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## Growth, yield, quality and economics of soybean as influenced by plant growth regulators and their stages of application

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### Abstract

Soybean has been principal food crop since long time as it produces 2-3 times more high quality protein per hectare than other pulses and cholesterol free oil. It is an excellent health food as it contains 40-42% quality protein, 23% carbohydrates and 20% cholesterol free oil. It is the cheapest and main source of dietary protein of majority of vegetarian (hence it is known as poor man's meat). Plant growth regulators are known to enhance the source-sink relationship and stimulate the translocation of photosynthates thereby helping in effective flower formation, pods and seed development and ultimately enhance the productivity of the crop. The field investigation was conducted at Regional Research Centre, Amravati under Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during kharif 2017-18 to 2019-20. The experiment was laid out in a factorial randomized block design with fifteen treatments combinations and three replications with a view to find out the effect of the four bio-regulators (salicylic acid, etrel, chloromequat chloride and nitrobenzene) and their stages of application on growth, yield and quality of soybean. From the pooled data of three years revealed that, application of nitrobenzene 20% @ 500 ppm found significantly more plant height (54.63 cm), number of branches plant<sup>-1</sup>(3.53), number of pods plant<sup>-1</sup>(28.95), test weight (11.06 g), seed yield (1981 kg ha<sup>-1</sup>), straw yield (2562 kg ha<sup>-1</sup>), protein content (39.45%), oil content (18.65%), GMR (Rs. 65460 ha<sup>-1</sup>), NMR (Rs. 34705 ha<sup>-1</sup>) and B:C ratio (2.12) and it was at par with chloromequat chloride @1000 ppm in all characters, whereas, application of growth regulators at flower initiation stage recorded numerically more plant height (53.37 cm), number of branches plant<sup>-1</sup> (3.26), number of pods plant<sup>-1</sup> (28.52), test weight (10.79 g), seed yield (1955 kg ha<sup>-1</sup>), straw yield (2498 kg ha<sup>-1</sup>), protein content (39.47%), oil content (18.62%), higher GMR (Rs. 65585 ha<sup>-1</sup>), NMR (Rs. 34102 ha<sup>-1</sup>) and B:C ratio (2.10). Interaction effect on growth, yield, yield attributes, quality and economics parameters showed non-significant effect.

**Keywords:** Soybean, growth regulators, salicylic acid, etrel, chloromequat chloride and nitrobenzene

### Introduction

Soybean is known as world's most important crop due to its high protein and oil content (Raei *et al.*, 2008) [10]. Soybean crop is most important source of vegetable oil in India that occupies 35-65% of total oil seed crop in country. The world production of edible oils consists of 30% soybean. Among the grain legumes, it has the greatest potential of producing the cheapest source of food protein (Rao and Reddy, 2010) [11]. Soybean revolutionized rural economy and lifted the socio-economic status of soybean farmers. However, the increase in the productivity over the years did follow the same place, and it is not more than half of the world average, hence there is tremendous scope to increase soybean production by enhancing productivity. Plant growth regulators are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates thereby helping in effective flower formation, fruit and seed development and ultimately enhance productivity of the crops. A growth regulator can improve the physiological efficiency including photosynthetic ability and can enhance the effective partitioning of assimilates from source and sink in the field crops. Hence considering these points in view the present study was undertaken with aim to study the effect of the four bio-regulators (Salicylic acid, Ethrel, Chloromequat chloride and Nitrobenzene) and their stages of application on growth, yield and quality of soybean.

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## Materials and Methods

A field experiment was conducted at Regional Research Centre, Dr.PDKV, Amravati, Maharashtra in 2017-18 to 2019-20 to study the effect of the four bio-regulators (Salicylic acid, Ethrel, Chloromequat chloride and Nitrobenzene) and their stages of application on growth, yield and quality of soybean. The soil of experimental field was medium black in texture. Fifteen plant growth regulators and stages of applications treatments combinations comprising of first factor had five plant growth regulators (water spray, Salicylic acid @ 50 ppm, Ethrel @ 200 ppm, Chloromequat chloride @1000 ppm and Nitrobenzene 20 percent @ 500 ppm and second factor had three stages of application (at flower initiation, at pod initiation and at flower initiation + pod initiation) were tried under factorial randomized block design with three replications. Gross and net plot size was 5.0 m X 3.60 m and 4.80 m X 2.70 m, respectively. Variety JS-335 were dibbled on 45 cm x 05 cm distance with RDF (30:75:30 NPK kg/ha) were applied. Data on growth, yield, quality and economic were recorded and statistically analyzed as per method suggested by Panse and Sukhatme, 1967<sup>[9]</sup>.

