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AP Solanke
Department of Agricultural Botany, College of Agriculture, VNMKV, Parbhani, Maharashtra, India

GS Pawar
Department of Agricultural Botany, College of Agriculture, VNMKV, Parbhani, Maharashtra, India

SR Dhadge
Department of Agricultural Botany, College of Agriculture, VNMKV, Parbhani, Maharashtra, India

BG Kamble
Department of Agricultural Botany, College of Agriculture, VNMKV, Parbhani, Maharashtra, India

Correspondence
AP Solanke
Department of Agricultural Botany, College of Agriculture, VNMKV, Parbhani, Maharashtra, India

Effect of plant growth regulators on growth and yield of soybean (*Glycine max*. (L.) Merrill.) applied at different stages

AP Solanke, GS Pawar, SR Dhadge and BG Kamble

Abstract
Plant growth substances are well-known to improve the source-sink connection and encourage the translocation of photo-assimilates there by helping in effective flower formation, fruit and seed development and ultimately increase the yield of crops. A field experiment was conducted at VNMKV, Parbhani, MH. during June 2017 to Oct 2017 in a Randomized Block Design (RBD) based on three replications with a view to find out the influence of different plant growth regulators applied at different stages on the growth and yield of soybean cv. Application of plant growth regulators at flower initiation stage (35 DAS) and pod initiation stage (50 DAS) on plant showed significant effect on plant height, number of branches plant-1, chlorophyll content (SPAD value), Dry weight plant-1 and seed yield of soybean. Results showed that spraying of GA_3 @ 100ppm produced the higher plant height (43.37cm, 56.72cm, 69.22cm) and higher leaf area observed (6.5dm^2, 11.57dm^2, 15.53dm^2), Spraying of CCC @ 250ppm produced the higher number of branches (3.04, 4.98, 5.87) and same in chlorophyll content and protein content and also gave the highest dry weight (19.16 g plant-1) of soybean at harvest. Results also revealed that Seed yield highest recorded in spraying of TIBA @ 50ppm (21.24q/ha) at par with CCC @ 250ppm and MC 500ppm as compared to other growth regulators. So TIBA acts an important role for increasing soybean yield, when it was applied at 35 DAS and 50 DAS.

Keywords: Foliar spray, growth regulators, *Glycine max* (L.) Merrill tiba

Introduction

Soybean (*Glycine max* L.) is the wonder crop of the 20th Century, a species of legume, native to China, which belongs to family leguminoaceae with sub-family Papilionaceae. It was introduced in India during 1960's and is gaining rapid recognition as a highly desirable oil seed crop. Soybean as an indispensable source of plant protein is become more vital. The seed supplies 30% of world vegetable oil and 60% of vegetable protein. Soybean seed consists of 18-22 percent oil and 40-42 percent protein content. It is the cheapest and main source of dietary protein of majority of vegetarian (hence it is known as poor man's meat). In Maharashtra soybean production during *kharif* 2017 was 31.89 lakh MT from an area of 34.48 lakh hectares with the productivity of 925 kg ha^{-1} (Anonymous 2017) [2]. However, in farmer's field its average yield is much lower due to lack of improved agricultural practices of which different growth regulators application is an important determinant for better performance of soybean.

Plant growth regulators when applied in very small quantity influence the plant growth. Several reports indicated that application of growth regulator improved the plant growth and yield. The 2, 3, 5-triiodobenzoic acid (TIBA) is well-known plant growth regulators. The application of TIBA in soybean resulted in higher grain yield (Pankaj kumar *et al*., 2001) [15]. GA_3 enlarged length of stem and flower number plant^{-1}. GA_3 accelerated stem elongation and bud development. Kinetin increased the fresh weight by increasing stem diameter in morning glory but reduced shoot length (Chaudhry and Khan, 2000) [6]. Salicylic acid is an endogenous signaling molecule and it has several functions, particularly the suppression of germination and growth, intervention with root absorption, reduced leaf abscission and transpiration (Ashraf *et al*., 2010; Hayat *et al*., 2010) [3, 7]. Application of salicylic acid also significantly increased root dry weight. Salicylic acid application to soybean and corn promoted dry weight and leaf area of plants (Khan *et al*., 2003) [10].

