (2010). Lower seed rate led to the increase in the canopy area and greater light interception. These changes in canopy formation increased crop growth rate, dry matter accumulation and ultimately the seed yield (De Bruin and Pedersen, 2008).

Seed yield per ha is the final expression of physiological and metabolic activities of plants. Seed yield per ha differed significantly between the methods of sowing, varieties and seed rates. Significant highest seed yield per ha was recorded in raised bed method (18.32 q). This may be owing to increase yield attributes like number of pods and seeds per plant. These results are in accordance with those of Bahr (2007) in chickpea and Singh (2013) in soybean. Among varieties, highest seed yield per ha was recorded in JS-335 (18.41 q). With respect to seed rates, 50 kg ha^{-1} recorded maximum seed yield per ha (17.05 q) as against the prevailing seed rate of 60 kg ha^{-1} (15.03 q/ha). These findings confirm the results of Kumar and Badiyala (2005) and Prajapati (2018).

Significant differences were noticed in seed germinationin soybean for methods of sowing, varieties and differed seed rates.Raised bed method has recorded highest seed germination (83.41 %) as compared to flatbed method (82.08 %). Among seed rates, 50 kg ha^{-1} recorded highest seed germination (83.18%), while, lowest was noticed in 70 kg ha^{-1} (81.12 %).This might be due to bolder seed size attained by better photosynthates accumulation in the seeds which might be due to nutrient uptake by the plants under raised bed method and sufficient availability of nutrients to plants under optimum plant population. Seed rates as they vary in the plant population are the major sources of variation in seed vigour. Vigour Index-I was noted highest at seed rate 50 kg ha^{-1}(2013) and lowest in seed rate at 70 kg ha^{-1}(1811).Under high plant population, stands compete for limited nutrient, water, light resources and subject to excessive vegetative growth resulting in smaller seeds with low vigour. These results are parallel to Reddy (2006) in groundnut and Kaske *et al.* (2015) in wheat.

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The B: C ratio was numerical more in raised bed method of sowing (1.57) and JS-335 (1.60) variety as compared to flatbed method (1.25) and variety JS-9560 (1.21). The seed rate @ 50 kg ha^{-1}depicted highest B: C ratio (1.50) as compared to 70 kg ha^{-1}. Hence, seed rate of 70 kg /ha could be optimized to 50 kg ha^{-1}in soybean crop.

The interactions also varied significantly among the treatments (Table-2). The interaction S_1T_3 (raised bed method of sowing x seed rate at 50 kg ha^{-1}) recorded maximum number of pods (42.62), seed yield $plant^{-1}$ (15.42 g) seed yield ha^{-1} (19.32 q), seed germination (85.00 %)and Vigour Index-I (2158) which was on par with S_1 T_1(raised bed method of sowing x seed rate at 70 kg ha^{-1}) with seed yield (18.99 q ha^{-1}). While, lowest seed yield was recorded in interaction of flatbed method of sowing with seed rate at 60 kg $ha^{-1}$$S_2$ T_2(13.41 q ha^{-1}). Overall, the interaction of $S_1V_1T_3$ recorded significantly maximum seed yield (21.73 q ha^{-1}) which was statistically on par with $S_1V_1T_1$(21.12q ha^{-1}). Hence the seed yield on soybean could be positively enhanced by adopting raised bed method of planting and the seed rate at 50 kg ha^{-1}.

CONCLUSION

From the present study it can be concluded that the higher seed yield could be obtained from the moderate seed rate and raised bed method of sowing. The raised bed method of sowing and lower seed rate of 50 kg ha^{-1} showed superiority with respect to yield and attributing characters when compared to flatbed method of sowing and seed rate of 70 kg ha^{-1}. Hence there is a possibility of optimizing the yield of soybean by adopting raised bed method of sowingand 50 kg ha^{-1} seed rate.

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Comment [Ma4]: Cite at least five articles of not more than three years from the date of publications.