## Results and Discussion

Different growth regulators and stages of application plays important role in plant height (cm), number of branches plant<sup>-1</sup>, number of pods plant<sup>-1</sup>, test weight (g), seed yield ha<sup>-1</sup>(kg), straw yield ha<sup>-1</sup>(kg), GMR, NMR, protein content (%) and oil content (%) of soybean.

### Effect on growth parameters

Pooled data of three years revealed that, application of Nitrobenzene 20% @ 500 ppm found significantly more plant height (54.63 cm) and number of branches plant<sup>-1</sup> (3.53) but at par with Chloromequat chloride @1000 ppm in both characters, whereas, application of growth regulators at flower initiation stage recorded numerically more plant height (53.37 cm) and number of branches plant<sup>-1</sup> (3.26). Interaction effect on growth parameters showed non-significant effect. Similar results were also obtained by Patil *et al.* (2011)<sup>[8]</sup> and reported that plant height is increased maximum by treatment nitrobenzene (20%). Increase in growth on tomato due to Nitrobenzene was observed by Deb *et al.* (2012)<sup>[3]</sup>. The treatments Nitrobenzene @ 3.0 ml L<sup>-1</sup> as foliar application gave the highest performance in respect of plant height, leaf area index and total dry matter in boro rice reported by Chowdhury *et al.* (2018)<sup>[2]</sup>.

### Effect on yield and yield attributing characters

Pooled data of three years revealed that, application of Nitrobenzene 20% @ 500 ppm found significantly more number of pods plant<sup>-1</sup>(28.95), test weight (11.06 g), seed yield (1981 kg ha<sup>-1</sup>), straw yield (2562 kg ha<sup>-1</sup>) and it was at par with Chloromequat chloride @1000 ppm in all characters whereas, application of growth regulators at flower initiation stage

recorded numerically more number of pods plant<sup>-1</sup> (28.52), test weight (10.79 g), seed yield (1955 kg ha<sup>-1</sup>) and straw yield (2498 kg ha<sup>-1</sup>). Interaction effect on yield and yield attributing characters showed non-significant effect. Since yield is the resultant of additive and complementary effect of plant growth and yield attributing parameters and these yield attributing characters had better expression at higher availability of nutrients due to adequate quantity and balanced proportion of plant nutrient supplied during the crop growth period which ultimately led towards an increase in seed and straw yields. The treatments Nitrobenzene @ 3.0 ml L<sup>-1</sup> as foliar application gave the highest performance in respect of effective tiller, total tillers (hill<sup>-1</sup>), panicle length, non-sterile spikelets, total spikelets, 1000-grain weight, grain yield (ha<sup>-1</sup>), straw yield (ha<sup>-1</sup>), biological yield (t ha<sup>-1</sup>) and harvest index (%) in boro rice reported by Chowdhury *et al.* (2018)<sup>[2]</sup>. Similar result was also obtained by Kumar and Son's (2011)<sup>[4]</sup> who found that the application of nitrobenzene ("Flora") increase the number of fruits plant<sup>-1</sup> is about 20–30%. Azizand Miah (2009)<sup>[1]</sup> reported that the application of flora (nitrobenzene) or chemical fertilizer either alone or in combination increased the 1000-grain weight in wetland rice. Nuruzzaman *et al.*, (1991)<sup>[6]</sup> also found that the maximum fruit weight was provided by the foliar application of Nitrobenzene on strawberry. Nitrobenzene is quickly absorbed into the plants, which has capacity to increase flowering in plants and maximum number of fruits per plant Mithila *et al.* (2012)<sup>[5]</sup>. The application of growth retardants, TIBA, mepiquat chloride and cycocel were more beneficial in terms of translocation of photoassimilates towards developing reproductive parts as compared to growth promoter kinetin and control reported by Pankaj Kumar *et al.* in soybean (2006)<sup>[7]</sup>.

### Effect on quality parameter

Pooled data of three years showed that, application of Nitrobenzene 20% @ 500 ppm found significantly more protein content (39.45%) and oil content (18.65%) but at par with Chloromequat chloride @1000 ppm in both characters whereas, application of growth regulators at flower initiation stage recorded numerically more protein content (39.47%) and oil content (18.62%). Interaction effect quality parameters showed non-significant effect.

### Effect on economics

Pooled data of three years showed that, application of Nitrobenzene 20% @ 500 ppm found significantly more GMR (Rs. 65460 ha<sup>-1</sup>), NMR (Rs. 34705 ha<sup>-1</sup>) and B:C ratio (2.12) but at par with Chloromequat chloride @1000 ppm in all characters, whereas, application of growth regulators at flower initiation stage recorded numerically higher GMR (Rs. 65585 ha<sup>-1</sup>), NMR (Rs. 34102 ha<sup>-1</sup>) and B:C ratio (2.10). Interaction effect on showed non-significant effect.

