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DD Chavhan
Department of Agronomy, College of Agriculture, Dr. P.D.K.V., Nagpur, Maharashtra, India

SM Navlakhe
Department of Agronomy, College of Agriculture, Dr. P.D.K.V., Nagpur, Maharashtra, India

VS Khawale
Department of Agronomy, College of Agriculture, Dr. P.D.K.V., Nagpur, Maharashtra, India

ST Dangore
Department of Agronomy, College of Agriculture, Dr. P.D.K.V., Nagpur, Maharashtra, India

RB Kothikar
Department of Agronomy, College of Agriculture, Dr. P.D.K.V., Nagpur, Maharashtra, India

Corresponding Author:
DD Chavhan
Department of Agronomy, College of Agriculture, Dr. P.D.K.V., Nagpur, Maharashtra, India

Effect of methods of sowing and spacing on growth and yield of soybean (*Glycine max* L.)

DD Chavhan, SM Navlakhe, VS Khawale, ST Dangore and RB Kothikar

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Abstract
A field experiment entitled "Effect of methods of sowing and spacing on growth and yield of soybean (*Glycine max* L.)" was conducted at Agronomy Farm, College of Agriculture, Nagpur, during *kharif* season of 2021-22 in Factorial Randomized Block Design (FRBD) with eight treatments and three replications. Treatment combinations were comprised of two sowing methods viz., ridges and furrow and broad bed furrow and four treatments of spacing viz., 45 cm x 5 cm, 45 cm x 10 cm, 45 cm x 15 cm and 45 cm x 20 cm. Results revealed that, growth and yield attributes *viz.*, plant height, number of branches plant^{-1}, number of root nodules plant^{-1}, number of days to 50 % flowering, dry matter production plant^{-1}, number of pods plant^{-1}, weight of grains plant^{-1} and straw yield plant^{-1}, seed and straw yield (q ha^{-1}) were significantly higher due to methods of sowing on broad bed furrow. As regards spacing, growth and yield attributes viz., plant height, number of branches plant^{-1}, number of root nodules plant^{-1}, dry matter production plant^{-1}, number of pods plant^{-1}, weight of grains plant^{-1} and straw yield plant^{-1} were significantly higher at spacing 45 cm x 20 cm. However seed and straw yield (q ha^{-1}), gross monetary returns, net monetary returns (Rs. ha^{-1}), protein and oil yield (kg ha^{-1}) were significantly maximum at spacing 45 cm x 5 cm whereas, interaction between methods of sowing and spacing were found non-significant.

Keywords: Sowing, spacing, growth, yield, soybean

Introduction
Among the pulses grown in India and Maharashtra, soybean is important pulse growing crop. Soybean (*Glycine max* L.) is most important legume crop belonging to the family leguminosae, subfamily Papilionaceae and genus *glycine*. Soybean was cultivated in China from 3000 B.C. It has witnessed phenomenal growth in production, processing and trade from last few years and has revolutionized the rural economy and improved socio-economic status of the farmers. It is one of the important oilseed crop, commonly used as pulse, oilseed, vegetarian meat and soya milk and has been rightly known as "Wonder crop" or "Golden Bean" of the 21st century. It is a reach source of protein (40 to 42%) and oil (20%). It also contains 30% carbohydrates, 5% minerals, 4-5% crude fibers, 0.5% lecithins and 4% saponin. Nutritionally soybean is a good source of vitamin and amino acid (lysine, glycine and tryptophan). It is also a good source of isoflavones and therefore it helps in preventing heart diseases and cancer (Anusha *et al*. 2021) [3]. Due to multiple use of soybean is also known as wonder crop. In Maharashtra, Vidarbha region has attained the highest production of crop, as the average rainfall ranges between 800 to 1000 mm, also black cotton soil of the region is more suitable for the production. In the year 2019-2020, the total production of soybean in Vidarbha was 48.25 lakh tones and area sown was 41.24 lakh ha. indicating the productivity 853 kg ha^{-1}. Sowing is an art of placing the seeds in soil to have good germination in the field. There are different methods of sowing adopted for soybean such as drilling, dibbling, ridge and furrow and broad bed furrow (BBF). Among these, ridges and furrow and broad bed furrow (BBF) method are adopted to conserve soil moisture and increase seed yield (Kinge *et al*. 2020) [11]. Ridges and furrow comprise ridges and furrows to sow the seeds and store the water respectively and broad bed furrow (BBF) is another method of sowing, newly adopted technology consist of 3-4 rows of crop on bed and furrows for water conservation. Both methods are adopted to increase the growth and yield of crop than normal sowing methods. Spacing is the distance between two rows and two plants. It is an important factor for any crop production because it determines the initial and final plant

