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Response of soybean (*Gycine max* L.) to exogenous application of gibberellic acid under rainfed conditions

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Abstract
A field experiment was carried out at Agriculture Research Station (Dr. PDKV), Buldana during 2016 on a vertisol soil, to study the response of soybean (*Gycine max* L.) to exogenous application of gibberellic acid under rainfed conditions. In soybean, 10 treatments comprising gibbrellic acid–management practices (application of 15, 30, 45 ppm GA_3 at flowering, pod development stages and control) were tested on vertisol. Results indicated that two applications of 45 ppm GA_3 at flowering and pod development stages recorded significantly higher plant height, number of branches /plant, number of pods/ plant, seed index and grain yield (21% more than control), higher oil yield, rain water use efficiency and higher gross and net monetary returns.

Keywords: Soybean, foliar application, GA_3, rain water use efficiency (RUE), oil content

Introduction

India has the fifth largest vegetable oil economy in the world. After cereals, oilseeds are the second largest agricultural commodity, accounting for the 14 per cent of the gross cropped area in the country. However, the country is meeting its edible oil demand by importing almost 50 per cent of its requirement. The per capita consumption of the vegetable oil is increasing very rapidly due to increase in population and improved economic status of the population. The demand has increased to about 12.6 kg/year compared to 4 kg/year in 1961, and the projected demand for the year 2020 is 16.38 kg/year. To meet this demand, the country will require nearly 21.8 million tons of edible oil. In this scenario, soybean could play a pivotal role. Due to the advances in knowledge of lipid biochemistry and the possibilities of enhancing quality and yield of edible oil in soybean, this has the potential of becoming a major oil producing crop globally (Agrawal *et al.*, 2013) [2]. Despite having made rapid stride for both coverage and total production, soybean still suffers on productivity front. There are a number of constraints, pertaining to climate, edaphic, production, and technology aspects that hinder higher productivity.

Plant growth regulators are organic compounds which, in small amounts, somehow modify a given physiological plant process. Gibberellins (GAs) play an essential role in many aspects of plant growth and development, such as seed germination, stem elongation and flower development (Yamaguchi & Kamiya, 2000) [14]. Maske *et al.* (1998) [5, 8] reported that application of GA_3 on soybean at early growth stages resulted in increased number of branches plant^{-1}. Foliar application of GA_3 increased number of flowers, pods and test weight in soybean (Uddin, 2002) [12]. Application of GA_3 increased the seed yield of soybean crop (Deotale *et al.*, 1998, Maske *et al.*, 1998 and Uddin *et al.*, 2002) [5, 8, 12]. Gibberellin proved to be potential in increasing the yield components like the number of pods and seeds which resulted to the increase in yield in soybean crop (Leite *et al.*, 2003) [7]. With this background in view, the present investigation was planned with the following objectives: To assess the effect of GA3on growth and yield of soybean to assess the effect of GA3 on economics of soybean production.

Materials and Methods

The present experiment was conducted at the Agriculture Research Station (Dr. PDKV), Buldana, Maharashtra, India during 2016. The soil of experimental plot was clayey and slightly alkaline (pH 7.9), with available nitrogen (245kg/ha), phosphorus (20.8 kg/ha) andpotassium (336 kg/ha) content. Geographically Buldana is situated between 20^{0}32'07.27N 76^{0}11'24.43E and its mean height above sea level is 654 m. It receives most of the rainfall from South-West monsoon, commencing from middle of June. The normal monsoon season precipitation approximates to about 720 mm receives in about 40 to 45 rainy days from the middle of June to September. The details of the crop season rainfall and its distribution during the experimentation period are given in Table 2 and 3 and also depicted in fig. 1. For studying the response of soybean (*Glycine max* L.) to exogenous application of gibrellic acid under rainfed conditions, randomized block design was used. The details of the treatments and symbols used are given in Table 1. In all, there were ten treatments replicated three times. The experimental field was laid out in 30 unit plots, each plot measuring 10.80 m^2 (3.6m x 3.0m). There were eight rows of soybean crop in each plot and sixty plants in each row. One row of crop from both sides of length and also both sides of breadth were left as guard rows. The net plot consisted of six rows with fifty eight plants per row (2.70m x 2.90m).