The use of growth regulators is becoming popular to increase crop yield and varieties of such substances are available in the market which is being utilized for crop production. Therefore, keeping in view the importance of different growth regulators in increasing crop growth and yield, a study was carried out to compare the effect of TIBA, CCC, MH, GA_3, IAA, salicylic acid and ABA on the growth and yield of soybean.

Materials and Methods
Site description
A field experiment was conducted at VNMKV, Parbhani, MH. during June 2017 to Oct 2017 in in Rabi season which was situated at 19°16′ N latitude and 76□47□ E longitude and at an 409 altitude above the sea level. The soil of the experimental site was black cotton. The experimental site is under subtropical climatic conditions and the weather condition during the experiment is presented in table 1.

Experimental treatments
The experiment was consisted of four plant growth regulators *viz.,* Control (water) (T_1), Salicylic acid @ 50ppm (T_2), IAA @ 100ppm (T_3), CCC @ 250ppm (T_4), Mepiquat chloride @ 500ppm (T_5), ABA @ 10ppm (T_6), TIBA @ 50ppm (T_7), Gibberellic acid (GA_3) @ 100ppm (T_8), MH @ 1000ppm (T_9) and two stages of application *i.e* flower initiation stage at 40 DAS and pod initiation stage at 50 DAS

Planting materials, design and plot size
The variety MAUS-158 was used and experiment was arranged in Randomized Complete Block Design (RCBD) with three replications and comprised of 27 unit pots. The size of each pot was 2.7m x 4m.

Fertilizer application and sowing of seeds in the pot
Urea, Single super phosphate (SSP), Muriate of potash (MOP) and DAP were used as a source of nitrogen, phosphorous, potassium, sulphur, boron and molybdenum, respectively. The fertilizers urea, SSP, MOP, and DAP were applied as per recommendation.

Preparation and application of plant growth regulators
All the growth regulators solution made by dissolved in specific solvent and then mixed with water. Plant growth regulators were foliar sprayed as per treatment at different stages of crop by a mini hand sprayer.

Chlorophyll content (SPAD value)
Chlorophyll content of leaves was measured at an interval of 15 days starting from 30 DAS till harvest. Mature leaves were measured all time. Three mature plant of each pot were measured by using portable chlorophyll Meter (SPAD -502, Minolta, japan)

Statistical analysis
Collected data on different parameters were statistically analyzed by using “Analysis of variance method” (Panse and Sukhatme, 1967)

Table 1: Weather data of the experimental site during the period from June to october 2017

Year	Month	Mean temperature (°C)		Rainfall (mm)
		Maximum	Minimum	
	June	34.5	24.0	259.8
2017	July	31.8	23.0	115.9
	Auguest	29.6	22.7	285.1
	September	25.7	22.6	164.7
	October	30.3	19.8	170.2

Results and Discussion
Plant height
Different plant growth regulators and stages of application exposed significant variation in plant height at different days after sowing (DAS) (Table 2). Plant height increased with increasing its growing period but at harvest it slightly decreased. . After 1st spraying the measured plant height in treatment T8 - GA3 @ 100 ppm (43.37 cm) was significantly higher plant height and at par with T3 - IAA @ 100 ppm (42.53 cm) and T7 - Salicylic Acid @ 50 ppm (41.12 cm). However lower plant height was recorded in T4 - CCC @ 250 ppm (32.16 cm) as compared to T1 - Control (38.24 cm) and similar trend of observation are observed after 2nd spraying and At harvest. Similar observation observed by Mehetre and lad (1995) [14] in soybean, Sarkar *et al*., (2002) [18] in soybean, Leite *et al*., (2003) [13] in soybean, Bora *et al*., (2006) [4] in pea, Upadhyay *et al*., (2015) [22] in soybean, The recorded plant height in treatment T2 -Salicylic Acid @ 50ppm, T4 CCC @ 250ppm, T9 MH @ 1000ppm T5 Mepiquat chloride @ 50ppm and T6 -ABA @ 10ppm was shown the reduction in plant height as compared to control treatment and T4 – CCC @ 250ppm caused greater reduction in plant height as compared with control and all other treatment. These results are in conformity with the findings of Patil (1994) in soybean, Hunje *et al*., (1995) [8], Kothule *et al*., (2003) [12], Pankaj kumar *et al*., (2002), Sarkar *et al*., (2002) [18] in soybean.