**Table 1:** Growth, yield parameters and yield of soybean as influenced by growth regulators and stages of application

Treatments	Plant Height (cm)				Number of branches per plant at harvest				Number of pods per plant at harvest				Test Weight (g)				Seed yield (kg/ha)			
	2017-18	2018-19	2019-20	Pooled	2017-18	2018-19	2019-20	Pooled	2017-18	2018-19	2019-20	Pooled	2017-18	2018-19	2019-20	Pooled	2017-18	2018-19	2019-20	Pooled
<b>Factor A: Application of Growth Regulators</b>																				
G1: Water spray	52.57	49.63	57.53	53.03	3.06	2.52	2.84	2.84	15.91	21.11	37.36	24.79	9.37	10.08	11.41	10.26	1535	1565	1977	1692
G2: Salicylic acid @ 50ppm	47.78	48.10	57.97	51.28	3.35	2.55	2.86	2.87	16.15	22.87	40.45	26.49	9.69	10.17	11.01	10.29	1558	1679	2157	1799
G3: Ethrel @ 200 ppm	48.37	45.78	48.93	47.70	3.28	2.67	2.91	2.91	17.45	24.17	39.77	27.13	9.82	10.29	11.44	10.52	1651	1694	2205	1851
G4: Chloromequat	47.05	45.24	48.06	46.78	3.53	3.17	3.35	3.35	17.98	24.70	41.31	28.00	10.09	10.53	11.80	10.81	1734	1729	2213	1892

Chloride @ 1000 ppm																				
G5: Nitrobenzene 20% @ 500 ppm	57.47	51.70	54.71	54.63	3.71	3.44	3.53	3.53	18.73	25.89	42.23	28.95	10.10	11.09	11.98	11.06	1799	1822	2321	1981
SE (m) <sub>±</sub>	2.49	2.21	2.25	2.57	0.19	0.20	0.12	0.14	0.90	1.19	1.61	0.62	0.23	0.31	0.30	0.17	83.92	71.81	89.27	35.36
CD at 5%	7.47	6.65	6.74	7.72	0.58	0.62	0.36	0.42	2.70	3.57	4.84	1.86	0.70	0.93	0.91	0.51	251.60	215.50	267.61	105.99
Factor B : Stages of application																				
S1: At flower initiation.	53.77	50.35	55.99	53.37	3.52	3.01	3.26	3.26	18.62	24.68	42.25	28.52	10.04	10.61	11.73	10.79	1773	1763	2328	1955
S2: At pod initiation.	50.92	46.26	54.37	50.45	3.45	2.69	3.00	3.00	17.06	23.79	38.64	26.49	9.92	10.25	11.05	10.41	1646	1622	2069	1779
S3: At flower initiation + pod initiation.	47.09	47.66	49.96	48.24	3.20	2.92	3.04	3.04	16.05	22.77	39.79	26.20	9.49	10.43	11.81	10.58	1549	1709	2128	1795
SE (m) <sub>±</sub>	2.19	1.74	2.59	2.08	0.14	0.13	0.11	0.17	0.73	0.69	1.87	1.01	0.20	0.12	0.10	0.38	72.58	59.73	109.65	80.91
CD at 5%	6.57	5.23	7.78	6.25	0.42	0.40	0.34	0.52	2.20	2.09	5.62	3.04	0.60	0.38	0.31	1.14	217.62	179.05	328.69	242.55
Interaction SE (m) <sub>±</sub>	1.73	1.14	1.71	1.40	0.29	0.27	0.19	0.12	0.72	0.94	1.59	0.72	0.29	0.32	0.33	0.23	78.35	56.44	71.38	49.38
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**Table 2:** Yield parameters and economics of soybean as influenced by growth regulators and stages of application