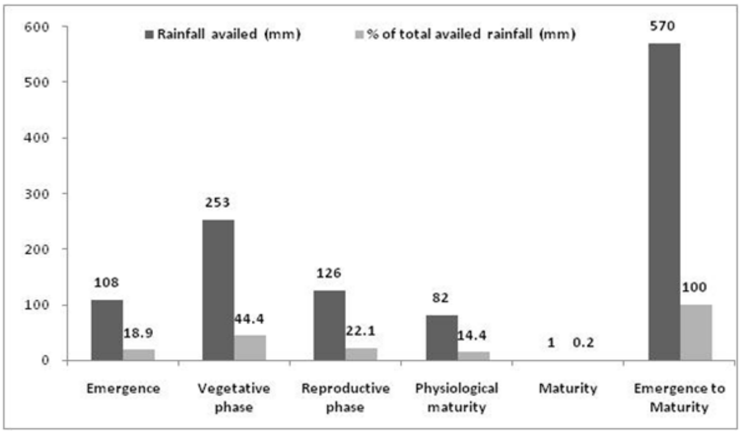

Fig 1: Rainfall availed by the soybean crop during different phenophases

Table 1: Experiment treatment details and symbols used

S. No.	Treatment details	Symbols used	Number of GA_3 applications	Quantity of 1000ppm GA_3 stock solution utilized
1	Control (no application of GA_3)	T_1	Nil	Nil
2	Foliar application of 15 ppm GA_3 at Flowering	T_2	01	15ml/ liter water
3	Foliar application of 30 ppm GA_3 at Flowering	T_3	01	30ml/ liter water
4	Foliar application of 45 ppm GA_3at Flowering	T_4	01	45ml/ liter water
5	Foliar application of 15 ppm GA_3 at Pod development	T_5	01	15ml/ liter water
6	Foliar application of 30 ppm GA_3 at Pod development	T_6	01	30ml/ liter water
7	Foliar application of 45 ppm GA_3 at Pod development	T_7	01	45ml/ liter water
8	Foliar application of 15 ppm GA_3 at Flowering & Pod development	T_8	02	15ml/ liter water
9	Foliar application of 30 ppm GA_3 at Flowering & Pod development	T_9	02	30ml/ liter water
10	Foliar application of 45 ppm GA_3 at Flowering & Pod development	T_{10}	02	45ml/ liter water

Table 2: Rainfall details during the experimental period

Standard Meteorological Week	Period		Rainfall received (mm)
23	04.06.2016	10.06.2016	32
24	11.06.2016	17.06.2016	0
25	18.06.2016	24.06.2016	45
26	25.06.2016	01.07.2016	65
27	02.07.2016	08.07.2016	41
28	09.07.2016	15.07.2016	124
29	16.07.2016	22.07.2016	19
30	23.07.2016	29.07.2016	80
31	30.07.2016	05.08.2016	85
32	06.08.2016	12.08.2016	5
33	13.08.2016	19.08.2016	3
34	20.08.2016	26.08.2016	18
35	27.08.2016	02.09.2016	0
36	03.09.2016	09.09.2016	8
37	10.09.2016	16.09.2016	35
38	17.09.2016	20.09.2016	89
39	24.09.2016	30.09.2016	40
40	01.10.2016	07.10.2016	1
41	08.10.2016	14.10.2016	0
42	15.10.2016	21.10.2016	0
43	22.10.2016	28.10.2016	0
		Total	690

Table 3: Rainfall availed by the soybean during the experimental period

Phenophase	Period	Rainfall availed (mm) by soybean crop	Percentage of total rainfall availed (%)
Emergence	07.07.2016 to 11.07.2016	108	18.9
Vegetative phase	12.07.2016 to 21.08.2016	253	44.4
Reproductive phase	22.08.2016 to 24.09.2016	126	22.1
Physiological maturity	25.09.2016 to 08.10.2016	82	14.4
Maturity	09.10.2016 to 26.10.2016	01	0.2
Emergence to Maturity	07.07.2016 to 26.10.2016	570	100.0

Seeds of soybean variety JS- 335 were sown @ 30 kg/ ha (444444 plants/ ha) with the spacing of 45cm between rows and 05cm between plants on 7th July 2016. A fertilizer dose of 30 kg N, 75 kg P_2O_5 and 30 kg K_2O/ ha through urea, single super phosphate and muriate of potash was applied at the time of sowing (basal application) to all the plots. Foliar application of gibberellic acid was done as per the treatments. For the foliar application of gibberellic acid a stock solution of 1000ppm was prepared by using 1.1g gibberellic acid technical (90%) along with promix (solvent) dissolved in distilled water and made the volume to 1000ml using volumetric flask and from this stock solution required amount of the gibbrellic acid as per the treatments was utilized for foliar application (Table 1).Timely recommended plant-protection measures for soybean crop were followed to save the crop from pests and diseases. The soybean crop was harvested manually. Different growth and yield components were recorded periodically.The data on various parameters recorded from experimental plots were statistically analyzed as suggested by Panse and Sukhatme (1995) [9] by using 'F' test at P=0.05.