population in field, provide proper aeration in crop canopy and reduce competition for nutrient, sunlight and moisture which may be optimized by suitable plant density enhancing the growth and yield of crop. (Kumar *et al*. 2018) [12].

Materials and Methods

The present field experiment entitled "Effect of sowing methods and spacing on growth and yield of soybean (*Glycine max* L.)" was carried out during *kharif* season 2021-22. The experiment was laid out in FRBD with two levels of sowing methods as one factor and four levels of spacing as another factor with eight treatment combination replicated three times. Seeds were obtained from Head, Regional Research Centre, Amravati of Dr. P.D.K.V., Akola. Soybean variety of AMS-100-39 (PDKV Amba) used for experiment. The seed of soybean variety AMS-100-39 was treated with thiram @ 3 g kg-1 of seed and inoculated with *rhizobium* before sowing in order to keep the crop from seed born diseases. Seed rate of soybean was used as per recommended. Sowing of seed as per treatment was done on 28th June 2021 at an optimum soil moisture level. Appropriate and timely plant protection measures for control of leaf eating caterpillar were followed. Before harvesting the crop from each net plots, five plants from each plot were taken for recording post harvest observation. Then net plot rows were harvested, winnowed and cleaned separately plot wise. The produce was sun dried and weight was recorded. Yield ha^{-1} was calculated. Standard method of analysis of variance was used for analyzing the data for FRBD design (Panse and Sukhatme, 1967) [14]. The "F" test of significance was used for testing the null hypothesis and a standard error of mean in order to determine whether the result of treatment real and discernible from chance effects and where the treatment effects were found to be significant, the critical difference (C.D.) at 5 percent probability level was calculated for comparison of treatments.

Results and Discussion (Table 1)

Growth attributes

Plant height (cm)

Effect of sowing methods

The data revealed that, there were significant differences in plant height at different growth stages except at 30 DAS due to different sowing methods. Significantly maximum plant height (46.94 cm, 52.20 cm and 53.77 cm) of soybean was noticed under sowing of soybean on broad bed furrow at different growth stages (60, 90 DAS and harvest) respectively than ridges and furrow (46.37 cm, 51.71 cm and 53.05 cm) at 60, 90 DAS and harvest respectively. The increase in plant height of soybean due to sowing method might be due to effect of favorable seed bed, soil moisture, soil aeration and better availability of sunlight on broad bed furrow. It is directly related with cell division, enlargement and elongation, vigorous root growth and formation of chlorophyll resulting in higher photosynthesis which might have resulted to higher plant height. Kinge *et al*. (2020) [11] also reported a similar result which supports the present findings that maximum plant height was observed when soybean planted on broad bed furrow.

Effect of spacing

The differences in plant height were significantly influenced by different spacings at various growth stages except at 30 DAS of soybean. The plant height of soybean was recorded significantly highest (48.15 cm, 53.22 cm and 54.70 cm) at 60 DAS, 90 DAS and harvest, respectively at spacing of 45 cm x 5 cm as compared to other spacings. However, it was at par with spacing of 45 cm x 10 cm (47.56 cm, 52.77 cm and 54.39 cm) at 60 DAS, 90 DAS and at harvest, respectively. Lowest plant height (24.16 cm, 44.89 cm, 50.40 cm and 51.40 cm) was observed at 30 DAS, 60 DAS, 90 DAS and at harvest, respectively with spacing of 45 cm x 20 cm. The increase in plant height due to spacing might be due to the fact that in early growth stages of the crop, when the plant are small, much of the light is not intercepted by the leaves and thus at this stage, narrow spacing provides better utilization of light which may resulted in increased plant height mainly because of increased competition within plants in closer row spacing. These results are in close accordance with the findings of Rahman *et al.* (2013) [16] and Aastha and Singh (2016) [1] also reported that maximum plant height was observed when soybean grown with narrow spacing.

