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Growth, Yield and Economics of Soybean (G*lycine max*) as Influenced by Growth Regulating Substances and Time of Application

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Field experiments were conducted at millet breeding farm of Tamil Nadu Agricultural University, Coimbatore (11°29"N latitude and 77° 08" E longitude at an altitude of 256 MSL), India during *Kharif* 2012, 2013 and 2014 in split plot design. The experiment comprised of twelve treatment combinations with four plant growth regulators (salicylic acid @ 100 mg/l, ethrel @ 200 mg/l, cycocel @ 500 mg/l and water spray) in main plots and three stages of application (at flower initiation, pod initiation and flower + pod initiation) in sub plot replicated thrice. Foliar spray of salicylic acid@ 100 mg/l was significantly higher Pods per plant than cycocel @ 500 mg/l, ethrel @ 200 mg/l and water spray. Salicylic acid 100 mg/l recorded significantly higher seed yield and but was found to statistically on par with cycocel @ 100 mg/l. Pods per plant with application of plant regulators at flower + pod initiation stages were significantly higher than application either at flower or pod initiation. Application of growth regulators at flower and pod initiation gave significantly higher seed yield than flower and pod alone. The pooled mean revealed that growth regulators at flower + pod initiation stages gave 16.07 % and 12.50 % higher yield than spraying growth regulators either at flower initiation or pod initiation stage alone.

Key words: Agronomic performance, Cycocel, Ethrel, Salicylic acid, Soybean.

Soybean is called as "Miracle bean" (*Glycine max* (L.) Merill) is a 'Two in one' crop containing about 40 per cent protein and 20 per cent oil, has now become the largest source of protein and oil in the world. The estimated global production of soybean is 315.10 million tonnes harvested from an area of 118.0 million ha and the productivity is 2.67 tonnes ha^{-1}. In India, the area under soybean is 10.02 million hectares with an annual production of 11.64 million tonnes and the productivity is 1.06 tonnes ha^{-1} (Satheeshkumar, 2015).

In soybean, at the time of pod initiation the photosynthates sometimes may not be diverted to the developing sinks, but go to the vegetative parts for their growth. There is a need to give the signal of developing sinks to the plants, so that the dry matter accumulated may go to the developing pods. The role of plant growth regulators is well established in improvement of morpho-physiological attributes of the crop plants. The plant growth regulators stimulate vegetative growth and enhance the yield potential. Some of the growth regulators like salicylic acid, ethrel and cycocel may play a big role in increasing the seed yield of soybean. Growth regulators are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates, thereby helping in effective pod formation, seed development and ultimately the productivity. Salicylic acid is an endogenous growth regulator of phenol in nature, which participates in the regulation of physiological processes in plant such as stomatal closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance (Khan *et al*, 2003). Vaiyapuri *et al.* (2012) reported that application of salicylic acid @ 100 mg/l increased the dry matter production in soybean. Khan *et al.* (2003) reported that application of salicylic acid enhanced the photosynthetic rate, stomatal conductance and transpiration rate in soybean. Ethylene released from ethrel could possibly be utilized for promoting pod growth. (Abbas, 1991) The author has shown that early application of bio-regulator would be an useful practice that could improve the yield of soybean in Indo Gangetic plains. Furthermore, it has been reported that salicylic acid application increases carbon dioxide (CO_2) assimilation and photosynthetic rate, thus increasing dry matter (Szepesi *et al.*, 2005). Keeping all this in mind, the studies were conducted to assess the effect of growth regulators on growth, yield and economic analysis of soybean production.

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Materials and Methods

Field experiments were conducted at millet breeding farm of Tamil Nadu Agricultural University, Coimbatore (11°29"N latitude and 77° 08" E longitude at an altitude of 256 MSL), during *Kharif* 2012 to 2014 in split plot design. Experiment comprised of twelve treatment combinations with four plant growth regulators application (salicylic acid @ 100 mg/l, ethrel @ 200 mg/l, cycocel @ 500 mg/l and water spray) in main plots and three stages of application time (at flower initiation, pod initiation and flower + pod initiation) in sub plots, were replicated thrice. The soil of the experimental field was sandy loam, low in organic carbon (0.29%) and low in nitrogen (180 kg / ha). The variety Co (Soy3) was raised using fertilizer dose @ 20 kg N, 80 kg P_2O_5 and 40 kg K_2O ha^{-1} at the time of sowing. Pendimethalin (Stomp 30EC) herbicide @ 0.45 kg/ha was applied using 500 litres of water on the same day followed by one hand hoeing (four weeks after sowing) in all the years of the study to control weeds.