Treatments	Straw yield (kg/ha)				Gross Monetary Returns (Rs/ha)				Net Monetary Returns (Rs/ha)				B:C Ratio			
	2017-18	2018-19	2019-20	Pooled	2017-18	2018-19	2019-20	Pooled	2017-18	2018-19	2019-20	Pooled	2017-18	2018-19	2019-20	Pooled
Factor A: Application of Growth Regulators																
G1: Water spray	1893	1952	2680	2175	46811	53015	67929	55918	17781	23985	35299	25688	1.61	1.80	2.08	1.84
G2: Salicylic acid @ 50ppm	1923	1982	2904	2270	47528	56721	74107	59452	18060	27253	41038	28784	1.61	1.90	2.24	1.93
G3: Ethrel @ 200 ppm	2038	2096	3008	2381	50368	57384	75797	61183	20760	27776	42589	30375	1.70	1.90	2.28	1.97
G4: Chlormequat Chloride @ 1000 ppm	1925	1984	2973	2294	52894	58334	76007	62412	23472	28912	42985	31790	1.79	2.00	2.30	2.03
G5: Nitrobenzene 20% @ 500 ppm	2231	2289	3167	2562	54871	61739	79768	65460	25316	32184	46613	34705	1.85	2.10	2.41	2.12
SE (m) <sub>±</sub>	111.80	111.80	150.72	55.89	2559.73	2255.82	3092.95	1187.08	2559.78	2255.82	3092.95	1187.08	---	---	---	---
CD at 5%	335.14	335.14	451.81	167.56	767308	6761.94	9271.28	3558.33	7673.08	6761.94	9271.27	3558.33	---	---	---	---
Factor B : Stages of application																
S1: At flower initiation.	2159	2218	3116	2498	54064	59747	79942	64585	24781	30664	47060	34102	1.84	2.04	2.43	2.10
S2: At pod initiation.	2018	2076	2830	2308	50189	55041	71106	58779	20906	25758	38223	28296	1.71	1.87	2.16	1.91
S3: At flower initiation + pod initiation.	1829	1899	2994	2204	47231	57528	76116	59292	17547	27844	39832	28408	1.59	1.93	2.19	1.90
SE (m) <sub>±</sub>	106.53	106.53	120.91	94.50	2213.87	1947.80	3733.84	2540.91	2213.87	1947.80	3733.84	2540.91	---	---	---	---
CD at 5%	319.35	319.35	362.46	283.29	6636.20	5838.63	11192.37	7616.51	6636.20	5838.63	11192.37	7616.51	---	---	---	---
Interaction SE (m) <sub>±</sub>	99.14	97.11	90.84	58.98	2389.34	1865.19	2432.73	1585.02	2389.34	1865.19	2432.73	1585.02	--	--	--	--
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	---	---	---	---

**Table 3:** Quality of soybean as influenced by growth regulators and stages of application

Treatments	Protein content (%)				Oil content (%)			
	2017-18	2018-19	2019-20	Pooled	2017-18	2018-19	2019-20	Pooled
Factor A: Application of Growth Regulators								
G1: Water spray	39.07	39.12	38.77	38.81	18.22	18.04	18.51	18.13
G2: Salicylic acid @ 50ppm	39.09	39.51	38.91	39.17	18.32	18.35	18.82	18.24
G3: Ethrel @ 200 ppm	39.35	39.56	38.95	39.48	18.39	18.36	18.63	18.46
G4: Chlormequat Chloride @ 1000 ppm	39.44	39.65	39.06	39.47	18.48	18.50	18.66	18.55
G5: Nitrobenzene 20% @ 500 ppm	39.57	39.63	39.14	39.45	18.60	18.63	18.74	18.65
SE (m) <sub>±</sub>	0.39	0.43	0.35	0.21	0.48	0.51	0.39	0.12
CD at 5%	NS	NS	NS	0.63	NS	NS	NS	0.38
Factor B : Stages of application								
S1: At flower initiation.	39.45	39.61	39.19	39.47	18.53	18.64	18.70	18.62
S2: At pod initiation.	39.39	39.59	38.87	39.30	18.38	18.19	18.55	18.30
S3: At flower initiation + pod initiation.	39.07	39.28	38.83	39.06	18.30	18.69	18.76	18.58
SE (m) <sub>±</sub>	0.37	0.31	0.28	0.16	0.45	0.40	0.35	0.10
CD at 5%	NS	NS	NS	0.48	NS	NS	NS	0.31
Interaction SE (m) <sub>±</sub>	0.35	0.37	0.40	0.26	0.33	0.32	0.34	0.28
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

**Conclusion**

Pooled data over the three years revealed that, application of Nitrobenzene 20% @ 500 ppm showed significantly superior over all the treatments except Chlormequat Chloride @ 1000 ppm in respect of seed yield (1981 kg ha<sup>-1</sup>), straw yield (2582 kg ha<sup>-1</sup>), GMR (Rs. 65460 ha<sup>-1</sup>), NMR (Rs. 34705 ha<sup>-1</sup>), B:C ratio

(2.12), protein content (39.45%) and oil content (18.65%). Application of growth regulator at flower initiation stage was found numerically superior over all other treatments in respect of seed yield (1955 kg ha<sup>-1</sup>), straw yield (2494 kg ha<sup>-1</sup>) and also recorded higher GMR (Rs. 64585 ha<sup>-1</sup>), NMR (Rs. 34102 ha<sup>-1</sup>), B:C ratio (2.12), protein content (39.47%) and oil content

(18.62%). Considering above facts, for getting higher yield and monetary returns, spraying of Nitrobenzene 20% @ 500 ppm (2.5 ml /L of water) at flower initiation stage is recommended in soybean crop followed by Chlormequat Chloride @ 1000 ppm.

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