Plant height of soybean was found to be non-significant at all growth stages due to interaction with sowing methods and spacing.

Number of branches $plant^{-1}$

Effect of sowing methods

Data revealed that there were significant differences in plant height by different sowing methods at various growth stages except at 30 DAS. Significantly highest number of branches $plant^{-1}$ (4.05, 5.13 and 5.13 branches) were found under sowing of soybean on broad bed furrow at different growth stages (60 DAS, 90 DAS and at harvest) respectively than ridges and furrows (3.74, 4.78 and 4.78 branches) at 60 DAS and 90 DAS and at harvest, respectively. As number of branches of soybean increased under sowing of soybean on broad bed furrow due to more plant height, space available for side rows, maximum availability of sunlight, and continuous moisture conservation in furrow indicates into maximum number of branches $plant^{-1}$. The above results are in conformity with the results were also reported by Kadam *et al*. (2020) [9] and Kinge *et al*. (2020) [11].

Effect of spacing

The number of branches $plant^{-1}$ was significantly influenced by different spacing at various growth stages of soybean except spacing at 30 DAS. The number of branches $plant^{-1}$ in soybean significantly highest (4.35, 5.72 and 5.72 branches) at 60 DAS, 90 DAS and at harvest respectively at spacing of 45 cm x 20 cm as compared to other spacing. However, it was at par with the spacing of 45 cm x 15 cm (3.99, 5.49 and 5.49 branches) at 60 DAS, 90 DAS and at harvest, respectively and lowest number of branches $plant^{-1}$ (2.38, 3.46, 4.05 and 4.05 branches) were found at 30 DAS, 60 DAS, 90 DAS and at harvest, respectively at spacing 45 cm x 5 cm. This might be due to wider row spacing gave sufficient space, moisture and sufficient availability of sunlight which resulted into good number of branches in soybean. Similar findings are also reported by Keisham *et al.* (2021) [10] and Patel *et al.* (2022) [15] that support the present findings.

The numbers of branches $plant^{-1}$ of soybean were found to be non- significant at all growth stages due to interaction with sowing methods and spacing.

Number of nodules plant^{-1}

Effect of sowing methods

Data presented in Table 12 shows that the number of root nodules plant^{-1} significantly influenced by different sowing methods at various growth stages except at 20 DAS. Significantly maximum number of root nodules (18.38 and 24.57 root nodules) were observed under sowing of soybean on broad bed furrow at different growth stages (40 DAS and 60 DAS) respectively than ridges and furrow (17.82 and 24.06 root nodules) at 60 DAS and 90 DAS) respectively. The overall better growth and development with support of conserved soil moisture and good soil aeration on broad bed furrow resulted into maximum number of root nodules in soybean. The above result are correlated with finding of Gupta *et al*. (2017) [7] and Dhale *et al*. (2021) [6].

Effect of spacing

Data revealed that the number of root nodules plant^{-1} was significantly affected by adopting different spacings in soybean whereas at 20 DAS the results were non-significant. The number of root nodules plant^{-1} was found significantly higher (19.06 and 25.45 root nodules) at growth stages of 40 DAS and 60 DAS respectively at spacing of 45 cm x 20 cm as compared to other spacing. However, it was at par with the spacing of 45 cm x 15 cm (17.71 and 24.04 root nodules) at 40 DAS and 60 DAS respectively and lowest root nodules (10.11, 17.26 and 22.55 root nodules) were observed at 20 DAS, 40 DAS and 60 DAS respectively. It might be the result of maximum root nodulation in soybean at wider spacing due to less competitive stress of various nutrients as well as space congestion among plant at wider spacing which enhanced the root development and good soil aeration. These results are in close conformity with finding of Lone *et al*. (2009) [13] Keisham *et al*. (2021) [10].

The number of root nodules plant^{-1} of soybean was found to be non- significant at all growth stages due to interaction with sowing methods and spacing.