Results and Discussion

Growth and yield parameters

Exogenous application of GA_3 significantly influenced the soybean plant height, branches /plant, pods/ plant, seed index and grain yield/ plant (Table 4). Two applications of 45 ppm GA_3 at flowering and at pod development stages (T_{10}) recorded significantly higher plant height, number of branches /plant, number of pods/ plant, seed index and grain yield/ plant. Superiority in growth parameters of soybean is due to foliar application of different concentrations of GA_3 over control possibly due to the physiological effects of gibberellins on growth parameters of plants like cell elongation and cell division, increase in photosynthetic activity and better food accumulation. The increase in plant height may be due to the effect of GA_3 on cell division and cell enlargement and also GA_3 stimulated the growth and expansion of cells through increasing the wall plasticity of the cells (Reza *et al.*, 2015) [10]. The foliar application of GA_3 at flower initiation and pod formation stage might have reduced flower drop and caused efficient translocation of photosynthates from source to sink. This might have significantly increased the number pods/ plant, grain mass and yield/ plant. Similar results were observed by Akter *et al.*, (2007) [3] and Ganapathy *et al.*, (2008) [6].

Table 4: Effect of different treatments on growth and yield parameters of soybean

Treatments	Plant height (cm)	No. of branches/ plant	No. of pods/ plant	Seed Index (g)	Grain yield/ plant (g)
T_1	40.73b	4.53b	37.33b	9.40b	7.19b
T_2	41.33b	5.00b	39.93b	9.63b	7.73b
T_3	42.67a	5.33b	46.27a	9.97a	9.33a
T_4	44.33a	5.60a	46.40a	10.07a	9.33a
T_5	44.67a	5.73a	47.33a	9.72b	9.53a
T_6	40.67b	5.13b	43.93a	9.97a	8.77a
T_7	42.00a	5.20b	45.67a	9.97a	9.17a
T_8	46.00a	5.93a	48.27a	10.22a	9.73a
T_9	46.00a	6.27a	48.93a	10.27a	9.83a
T_{10}	48.33a	6.73a	48.93a	10.44a	9.90a
SEm±	1.63	0.39	1.89	0.16	0.49
CD (P=0.05)	4.84	1.17	5.62	0.47	1.46

Means followed by the same letter do not differ significantly at the 0.05 probability level

Grain and straw yield

Application of GA_3 significantly influenced the soybean grain yield (Table 5). Two applications of 45 ppm GA_3 at flowering and at pod development stages (T_{10}) recorded significantly higher grain yield (2733.06 kg/ ha). It has also recorded 21% more soybean grain yield than that of control plot (2260.52 kg/ ha). The grain yield of soybean increased due to cumulative effect of yield attributing characters and enhanced photosynthetic efficiency and greater diversion of assimilates towards reproductive organs. Results are in agreement with the work of Agawane and Parhe (2015) [1] and Upadhyay and Ranjan (2015) [13].

Harvest Index

Application of GA_3 significantly influenced the soybean harvest index (Table 5). Two applications of 45 ppm GA_3 at flowering and at pod development stages (T_{10}) recorded significantly higher harvest index (44.14%) and it was at par with the two applications of 15 ppm GA_3 (T_8), 30 ppm GA_3 (T_9) and single application of 45 ppm GA_3 at pod development stage (T_7). The higher harvest index indicated that, GA_3 application accelerated assimilate supply to sink, which is in agreement with the results of Akter *et al.* (2007) [3].