Number of branches plant^{-1}
Number of branches plant-1 varied significantly due to different plant growth regulators and stages of application at different DAS (Table 2). After 1st spraying, the observed no. of branches per plant in treatment T4- CCC @ 250 ppm (3.04) was significantly higher no. of branches per plant and at par with T2-Salicylic Acid @ 50 ppm (2.8) and T9- MH @ 1000 ppm (2.91). T8 GA3 @ 100 ppm (2.15) recorded lower no.of branches per plant as compared to T1 - Control (2.55). After 2nd spraying, the observed no.of branches per plant in treatment T4- CCC @ 250 ppm (4.98) was significantly higher no.of branches per plant and at par with T2 Salicylic Acid @ 50 ppm (4.59) and T9 MH @ 1000 ppm (4.77). But T8- GA3 @ 100 ppm (3.05) recorded lower no. of branches per plant as compared to T1-Control (4.01). After harvest, the observed no. of branches per plant in treatment T4- CCC @ 250 ppm (5.87) was significantly higher no. of branches per plant and at par with T2 Salicylic Acid @ 50 ppm (5.37) and T9¬-MH @ 1000 ppm (5.58). But T8- GA3 @ 100ppm (3.38) recorded lower no. of branches per plant as compared to T1–Control (4.56).

These results are in conformity with the findings of Hunje *et al*., (1995) [8] in soybean, Kothule *et al*., (2003) [12], Pankaj kumar *et al*., (2002) where they observed and also concluded that it an increase in number of branches by CCC might be due to inhibition of apical bud dominance and breaking of lateral bud dormancy.

Total weight plant^{-1}
Different plant growth regulators and stages of application exerted significant effect on dry weight plant^{-1} of soybean at different DAS (Table 3). After 1st spraying, the measured total dry weight per plant in treatment was significantly higher T_7-TIBA @ 50ppm (8.11gm) and at par with T_4-CCC @ 250ppm (7.92 gm) and T_5-Mepiquat chloride (7.85 gm), However the lowest total dry weight per plant was recorded in T_1-Control (5.77 gm). After 2nd spraying, the measured total dry weight per plant in treatment was significantly higher T_7-

TIBA @ 50 ppm (14.43 gm) and at par with T4-CCC @ 250ppm (14.09 gm) and T5- Mepiquat chloride @ 500ppm (13.97 gm), however the lowest total dry weight per plant was recorded in T1-Control (9.63 gm). At harvest, the measured total dry weight per plant in treatment was significantly higher T7- TIBA @ 50 ppm (19.62 gm) and at par with T4-CCC @ 250 ppm (19.16 gm) and T5- Mepiquat chloride (18.99 gm), however the lowest total dry weight per plant was recorded in T1¬- Control (11.84 gm).

Similar results were recorded by Ramesh *et al*. (2013) where they also concluded that application of CCC and Mepiquat chloride increases total dry weight, yield and other yield attributing character. The results are in agreement with findings Mehetre and Lad, (1995) [14] in soybean, Pankaj Kumar (2001) [15] in soybean, Sarkar *et al*., (2002) [18] in soybean, Kothule *et al*. (2003) [12] in soybean.

Leaf area plant^{-1}

Different plant growth regulators spraying application exerted significant effect on leaf area plant-1 of soybean at different DAS (Table 3). After 1st spraying, recorded leaf area per plant in treatment T8-GA3 @ 100ppm (6.5 dm2) was significantly higher and at par with T3-IAA @ 100ppm (6.42 dm2) and T7-TIBA @ 50ppm (6.19dm2), However the lower leaf area per plant was recorded in treatment T1- Control (3.97 dm2). After 2nd spraying, recorded leaf area per plant in treatment T8 -GA3 @ 100 ppm (11.57 dm2) was significantly higher and at par with T3 -IAA @ 100ppm (11.42 dm2) and T7 - TIBA @ 50ppm (11.01dm2), However the lower leaf area per plant was recorded in treatment T1-Control (6.7 dm2). At harvest, recorded leaf area per plant in treatment T8 - GA3 @ 100 ppm (15.73 dm2) was significantly higher and at par with T3-IAA @ 100 ppm (15.53 dm2) and T7 - TIBA @ 50 ppm (14.75 dm2), However the lower leaf area per plant was recorded in treatment T1-Control (8.44 dm2).