Dry matter production plant^{-1} (g)

Effect of sowing methods

The dry matter accumulation plant^{-1} was significantly influenced by different sowing methods at various growth stages in soybean except at 30 DAS. There were significantly highest dry matter production plant^{-1} (14.04 g, 26.31 g and 30.00 g) recorded under sowing of soybean on broad bed furrow at different growth stages (60 DAS, 90 DAS and at harvest) respectively than ridges and furrow (4.82 13.74 g, 27.73 g and 29.54 g) respectively. This might be due to luxurious growth and higher growth attributes noticed under the sowing of soybean on broad bed furrow than ridges and furrow and thus overall growth resulted into higher dry matter production in BBF planted soybean. Similar results were reported by Kadam *et al*. (2020) [9].

Effect of spacing

The dry matter production plant^{-1} was significantly influenced by different spacings in soybean except at 30 DAS. The significantly higher dry matter production plant^{-1} (14.51 g, 27.02 g and 30.99 g) at various growth stages (60 DAS, 90 DAS and at harvest) respectively, at spacing of 45 cm x 20 cm as compared to other spacing. However, it was found at par with spacing 45 cm x 15 cm (14.41 g, 26.55 g and 30.55 g) at 60 DAS, 90 DAS and at harvest respectively while lowest dry matter production plant^{-1} (4.84 g, 13.05 g, 24.88 g and 28.18 g) was recorded at 30 DAS, 60 DAS, 90 DAS and at harvest respectively. The dry matter production plant^{-1} increased at spacing 45 cm x 20 due to wider row spacing might be attributed to the maximum plant growth and number of branches plant^{-1} which might be due optimum utilization of space for interception of sunlight and moisture. Similarly, Keisham *et al*. (2021) [10] reported that maximum dry matter production plant^{-1} was observed at wider spacing in soybean.

The dry matter production plant^{-1} of soybean was found to be non-significant due to interaction with sowing methods and spacing.

Yield attributes

Number of pods plant^{-1}

Effect of sowing methods

The number of pods plant^{-1} was significantly influenced by different sowing methods. The number pods plant^{-1} (51.29 pods) was recorded significantly higher under sowing of soybean on broad bed furrow than sowing on ridges and furrow (50.84 pods). This might be due to maximum overall growth adding in better yield attributing characters due to favorable seed bed, good soil aeration, more space between plant, sufficient availability of sunlight and more moisture conserved in furrow and it support at critical growth stages like flowering, pod formation which resulted into higher number of pods plant^{-1} under sowing of soybean on broad bed furrow. These findings are in close accordance with Dhale *et al*. (2021) [6].

Effect of spacing

The number of pods plant^{-1} was significantly influenced due to different spacings in soybean. The number of pods plant (52.10 pods) was significantly highest at spacing of 45 cm x 20 cm as compared to other spacing. However, it was found at par with the spacing of 45 cm x 15 cm (51.67 pods) whereas lowest pods (49.98) at spacing of 45 cm x 5 cm. This was might be due to less competition, good vegetative growth, sufficient availability of sunlight and moisture availability for better reproductive growth and better source sink relationship at wider spacing which resulted into maximum number of pods plant^{-1}. Similar observations are noted by Kumar *et al*. (2018) [12].

The number of pods plant^{-1} of soybean was found to be non-significant at harvest due to interaction with sowing methods and spacing.

Weight of grains plant^{-1} (g)

Effect of sowing methods

The weight of grains plant^{-1} was significantly influenced due to different sowing methods at harvest in soybean. The planting of soybean on broad bed furrow gave significantly highest weight of grains plant^{-1} (16.75 g) over the sowing of soybean on ridges and furrow (15.90 g). Increase in the weight of grains plant^{-1} under sowing of soybean on broad bed furrow might be resulted due to higher number of branches, pods and root nodules plant^{-1}, good soil aeration and bold size of seed due to synthesis and translocation of food material. These results are in conformity with the results of Jadhav *et al*. (2012) [8].

