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Effect of sowing dates and plant densities on growth and yield of soybean (*Glycine max* L.)

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Abstract
A field experiment was conducted during the *Kharif* season of 2020 at the Krishi Vigyan Kendra (KVK), Yagantipalli (Village), Kurnool (District) (A.P.). The soil of the experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.48%), available N (171 kg/ha), available P (13.60 kg/ha), and available K (215.4 kg/ha). The experiment was laid out in Randomized Block Design with 9 treatments and replicated thrice. The results revealed that the steady increase in growth attributes of Soybean *viz*., plant height (69.88 cm), plant dry weight (23.67 g) was observed significantly highest with sowing date July 1st fortnight and spacing with 30 x 10 cm, highest leaf area index (5.09) maximum highest number of pods per plant (30.73), number of seeds/pod (2.97), seed index (8.58 g), highest shelling percent (78.27%), grain yield (2.43 t/ha) and haulm yield (3.96 t/ha) as compared to other treatments.

Keywords: Fortnight, growth, plant densities, soybean, yield

Introduction
Soybean [*Glycine max* (L.) Merrill] is known as leguminous crop and belongs to the family leguminaceae. It has an Eastern Asian origin. Soybean is an important legume as well as oilseed crop and an excellent source of high-quality protein and oil. Soybean ranks third among the oilseed crops grown in India after groundnut and rapeseed-mustard. Soybean accounts for 54 percent of global oilseed production. India ranks fifth in the world in the area and production of soybean after the United States of America. Brazil, Argentina, and China. In India, soybean is cultivated in about 12 M. ha with a production of 12 mt and average productivity of 1079 kg ha^{-1} (SOPA, 2013). Soybean is an excellent health food and contains 40% quality protein, 23% carbohydrates, and 20% cholesterol-free oil. Soybean protein is rich in valuable amino acid, lysine (5%) which is deficient in most cereals. It also contains 60% polyunsaturated fatty acid (52.8% linolenic acid + 7.2% linoleic acid).

Planting density is an important determinant of seed yield and it plays an important role in modulating the environmental factors related to the growth and development of the crop. The planting geometry and plant population have not yet been established for a *Kharif* seed crops and newly released cultivars with their seed size or test weight. Planting soybean in rows ensures easy intercultural operations and helps to attain in higher yield. The row spacing recommended for soybean in the *Kharif* season is 40 cm (Basol T.L. (2013) [3] and it is 45 cm and 30 cm for regular *Kharif* season crop in Maharashtra. However, the relevant research finding in this line for different cultivars is highly scarce. More scientific efforts are needed to increase the productivity of soybean per unit area, and per unit time with optimum row spacing. It is necessary to maintain an optimum plant population to get high productivity. Therefore, it is necessary to study the behavior of soybean cultivars under various row spacing. The effect of different row spacing on yield performance of soybean cultivars might help to determine variety-specific row spacing to obtain high yield.

Sowing date is an important factor affecting soybean growth, development, seed yield, and quality. Fine-tune management of soybean by sowing date is a good approach to improve growth and development and to enhance the yield potential with good quality seed. Sowing date is the most important and least expensive cultural consideration that impacts soybean seed yield and quality. The optimum time of sowing enables favorable environmental conditions for growth and seed yield. In India, the average yield of soybean is less than the world average yield, mainly due to non-availability of quality seed, use of low yield potential varieties, poor agronomic practices, poor seed storability besides the optimum time of sowing. Among the agronomic practices, sowing date has a remarkable influence on soybean yield.

However, the effect of sowing dates on soybean grain yield depends on genetic and environmental conditions (Egli and Cornelius, 2009) [6]. Environmental factors like extremely high temperature and moisture stress, which are often associated with delayed planting, have a negative effect on plant development and yield. Being a facultative photoperiod sensitive crop, it's development and grain yield are influenced by day length and temperature (Egli and Bruening, 2000) [5]. Sowing date is found to affect seed germination (Andric *et al*., 2007) [2], vegetative and reproductive performance (Bastidas *et al*., 2008) [4], and hence leading to a reduction in grain yield (Egli and Cornelius, 2009) [6]. Generally, the combined effect of photoperiod, temperature, and precipitation with delayed planting, most likely contributes to decreased duration of vegetative and reproductive growth stages, reduced photosynthesis, and plant growth and therefore significant reduction in grain yield of soybean.

Materials and Methods

The present investigation was undertaken at Research Farm, Krishi Vigyan Kendra, Yagantipalli, Kurnool District, Andhra Pradesh, during *Kharif* 2020 which is located at 15° 32' 79" N latitude, 78° 18' 71" E longitude, and 273m altitude above the mean sea level (MSL). The soil of the experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.2), low in organic carbon (0.48%), available N (171.48 kg/ha), available P (13.6 kg/ha), and available K (215.4 kg/ha). The treatments consist of three different dates of sowing and random spacing. The experiment was laid out in Randomized Block Design with nine treatments each replicated thrice. The treatments were T_1: July 1st fortnight + 30x 10 cm; T_2: July 1st fortnight + 40 x 10 cm; T_3: July 1st fortnight + 50 x 10 cm; T_4: July 2nd fortnight + 30x 10 cm; T_5: July 2nd fortnight + 40 x 10 cm; T_6: July 2nd fortnight + 50 x 10 cm; T_7: August 1st fortnight + 30x 10 cm; T_8: August 1st fortnight + 40 x 10 cm; T_9: August 1stfortnight + 50 x 10 cm; The recommended dose of inorganic fertilizer (RDF) was 30 kg N + 40 kg P_2O_5 + 60 kg K_2O per ha and the sources were Urea, Diammonium Phosphate and muriate of potash respectively.