Table 5: Effect of different treatments on grain and straw yield, oil content, oil yield and rainfall use efficiency of soybean

Treatments	Grain yield/ ha (kg)	Straw yield/ ha (kg)	Harvest Index (%)	Oil content (%)	Oil yield (kg/ ha)	Rain water use efficiency (kg/mm/ha)
T_1	2260.52b	3358.85	40.29b	18.45	417.0b	3.97
T_2	2379.72b	3469.54	40.74b	18.48	439.7b	4.17
T_3	2622.37a	3622.79	41.98b	18.47	484.4a	4.60
T_4	2626.63a	3678.13	41.76b	18.48	485.4a	4.61
T_5	2660.69a	3724.96	41.74b	18.48	491.7a	4.67
T_6	2545.75a	3627.05	41.28b	18.49	470.8a	4.47
T_7	2588.32a	3546.16	42.23a	18.49	478.5a	4.54
T_8	2677.72a	3571.71	42.90a	18.48	494.8a	4.70
T_9	2724.54a	3456.77	44.14a	18.50	504.0a	4.78
T_{10}	2733.06a	3461.02	44.14a	18.50	505.6a	4.79
SEm±	95.29	216.22	0.70	0.03	17.6	-
CD (P=0.05)	283.08	NS	2.07	NS	52.3	-

Means followed by the same letter do not differ significantly at the 0.05 probability level
NS= Non significant

Oil content and oil yield

The effect of exogenous application of GA_3 on oil content in soybean grain (%) was found non- significant (Table 5). However, two applications of 30 and 45 ppm GA_3 at flowering and pod development stages recorded the highest oil content in soybean grain, whereas no application of GA3 (control) recorded the lowest oil content in soybean grain. This shows that the GA_3 has not much influence on oil content. This finding is well supported by Sharma *et al.* (2017). Oil yield (kg/ ha) was significantly influenced by the application of GA_3 (Table 5). All the treatments recorded statistically similar oil yield (kg/ ha) except no application of GA_3 (control) and single application of GA_3 at flowering stage (T_2). The highest oil yield (505.6 kg/ ha) was observed under the treatment two applications of 45 ppm GA_3 at flowering and at pod development stages (T_{10}). The increase in the oil yield is directly correlated with the grain yield of the soybean. The best treatment recorded the higher grain yield of soybean and resulted in higher oil yield.

Rain Water Use Efficiency (RUE)

Rain water use efficiency (kg/ mm/ ha) was significantly influenced by the application of GA_3 (Table 5). Two applications of 45 ppm GA_3 at flowering and at pod development stages (T_{10}) recorded higher rain water use efficiency (4.79 kg/ mm/ ha). The lowest rain water use efficiency was observed with no application of GA_3 (3.97 kg/ mm/ ha). The best treatment recorded 20.65% more rain water use efficiency that the control treatment. This clearly indicates that application of GA_3 resulted in enhancing the effective use of rainfall by the soybean crop and it is reflected in the increment in yield.

Table 6: Economics of soybean as influenced by different treatments

Treatments	Cost of Cultivation (x 10^3 Rs/ ha)	Gross Monitory Returns (x 10^3 Rs/ ha)	Net Monitory Returns (x 10^3 Rs/ ha)	B:C ratio
T_1	24.07	67.81b	43.74b	2.81
T_2	24.40	71.39b	46.99b	2.92
T_3	24.92	78.67a	53.75a	3.16
T_4	25.07	78.80a	53.72a	3.14
T_5	24.83	79.82a	54.99a	3.21
T_6	24.80	76.37a	51.57a	3.08
T_7	25.02	77.65a	52.63a	3.10
T_8	25.02	80.33a	55.33a	3.21
T_9	25.37	81.74a	56.36a	3.22
T_{10}	25.68	81.99a	56.31a	3.19
SEm±	-	2.86	2.72	-
CD (P=0.05)	-	8.49	8.07	-

Means followed by the same letter do not differ significantly at the 0.05 probability level
Market rates of soybean grains @ Rs. 3000/- per quintal

Economics

Economics of soybean production was significantly influenced by the GA_3 application (Table 6). Two applications of 45 ppm GA_3 at flowering and pod development stages (T_{10}) recorded significantly higher gross and net returns (Rs. 81992/- and Rs. 56307/- gross and net returns, respectively), which were higher by Rs. 14716/- and Rs. 12567/- than that of no application of the GA_3 (Rs. 67816/- and Rs. 43740/- gross and net returns, respectively). The benefit: cost ratio was higher with the two applications of GA_3 at flowering and pod development stages (T_9). Increased grain yield owing to application of GA_3 significantly increased the gross and net monetary returns. The results confirm the findings of Aziz *et al.* (2012) [4].

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