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Table 1. Influence of sowing methods and seed rates in medium maturing variety JS-335 and early maturing variety JS-9560 for seed yield and quality in soybean

Treatments	Plant population /m^2	Plant height (cm)	Plant canopy diameter (cm^2)	No. of branches/ plant	No. of pods/ plant	No. of seeds/ plant	Seed yield/plant (g)	Seed yield / ha (q)	100 seed weight (g)	Seed germination (%)	Vigour index-I	B :C Ratio
Main plot treatments (Sowing methods) : Two												
S_1	28.54	44.77	22.50	4.80	37.72	86.4	14.07	18.32	15.04	83.41	1994	1: 1.57
S_2	17.41	30.56	20.04	3.10	34.67	72.7	11.42	14.09	14.40	82.08	1903	1: 1.25
Mean	**22.98**	**37.67**	**21.27**	**3.95**	**36.20**	**79.6**	**13.75**	**16.20**	**14.72**	**82.75**	**1948**	
SEm±	**0.58**	**1.65**	**0.34**	**0.20**	**0.68**	**4.81**	**0.61**	**0.18**	**0.23**	**0.17**	**52.3**	
CD(P=0.05)	**1.71**	**4.82**	**0.99**	**0.60**	**2.01**	**13.3**	**1.82**	**0.52**	**NS**	**0.50**	**NS**	
b.Sub plot treatments (Varieties) : Two												
V_1	24.37	39.43	27.33	4.50	36.39	93.0	14.900	18.41	15.90	84.71	2120	1: 1.60
V_2	17.42	35.90	15.21	3.40	36.00	66.0	12.600	14.00	13.53	80.79	1777	1: 1.21
Mean	**20.90**	**37.67**	**21.27**	**3.95**	**36.20**	**79.5**	**13.75**	**16.20**	**14.72**	**82.75**	**1948**	
SEm±	**0.60**	**2.34**	**0.53**	**0.18**	**1.09**	**1.84**	**0.76**	**0.87**	**0.29**	**0.39**	**51.0**	
CD(P=0.05)	**1.76**	**NS**	**1.54**	**0.52**	**NS**	**5.37**	**2.22**	**2.53**	**0.84**	**1.16**	**148.8**	
c.Sub-sub plot treatments (Seed rate): Three												
T_1	25.12	37.55	19.50	3.50	34.35	77.4	13.15	16.54	14.311	81.12	1811	1: 1.42
T_2	24.12	39.30	20.34	3.70	34.37	80.2	13.97	15.03	14.423	83.94	2022	1:1.30
T_3	19.68	36.15	23.97	4.60	39.86	90.9	15.12	17.05	15.428	83.18	2013	1:1.50
Mean	**22.97**	**37.67**	**21.27**	**3.93**	**36.19**	**79.5**	**13.75**	**16.21**	**14.72**	**82.75**	**1948**	
SEm±	**1.13**	**2.25**	**0.65**	**0.21**	**2.08**	**3.01**	**0.75**	**0.59**	**0.19**	**0.80**	**61.2**	
CD(P=0.05)	**3.31**	**NS**	**1.91**	**0.61**	**NS**	**8.80**	**2.19**	**1.72**	**0.58**	**NS**	**178.5**	

a. Main plot treatments (Sowing methods) : Two

S_1 : Raised bed

S_2 : Flat bed

b.Sub plot treatments (Varieties) : Two

V_1 : JS-335 (Medium duration variety)

V_2 :JS-9560 (Short duration variety)

c.Sub-sub plot treatments (Seed rate): Five

T_1 : Seed rate@ 70 kg per ha

T_2 : Seed rate@ 60 kg per ha

T_3 : Seed rate@ 50 kg per ha

Table 2Interaction effect of sowing method and seed rate on growth and yield of medium maturing soybean variety (V_1) JS-335 and early maturing variety (V_2) JS-9560