Statistical analysis

The data recorded where different characteristics were subjected to statistical analysis by adopting Fishers the method of analysis of variance (ANOVA) as described by Gomez and Gomez (2010). Critical difference (CD) values were calculated the 'F' test was found significant at a 5% level.

Results and Discussion

Growth Attributes

Plant height: Plant spacing differed significantly in respect of plant height. At harvest treatment T_1 with sowing date July 1st fortnight and spacing with 30 x 10 cm was shown significantly highest plant height (69.88 cm) as compared to other treatments, whereas treatment with sowing date July 1st fortnight and spacing with 40 x 10 was at par with date July 1st fortnight and spacing with 30 x 10 cm. Plant spacing 30 x 10 cm recorded maximum height followed by 45 x 10 cm. This might be due to row to row and plant to plant distance effect. Were observed a significant difference in plant height. In general plant height of soybean was directly proposed to the plant spacing. Observed that increase in plant height was observed with increased plant population. Abbas *et al*. (1994) [1].

Plant dry weight: At harvest treatment T_1 with sowing date July 1st fortnight and spacing with 30 x 10 cm was shown significantly highest plant dry weight (23.67 g) as compared to other treatments, whereas treatment with sowing date July 1st fortnight and spacing with 40 x 10 cm, treatment with sowing date July 2nd fortnight and spacing with 30 x 10 cm and were at par with date July 1st fortnight and spacing with 30 x 10 cm and treatment with sowing date July 2nd fortnight and spacing with 40 x 10 cm. Total dry matter accumulation was maximum in plant spacing 30 x 30 cm followed by 45 x 10 cm. This might be due to a higher number of leaves and larger leaf area resulted in more photosynthetic activities and more accumulation of carbohydrates and thereby increase in dry matter production and soybean crop fix atmospheric nitrogen that's why the plant growth was better than cereals crop. Prasad *et al*. (1993) [10] observed similar results.

Leaf Area Index (LAI)

The date of sowing significantly influenced the leaf area index. At harvest treatment T_7 with sowing date, August 1st fortnight and spacing with 30 x 10 cm was shown highest leaf area index (5.09) as compared to other treatments and other treatments were at par with date August 1st fortnight and spacing with 30 x 10 cm. Sowing in 1st fortnight of July recorded significantly higher leaf area index. This reduction of leaf area and LAI at growth stages might be due to inhibition of leaf area development and accelerated senescence of lower leaves of the plant. The difference in leaf area could be attributed to the difference in heat units (average temperature) between sowing dates. Significant reduction in leaf area among all cultivars of soybean when sowing was delayed beyond mid-June. This could be attributed to changes in plant architecture like lesser branching, lower number of leaves, and lesser plant height in the late sown crop. These changes resulted in smaller plants with lower leaf area and leaf area index (Pedersen and Lauer, 2003) [11]. Due to the higher number of leaves and all growth parameters increased with the increase of plant density up to a certain density and then declined. A Similar result was observed by Rahman and Hossain (2011) [12].

Yield attributes and yield: The seed yield, straw yield, and harvest index (%) were maximum in plant spacing of 30 x 10 cm as compared to other spacing due to more number of plants or higher plant density in closer spacing as compared to wider spacing. A Significant reduction in seed yield was observed when the sowing date was delayed from July to August. Lower seed yield was recorded in August's first fortnight sowing and this might be due to a shortened vegetative growth period. These results are in accordance with the findings of Khan *et al*. (2004) [5] who reported that early sowing of soybean produced significantly highest seed yield than delayed sowing. They further mentioned that higher yields of earlier sowings were ascribed to photoperiod response which lengthened both vegetative and reproductive stages, enabling the crop to produce more dry matter which was efficiently utilized by a prolonged pod filling period after flowering resulting in a higher seed yield. Sadegi and Niyaki (2013) [13] observed a steady decrease in soybean seed yield when sowing was delayed due to lack of sufficient vegetative growth, lower number of pods per plant, and reduced seed weight. Reduction in seed yield with delayed sowing was also confirmed and reported by Karaaslan *et al*. (2012) [7]; Nabi *et al*. (2012) [9].

Economics: Maximum Net returns (70060.8 INR /ha) and B: C ratio (2.07) were obtained with sowing date July 1st fortnight and spacing with 30 x 10 cm which was significantly superior over the rest of the treatments.