Effect of spacing

The weight of grains plant^{-1} was significantly influenced due to different spacings in soybean. The weights of grains plant^{-1} (17.30 g) were significantly highest at spacing of 45 cm x 20 cm as compared to other spacing. However, it was at par with the spacing of 45 cm x 15 cm (16.79 g) while lowest weight of grains plant^{-1} (15.09 g) was observed at the spacing of 45 cm x 5 cm. This was might be due to maximum number of pods plant^{-1} and less competition between plants for nutrient, soil moisture, space and solar radiation in wider spacing than closer spacing of soybean. These results lend support to those reported by Ali *et al*. (1999) [2].

The weight of grains plant^{-1} of soybean was found to be non-significant at harvest due to interaction with sowing methods and spacing.

Straw yield plant^{-1} (g)

Effect of sowing methods

The straw yield plant^{-1} was significantly influenced due to different sowing methods at harvest of soybean. The planting of soybean on broad bed furrow gave significantly highest straw yield plant^{-1} (22.55 g) over the sowing of soybean on ridges and furrow (21.54 g). This might be due overall cumulative effect good vegetative growth that influencing the better growth attributing characters (plant height, number of branches plant^{-1} and dry matter production plant^{-1}) under sowing of soybean on broad bed furrow due to less competition for nutrients, moisture and sunlight resulted into significant straw yield plant^{-1} in soybean on broad bed furrow. Singh *et al*. (2011) [17] also found similar results which support present findings.

Effect of spacing

The straw yield plant^{-1} was significantly influenced due to different spacing in soybean. The straw yield plant^{-1} (23.27 g) was significantly highest at spacing of 45 cm x 20 cm as compared to other spacings. However, it was at par with the spacing of 45 cm x 15 cm (22.68 g) and lowest straw yield plant^{-1} (20.53 g) was recorded at spacing of 45 cm x 5 cm. This was might be due to overall vegetative growth and their performance at wider spacing better than narrow spacing in soybean. The results of Choudhary *et al.* (2015) [5] also confirming the present findings.

The straw yield plant^{-1} of soybean was found to be non-significant at harvest due to interaction with sowing methods and spacing.

Test weight (g)

Effect of sowing methods

The test weight of soybean was not significantly influenced by different sowing methods.

Effect of spacing

The test weight of soybean at harvest was non-significant by different spacings.

The test weight plant^{-1} of soybean at harvest was found to be non-significant due to interaction with sowing methods and spacing.

Seed yield (q ha^{-1})

The seed yield (q ha^{-1}) of soybean was significantly influenced due to different sowing methods. The sowing of soybean on broad bed furrow gave significantly highest seed yield (20.38 q ha^{-1}) over the sowing of soybean on ridges and furrow (18.81 q ha^{-1}). This might be due to efficient utilization of moisture and nutrients under sowing of soybean on broad bed furrow favorably enhanced the growth attributes (number of branches and nodules plant^{-1}, etc.) and yield attributes (number of pods plant^{-1} and weight of grains plant^{-1}) which resulted into increase in total seed yield (q ha^{-1}) under sowing of soybean on broad bed furrow. Asewar *et al*. (2017) [4] and Swapna *et al*. (2020) [18] also reported similar results who recorded highest yield of crop with BBF.

Effect of spacing

The seed yield (q ha^{-1}) was significantly influenced due to different spacings at harvest of soybean. Seed yield (21.84 q ha^{-1}) was registered significantly highest at spacing of 45 cm x 5 cm as compared to other spacings. However, it was at par with the spacing of 45 cm x 10 cm (20.01 q ha^{-1}) and lowest seed yield (17.53 q ha^{-1}) was recorded at the spacing of 45 cm x 20 cm. This might be due to at narrow spacing higher plant population per unit area resulted into highest seed yield (q ha^{-1}) but all yield attributes (number of pods plant^{-1}, weight of grains plant^{-1} etc.) showed higher yield at wider spacing. Similar results were recorded by Kumar *et al*. (2018) [12] who reported more seed yield due to narrow spacing.

The seed yield (q ha^{-1}) of soybean was found to be non-significant due to interaction with sowing methods and spacing.