This is in accordance with Kalyankar *et al*. (2008) [9] who obtained significantly higher leaf area due to GA3 treatment in soybean. In their experiment they found that the application of growth promoter GA3(100ppm) and IAA (100ppm) increased leaf area due to positive effects on cell division and cell elongation leading to enhanced leaf growth and Punkaj kumar *et al*., (2002) in soybean concluded that CCC (250ppm), MC (500 ppm), TIBA (50ppm) these can reduced leaf area. The results are in agreement with findings Mehetre and Lad, (1995) [14] in soybean, Kothule *et al*., (2003) [12] in soybean, Chikkappiah *et al*., (2008) [5] in soybean.

Table 2: Effect of different plant growth regulators and stages of application on the plant height and no. of branches of soybean

Treatments	Plant height (cm)			No. of Branches		
	After 1st spraying	After 2nd spraying	At harvest	After 1st spraying	After 2nd spraying	At harvest
T_1 - Control	38.24	48.63	61.08	2.55	4.01	4.56
T_2 - Salicylic Acid @ 50ppm	36.16	45.92	55.79	2.8	4.59	5.37
T_3 - IAA@ 100ppm	42.38	55.53	67.46	2.21	3.16	3.63
T_4 - CCC@250ppm	32.16	41.16	49.68	3.04	4.98	5.87
T_5 - Mepiquat chloride @ 500ppm	35.91	44.87	54.49	2.6	4.1	4.67
T_6 - ABA @ 10 ppm	37.67	47.57	57.77	2.24	3.2	3.74
T_7 - TIBA @ 50 ppm	41.12	50.82	65.94	2.68	4.28	5.2
T_8 - GA3 @ 100ppm	43.37	56.72	69.22	2.15	3.05	3.38
T_9 - MH @1000ppm	32.6	41.75	51.15	2.91	4.77	5.58
S.E.	0.9	1.56	1.12	0.087	0.136	0.22
C.D.at 5%	2.705	4.7	3.38	0.261	0.408	0.66
General mean	37.75	48.353	59.09	2.58	4.015	4.666

Table 3: Effect of different plant growth regulators and stages of application on the total dry weight and leaf area per plant of soybean

Treatments	Total dry weight (dm^2)			Leaf area plant^{-1}		
	After 1st spraying	After 2nd spraying	At harvest	After 1st spraying	After 2nd spraying	At harvest
T_1 - Control	5.77	9.63	11.84	3.97	6.7	8.44
T_2 - Salicylic Acid @ 50 ppm	5.82	9.71	12.23	4.21	7.11	9.24
T_3 - IAA@ 100ppm	5.93	10.02	12.72	6.42	11.42	15.53
T_4 - CCC@250ppm	7.92	14.09	19.16	4.68	8.34	11.07
T_5 - Mepiquat chloride @ 500 ppm	7.85	13.97	18.99	5.51	9.92	13.29
T_6 - ABA @ 10 ppm	6.91	11.88	15.91	4.1	6.93	8.93
T_7 - TIBA @ 50 ppm	8.11	14.43	19.62	6.19	11.01	14.75
T_8 - GA3 @ 100ppm	6.76	11.62	15.1	6.5	11.57	15.73
T_9 - MH @1000ppm	7.16	12.31	16.49	4.76	8.52	11.45
S.E.	0.15	0.27	0.48	0.44	1.25	1.06
C.D.at 5%	0.44	0.82	1.44	0.95	2.65	2.26
General mean	6.91	11.96	15.78	5.15	9.07	12.05