Table 1: Effect of sowing dates and plant densities on Growth Attributes of soybean

Treatments	Plant height (cm)					Plant dry weight (g/plant)					Leaf Area Index (LAI)				
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest	20 DAS	40 DAS	60 DAS	80 DAS	At harvest	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
14th July 2020 + 30 x 10cm	8.31	33.08	54.34	64.44	69.88	1.20	4.27	13.05	19.54	23.67	0.094	0.331	1.71	5.22	4.64
14th July 2020 + 40 x 10 cm	8.11	26.39	49.25	62.69	67.79	1.55	4.08	12.46	18.76	22.89	0.093	0.407	2.36	7.15	4.36
14th July 2020 + 50 x 10 cm	7.91	28.67	46.33	57.65	62.72	1.31	3.61	10.84	17.14	21.27	0.087	0.507	2.65	7.97	4.55
28th July 2020 + 30 x 10 cm	8.11	29.37	47.80	59.58	64.82	1.24	3.95	12.39	18.69	22.81	0.073	0.402	1.95	5.81	5.04
28th July 2020 + 40 x 10 cm	8.04	29.13	42.65	59.72	64.98	1.20	3.71	11.13	16.22	22.70	0.096	0.453	2.00	5.95	4.73
28th July 2020 + 50 x 10 cm	8.24	31.29	46.67	58.78	63.96	1.44	3.66	10.98	17.28	21.41	0.046	0.438	2.33	7.15	4.76
15th August 2020 + 30 x 10 cm	8.24	28.35	47.04	58.99	64.18	1.07	3.74	11.22	16.36	20.12	0.065	0.321	1.63	4.85	5.09
15th August 2020 + 40 x 10 cm	8.03	28.35	41.63	57.75	62.83	1.47	3.81	11.44	17.74	21.87	0.038	0.240	1.31	3.98	4.61
15th August 2020 + 50 x 10 cm	8.17	28.51	43.30	59.33	64.55	1.22	3.86	11.59	16.26	19.28	0.049	0.261	1.21	3.69	4.31
S.Em (±)	0.23	1.20	2.23	1.33	1.25	0.11	0.11	0.32	0.42	0.34	0.005	0.032	0.16	0.42	0.42
CD (0.05%)	-	-	6.65	3.98	3.74	-	0.34	0.96	1.26	1.02	0.016	0.095	0.48	1.26	-

Table 2: Effect of sowing dates and plant densities on Yield Attributes and Yield of soybean

Treatments	No. of pods/plant	No. of seeds/pod	Seed index (g)	Shelling (%)	Grain yield (t/ha)	Haulm yield (t/ha)	Harvest index (%)
14th July 2020 + 30 x 10cm	30.73	2.97	8.58	78.27	2.40	3.97	37.74
14th July 2020 + 40 x 10 cm	30.31	2.93	8.37	76.29	2.26	3.71	37.94
14th July 2020 + 50 x 10 cm	27.14	2.69	8.33	73.75	1.98	3.42	36.63
28th July 2020 + 30 x 10 cm	28.46	2.79	8.23	76.51	2.31	3.77	37.99
28th July 2020 + 40 x 10 cm	26.68	2.66	8.52	74.70	2.05	3.49	37.06
28th July 2020 + 50 x 10 cm	24.11	2.46	8.53	72.07	1.97	3.71	34.72
15th August 2020 + 30 x 10 cm	26.49	2.64	8.12	70.16	2.16	3.47	38.34
15th August 2020 + 40 x 10 cm	26.76	2.67	8.19	74.57	2.08	3.21	39.35
15th August 2020 + 50 x 10 cm	26.87	2.67	8.00	70.23	2.05	3.48	37.10
S.Em (±)	0.91	0.06	0.17	1.73	0.75	1.24	1.35
CD (0.05%)	2.71	0.21	0.51	5.15	0.23	0.36	4.02

Table 3: Effect of sowing dates and plant densities on Economics of soybean

Treatments	Cost of cultivation (INR/ha)	Gross returns (INR/ha)	Net returns (INR/ha)	B:C Ratio
14th July 2020 + 30 x 10cm	33885	103946	70060.8	2.07
14th July 2020 + 40 x 10 cm	33705	97753.6	64048.6	1.90
14th July 2020 + 50 x 10 cm	33570	86293.5	52723.5	1.57
28th July 2020 + 30 x 10 cm	33885	99614.1	65729.1	1.94
28th July 2020 + 40 x 10 cm	33705	89099.6	55394.6	1.64
28th July 2020 + 50 x 10 cm	33570	87488.5	53918.5	1.61
15th August 2020 + 30 x 10 cm	33885	92932.9	59047.9	1.74
15th August 2020 + 40 x 10 cm	33705	88716.7	55011.7	1.63
15th August 2020 + 50 x 10 cm	33570	89111.8	55541.8	1.65

Conclusion

It can be concluded that Soybean sown in 1st fortnight of July with a spacing of 30 x 10 cm was recorded significantly higher seed yield (2.43 t/ha), Gross returns (1,03,946 INR/ha), Net returns (70,060.8 INR/ha) and Benefit Cost ratio (2.07).

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