Total chlorophyll content was determined at 90 days after sowing. Five plants were selected from the plots followed by drying at in an oven at 60±5°C. Dry matter accumulation per plant was calculated. The data on plant height and pods per plant were collected from randomly selected five plants per plot at the time of harvest. Twenty pods per plot were selected to record data on number of grains per pod. From the total produce of each plot, 100 grains were counted and weighed to express seed index. The crop was harvested when the pods were matured; the bundles were sun dried for few days and then threshed manually. The data on biological and grain yield were collected at the time of harvest. The economics of cultivation was calculated using prevailing prices of inputs and output. The data were subjected to analysis in split design using standard procedures.

Results and Discussion

Growth characters

The dry matter accumulation by soybean plants was significantly influenced by all the treatments in all the years (Table 1). Salicylic acid 100 mg/l recorded the highest dry matter accumulation, which was significantly higher than all the treatments in 2013. But, in 2012 and 2014 the overall mean was statistically on par with ethrel 200 g/l. It might be due to higher photosynthetic efficiency in this treatment, which might have accumulated higher dry matter. Growth regulator application was significantly influenced by the time of application. The highest dry matter accumulation was recorded in flower + pod initiation stage which was significantly higher than pod initiation stage alone. However, it was found to be on par with flower initiation. The chlorophyll content at 90 DAS was recorded to be the highest in salicylic acid 100 mg/l, which found to be statistically on par with ethrel 200 mg/l. However, Shi *et al* (2012) indicated that foliar application of 1.00 mM salicylic acid had increased the chlorophyll content of cucumber seedlings grown under heat stress. Application of growth regulators at flower + pod initiation stage recorded higher total chlorophyll content at 90 days after sowing. It was found to be significantly superior to other treatments. But, during 2012 and 2014 the mean data indicated that flower + pod initiation and flower initiation stage were statistically on par. The tallest plants were recorded in salicylic acid @100 mg/l, which was statistically on par with cycocel and ethrel during 2012, 2013 (Table 1). But in 2013, plants were recorded to be taller in salicylic acid. However the observations found to be on par with ethrel and cycocel. Cycocel acts as an anti-gibberellin dwarfing agent and its foliar application may induce deficiency of gibberellins in the plant and reduce the growth by blocking and conversion of geranyl pyrophosphate to coponyl pyrophosphate, which is the first step of gibberellin synthesis (Moore, 1980). Stage of application of growth regulators at flower + pod initiation significantly influenced the plant height. In 2012 and 2014, growth regulator application during flower + pod initiation stages recorded taller plants, which were on par with spraying at pod initiation stages. More number of branches per plant was recorded in salicylic acid @100 mg/l spray during 2014. But in 2012 and 2013 and the overall mean was on par with ethrel @ 200 mg/l and cycocel (Table 1). It might be due to the suppressing effect of cycocel and ethrel on apical dominance of the soybean plants (Kaur *et al.,*2015). Stage wise application of growth regulators significantly influenced the branches per plant. The number of branches per plant in growth regulators application at flower + pod initiation stages was found to be the highest (Table 1). The stem girth was significantly influenced by application of salicylic acid@100mg/l. Application of growth regulators at flower + pod initiation gave significantly higher stem girth than application at flower initiation stage alone.

Yield attributes and yield

All the growth regulators recorded significantly higher number of pods per plant than water spray (Table 2). The higher number of pods per plant was recorded in salicylic acid spray @ 100 mg/l; it was statistically on par with ethrel spray @ 200mg/l. Singh and Kaur (1981) reported that salicylic acid application on mungbean significantly increased the pods per plant and yield. Salicylic acid application also increased the number of flowers, pods/plant and seed yield of soybean (Gutierrez-Coronado *et al.*, 1998). Ethrel has been reported to improve productivity of pulse crops like cowpea, pigeonpea, mungbean and soybean by increasing the number of pods, seed weight and seed yield (Bora and Bahra, 1989). Ethylene released from ethrel could possibly be utilized for promoting pod growth as stated by Abbas (1991) and Grewal *et al.* (1993).They also stated that early development would be related to higher ethylene levels, thus decreasing flowering and pod shedding, thereby reducing abscission and improving better pod set.