Straw yield (q ha^{-1})

Effect of sowing methods

The straw yield (q ha^{-1}) of soybean was significantly influenced by different sowing methods at harvest. The sowing of soybean on broad bed furrow gave significantly highest straw yield (27.11 q ha^{-1}) over the sowing of soybean on ridges and furrow (25.07 q ha^{-1}). This might be due to enhanced vegetative growth (plant height, number of branches plant^{-1} and dry matter production plant^{-1} etc.) as resulted into highest straw yield (q ha^{-1}) on broad bed furrow due to better soil aeration, scope for more space, light interception and benefit for more moisture conserved on broad bed furrow than other sowing methods. Similarly, these results were correlated with Kinge *et al.* (2020) [11] who also reported higher straw yield due to sowing on broad bed furrows.

Effect of spacing

The straw yield (q ha^{-1}) was significantly influenced due to different spacings at harvest of soybean. Straw yields (28.82 q ha^{-1}) were found significantly highest at the spacing of 45 cm x 5 cm as compared to other spacing. However, it was at par with the spacing of 45 cm x 10 cm (26.56 q ha^{-1}) and lowest straw yield (23.62 q ha^{-1}) at the spacing of 45 cm x 20 cm. This might be due to at narrow spacing obtained higher plant population per unit area which resulted into highest straw yield (q ha^{-1}) but straw yield plant^{-1} was recorded more at wider spacing. Similar findings were also noticed by Ali *et al*. (1999) [2] and Rahman *et al*. (2013) [16].

The straw yield of soybean (q ha^{-1}) was found to be non-significant due to interaction with sowing methods and spacing.

Table 1: Effect of methods of sowing and spacing on growth and yield of soybean.

	Treatments	Plant height (cm)	Number of branches plant^{-1}	Number of nodules plant^{-1} at 60 DAS	Dry matter production plant^{-1} (g)	Number of pods plant^{-1}	Weight of grains plant^{-1} (g)	Straw yield plant^{-1} (g)	Test weight (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})
Factor A- Method of sowing											
M_1	Ridges and furrows	53.05	4.78	24.06	29.54	50.84	15.90	21.54	11.50	18.81	25.08
M_2	Broad bed furrows	53.77	5.13	24.57	30.00	51.29	16.75	22.55	11.52	20.38	27.11
SE (m) ±		0.19	0.12	0.14	0.11	0.13	0.28	0.23	1.45	0.51	0.62
CD at 5%		0.57	0.36	0.44	0.35	0.39	0.83	0.69	NS	1.54	1.87
Factor B-Spacing											
S_1	45 cm × 5 cm	54.70	4.05	22.55	28.18	49.98	15.09	20.53	11.45	21.84	28.82
S_2	45 cm × 10 cm	54.39	4.56	24.04	29.34	50.53	16.11	21.69	11.49	20.01	26.56
S_3	45 cm × 15 cm	53.10	5.49	25.25	30.55	51.67	16.79	22.68	11.54	19.02	25.37
S_4	45 cm × 20 cm	51.40	5.72	25.45	30.99	52.10	17.30	23.27	11.58	17.53	23.62
SE (m) ±		0.27	0.16	0.20	0.16	0.18	0.39	0.32	2.05	0.72	0.87
CD at 5%		0.81	0.50	0.62	0.49	0.55	1.18	0.97	NS	2.17	2.65
C. Interaction (A×B)											
SE (m) ±		0.38	0.23	0.29	0.23	0.26	0.55	0.45	2.90	1.01	1.23
CD at 5%		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
General mean		53.39	4.95	24.32	29.77	51.07	16.32	22.04	11.51	19.60	26.09

Conclusion

In Conclusion, the study examined the impact of different sowing methods and spacing on various growth and yield attributes of soybean. Significant variations were observed in plant height, number of branches, number of nodules, dry matter production, number of pods plant^{-1}, weight of grains plant^{-1}, straw yield, and seed yield among different treatments. Sowing soybean on broad bed furrow consistently showed superior results across several parameters compared to ridges and furrow, attributed to better soil moisture retention, soil aeration, and sunlight availability. Similarly, narrower spacing generally resulted in higher early growth attributes due to reduced inter-plant competition. These findings underscore the importance of optimizing planting methods and spacing to maximize soybean yield and quality. Further research could focus on integrating these practices with other agronomic techniques to enhance overall crop productivity sustainably.

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