Treatments	Plant population /m^2	Plant height (cm)	Plant Canopy diameter (cm)	No. of branches	No. of pods / plant	No. of seeds / plant	Seed yield /plant (g)	Seed yield/ plot (kg)	Seed yield / ha (q)	100 seed weight (g)	Seed germination (%)	Vigour index
S_1 T_1	31.62	44.77	20.27	4.0	35.97	74.8	12.47	1.709	18.99	14.686	81.12	1832
S_1 T_2	28.87	46.17	20.85	4.6	34.57	85.2	14.32	1.498	16.64	15.780	84.12	1993
S_1 T_3	25.12	43.37	26.37	5.7	42.62	99.0	15.42	1.730	19.32	16.469	85.00	2158
S_2 T_1	18.62	30.32	18.72	2.9	32.72	60.0	11.82	1.269	14.10	13.154	81.12	1790
S_2 T_2	19.37	32.42	19.82	2.8	34.17	75.3	13.62	1.207	13.41	13.066	83.75	2051
S_2 T_3	14.25	28.92	21.57	3.4	37.10	82.9	14.82	1.330	14.77	14.387	81.37	1867
Mean	**22.98**	**37.66**	**21.27**	**3.90**	**36.19**	**79.53**	**13.75**	**1.46**	**16.20**	**14.59**	**82.75**	**1948**
SEm±	**1.60**	**3.18**	**0.92**	**0.29**	**2.94**	**4.27**	**1.06**	**0.07**	**0.84**	**0.28**	**1.14**	**86.6**
CD(P=0.05)	**4.68**	**9.28**	**2.70**	**0.87**	**8.57**	**12.46**	**3.11**	**0.21**	**2.45**	**0.82**	**3.33**	**252.6**
$S_1V_1T_1$	33.50	52.80	25.80	4.7	38.45	90.8	13.10	1.902	21.12	15.910	83.25	1992
$S_1V_1T_2$	32.50	53.15	26.65	5.2	37.25	96.7	16.25	1.740	19.33	16.225	87.25	2313
$S_1V_1T_3$	26.50	44.65	33.40	6.7	46.80	119.1	16.95	1.936	21.73	16.310	87.75	2367
V_2 S_1T_1	29.50	36.75	14.75	3.2	33.50	58.8	11.85	1.517	16.86	13.463	79.00	1671
V_2 S_1T_2	25.50	39.20	15.05	3.9	31.90	73.7	12.40	1.256	13.96	13.463	81.00	1672
V_2 S_1T_3	23.75	42.10	19.35	4.8	38.45	79.0	13.90	1.524	16.93	14.850	82.25	1950
V_1 S_2T_1	17.50	29.45	25.60	3.1	29.40	60.4	12.75	1.446	16.07	15.025	81.25	1857
V_1 S_2T_2	22.00	29.05	14.75	3.0	31.45	90.0	14.90	1.395	15.50	15.335	87.00	2265
V_1 S_2T_3	14.50	27.50	26.00	3.9	35.00	101.4	15.45	1.507	16.74	16.628	81.75	1925
V_2 S_2T_1	19.75	31.20	11.85	2.8	36.05	59.7	10.90	1.097	12.13	12.845	81.00	1724
V_2 S_2T_2	16.75	35.80	13.65	2.5	36.90	60.6	12.35	1.018	11.31	12.670	80.50	1836
V_2 S_2T_3	14.00	30.35	16.60	2.9	39.20	64.3	14.20	1.153	12.81	13.925	81.00	1809
Mean	**22.98**	**37.67**	**20.29**	**3.89**	**36.20**	**79.54**	**13.75**	**1.45**	**16.20**	**14.72**	**82.75**	**1948**
SEm±	**2.27**	**4.49**	**1.30**	**0.42**	**4.15**	**6.03**	**1.50**	**0.11**	**1.19**	**0.39**	**1.61**	**122.5**
CD(P=0.05)	**6.63**	**13.13**	**3.82**	**1.23**	**12.13**	**17.62**	**4.39**	**0.32**	**3.47**	**1.16**	**4.72**	**357.4**
CV(%)	**15.7**	**18.9**	**12.3**	**18.5**	**20.9**	**15.2**	**18.9**	**14.4**	**14.7**	**5.40**	**3.9**	**12.6**