Time of application significantly influenced the number of pods per plant. The pods per plant in growth regulator application at flower + pod initiation stage was found to be the highest (Table 2), which was significantly higher than flower initiation and pod initiation alone during 2012-2014. The seed index was significantly influenced by growth regulator application at flower + pod initiation stage during 2012 (Table 2).

Table 1. Effect of growth regulators on growth and physiological parameters of soybean

Treatments	Dry matter production at 90 days (g/plant)				Total chlorophyll content at 90 DAS (mg/g)				Plant height (cm)				Branches/plant			
	2012	2013	2014	Mean	2012	2013	2014	Mean	2012	2013	2014	Mean	2012	2013	2014	Mean
Growth regulators																
Salicylic acid @ 100 mg/l	49.64	38.25	30.52	39.47	2.05	3.61	2.82	2.83	46.89	44.61	68.23	53.24	5.04	6.19	8.03	6.33
Ethrel @ 200 mg/l	48.08	35.23	30.51	37.94	1.88	3.23	2.51	2.54	45.20	47.46	61.23	51.30	4.81	5.92	6.63	5.88
Cycocel @ 500 mg/l	44.48	31.89	26.08	34.15	1.81	3.34	2.30	2.48	45.32	45.74	59.68	50.25	4.47	5.70	6.17	5.45
Water spray (Control)	39.41	27.56	26.11	31.03	0.71	2.12	1.89	1.57	39.36	40.29	54.29	44.65	3.83	5.22	5.70	4.92
SEd	2.39	2.03	1.29	1.10	0.05	0.30	0.21	0.19	1.73	2.23	18.34	7.43	0.23	0.28	0.27	0.26
CD (P=0.05)	4.96	4.21	2.71	22.21	0.11	0.61	0.41	0.38	3.58	4.62	37.97	15.39	0.48	0.58	0.56	0.54
Stage of application																
Flower Initiation	44.51	33.62	26.36	34.83	1.80	3.41	2.71	2.64	41.80	41.81	42.01	58.54	4.33	5.52	10.49	6.78
Pod Initiation	43.09	32.25	28.81	34.72	1.84	3.23	2.40	2.49	43.34	44.46	44.95	60.92	4.41	5.61	10.78	6.93
Flower + Pod Initiation	48.58	37.68	32.11	39.46	1.95	3.84	2.91	2.90	47.44	47.31	49.12	64.62	4.88	6.14	11.66	7.56
SEd	2.07	1.80	1.14	1.67	0.04	0.21	0.31	0.19	1.49	1.93	1.58	6.43	0.20	0.14	0.24	0.19
CD (P=0.05)	4.30	3.730	235	3.50	0.10	0.43	0.60	0.38	3.10	4.00	3.29	13.33	0.42	0.28	0.49	0.40
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Effect of growth regulators on yield attributes and yield of soybean

Treatments	Stem girth (cm)							Seed index (gm)				Haulm yield (kg/ha)			
	2012	Mean			2013	2014	Mean	2012	2013	2014	Mean	2012	2013	2014	Mean
Growth regulators															
Salicylic acid @ 100 mg/l	2.19	2.30			52.65	56.73	52.96	14.21	12.88	14.16	13.75	2194	1985	3563	2580
Ethrel @ 200 mg/l	1.99	2.00			49.98	56.24	52.06	13.62	14.54	15.03	14.40	1764	2304	3062	2376
Cycocel @ 500 mg/l	1.84	1.85			43.36	47.64	44.79	12.84	13.14	14.12	13.37	1646	1729	2683	2019
Water spray (Control)	1.62	1.63			38.92	43.26	40.24	11.83	12.10	13.10	12.34	1532	1609	2460	1867
SEd	0.08	0.09			2.61	2.09	2.13	0.57	0.73	0.64	0.65	117	106	562	261
CD(P=0.05)	0.17	0.20			5.41	4.34	4.43	1.18	NS	NS	NS	243	220	271	244
Stage of application															
Flower Initiation	1.82		1.84	42.82	42.82	80.26	55.30	12.74	13.03	13.52	13.10	1638	1720	2787	2048
Pod Initiation	1.90		1.92	45.06	45.06	84.63	58.25	13.09	13.40	14.08	13.52	1730	1817	2904	2150
Flower +Pod Initiation	2.01		2.07	48.13	50.81	93.19	64.04	13.54	13.07	14.37	13.66	1984	2183	3214	2460
SEd	0.07		0.08	1.47	2.26	1.81	1.85	0.49	0.63	0.52	0.55	101	92	238	144
CD (P=0.05)	0.15		0.17	3.06	4.69	3.76	3.84	NS	NS	NS	NS	211	191	494	299
Interaction	NS		1.84	6.32	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3. Effect of growth regulators on economics of soybean

Treatments	Seed yield (kg/ha)				Cost of cultivation (Rs/ha)				Net returns (Rs/ha)				B:C ratio			
	2012	2013	2014	Mean	2012	2013	2014	Mean	2012	2013	2014	Mean	2012	2013	2014	Mean
Growth regulators																
Salicylic acid @ 100 mg/l	1229	1377	1375	1264	10309	10929	11679	10972	5668	12851	15821	11447	1.55	2.18	2.35	2.03
Ethrel @ 200 mg/l	991	1189	1181	1183	10683	11303	12053	11346	2200	16237	11567	10001	1.21	2.44	1.96	1.87
Cycocel @ 500 mg/l	925	1036	1035	999	10416	11076	11826	11106	2109	9644	8874	6876	1.15	1.87	1.75	1.59
Water spray (Control)	860	952	952	921	10283	10943	11393	10873	1897	8097	7647	5880	1.09	1.74	1.67	1.50
SEd	56	64	50	57												
CD (P=0.05)	116	132	105	118												
Stage of application																
Flower Initiation	920	1031	1345	1099	10280	10940	11600	10940	1680	9680	15300	8887	1.16	1.88	2.32	1.79
Pod Initiation	972	1089	1401	1154	10280	10940	11600	10940	2356	10840	16420	9872	1.23	1.99	2.42	1.88
Flower +Pod Initiation	1112	1295	1551	1319	10885	11545	12205	11545	3571	14355	18815	12247	1.33	2.24	2.54	2.04
SEd	48	55.	44	49												
CD (P=0.05)	101	115	91	102												
Interaction	NS	NS	NS	NS												

Pooled mean of 2013-14 the highest seed index was recorded in application at flower + pod initiation stage. Time of application should not influence the seed index. The increase in seeds/ pod and seed index with growth retardant treatments might be due to better translocation of photosynthates by shortening the plant height.

Haulm yield was significantly influenced by all the treatments in all the years (Table 2). Application of salicylic acid @100 mg/l recorded significantly higher haulm yield than all other treatments. This treatment recorded 13, 19 and 24 % higher haulm yield than cycocel, ethrel and water spray, respectively. During 2012 and 2014, the highest haulm yield was recorded in salicylic acid spray @100 mg/l, which was significantly higher than any other growth regulators.

Time of application of growth regulators at flower +pod initiation stages influenced the haulm yield significantly. All the growth regulators recorded significantly higher seed yield than water spray. Among them salicylic acid spray @100 mg/l was found to be better than others (Table 3). It might be due to higher seed index. The use of plant growth regulators has been found to greatly affect the reproductive development, partitioning coefficient, seed yield per plant and seed quality (Setia *et al*, 1996). The seed yield recorded in salicylic acid spray @100 mg/l was 6.41, 20.96 and 27.13% higher in cycocel, ethrel and water spray, respectively. During 2012-14, when mean values were compared salicylic acid sprays @ 100 mg/l recorded the highest seed yield but, it which was found to be statistically on par with ethrel 200 mg/l. It might be due to more number of pods per plant.Vaiyapuri *et al.* (2012) reported higher seed yield of soybean with application of salicylic acid @100 mg/l due to increased numbers of pods per plant, seed yield and higher pod setting. Time of application of growth regulators at flower + pod initiation gave significantly higher seed yield than either flower or pod alone

Economics

The cost of ethrel was more, so the cost of cultivation was the highest in this treatment. Cost of application of growth regulators was found to be the highest, when it was used in two stages of growth *i.e.* at flower and pod initiation. Application of all growth regulators significantly increased the net returns as compared to water spray. It was mainly due to increased grain yield in such treatments. The highest net returns and benefit cost ratio were recorded in salicylic acid @100 mg/l during flower initiation and pod initiation stages. However, net returns in salicylic acid @100 mg/l and ethrel @200 mg/l was almost similar in all the years pooled mean. Interaction effects were found to be non-significant in respect of all the characters. It could be concluded from the study that application of salicylic acid @100 mg/l at flower and pod initiation stages will help to enhance the grain yield, net returns and benefit cost ratio in soybean.

Conclusion

It could be concluded from the study that application of salicylic acid @100 mg/l at flower and pod initiation stages will help to enhance the grain yield, net returns and benefit cost ratio in soybean

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