Chlorophyll content (SPAD value)

Different plant growth regulators and stages of application showed significant variation in case of chlorophyll content of soybean leaf at different DAS (Table 4). Before 1st spraying, Significantly higher chlorophyll (SPAD value) was estimated under T_4 - CCC @ 250ppm (48.89) at par with T_9 - MH @ 1000ppm (48.17) while, the lowest chlorophyll (SPAD value) was noted in T_1 - Control (39.44). After 1st spraying, different plant growth regulators spraying showed maximum chlorophyll was expressed in treatment T_4 - CCC @ 250ppm (51.72) at par with T_9 - MH @ 1000ppm (50.83) and lowest chlorophyll (SPAD value) was estimated in T_1 - Control (41.78). After 2nd spraying, Chlorophyll (SPAD value) was tremendously decreases in that stage. The significantly maximum Chlorophyll (SPAD value) was recorded in treatment T_4 - CCC @ 250ppm (33.82) at par with T_9 -MH @ 1000ppm (30.65) while, the lowest chlorophyll (SPAD value) was noted in T_1- Control (26.12).

The results in case of chlorophyll (SPAD) is in agreement with the findings of Reena Tagade *et al*., (1998) [20], Pankaj

Kumar *et al*.,(2002) in soybean, Senthil *et al.*, (2003) [19] in soybean, Reddy *et al.*, (2009) [17], Khatun *et al*.,(2016) [11] in soybean.

Protein content (%)

Protein content in percentage is presented in the table 4 which was found to be non-significant. Data ranges from 38.83% (T_1) to 42.11% (T_9) for protein content. Higher protein content was recorded by treatment T_4 - CCC @ 250 ppm (42.11), followed by treatment T_4, T_2, T_6, T_7, and T_5. Lowest protein content was recorded by T_1 (control) (38.83%).

The results in case of protein content is in agreement with the findings of Sarkar *et al.* (2002) [18] in soybean, Bora and Sharma (2006) [4] in pea, Travaglia *et al*., (2009) [21], Devi *et al*., (2012).

Table 4: Effect of different plant growth regulators and stages of application on the chlorophyll content (SPAD), Protein content percentage, Seed yield per plot and seed yield per hectar of soybean

Treatments	Chlorophyll content (SPAD)			Protein content	Seed yield (kg/plot)	Seed yield (q/ha)
	After 1st spraying	After 2nd spraying	At harvest			
T_1 - Control	39.44	41.78	26.12	38.83	1.82	16.85
T_2 - Salicylic Acid @ 50 ppm	43.08	44.09	28.43	41.44	1.96	18.14
T_3 - IAA@ 100ppm	41.13	42.97	27.74	39.18	1.89	17.5
T_4 - CCC@250ppm	48.89	51.72	33.82	42.11	2.11	19.53
T_5 - Mepiquat chloride @ 500 ppm	46.98	48.56	29.84	40.82	2.16	20.1
T_6 - ABA @ 10 ppm	44.76	46.69	29.05	41.24	2.01	18.61
T_7 - TIBA @ 50 ppm	43.83	44.91	28.76	41.22	2.29	21.24
T_8 - GA3 @ 100ppm	41.77	43.48	27.93	39.18	1.85	17.12
T_9 - MH @1000ppm	48.17	50.83	30.65	41.54	2.07	19.16
S.E.	0.2697	0.3058	0.4851	1.02	0.06	0.69
C.D.at 5%	0.81	0.92	1.46	NS	0.19	2.07
General mean	44.23	46.11	29.15	40.62	2.02	18.69

Seed yield (q/ha)

Different plant growth regulators and stages of application showed significant variation in case of chlorophyll content of soybean leaf at different DAS (Table 4). Treatment T_7 (TIBA @ 50 ppm) gave significantly highest seed yield per plant, seed yield per plot and seed yield per hectare followed by T_4 (CCC @ 250 ppm) and T_5 (MC @ 500 ppm) respectively. These results are in conformation with the findings Sarkar *et al.*, (2002) [18], Pankaj Kumar *et al.*, (2002), Devi *et al*., (2012), Agawane *et al.*, (2015) [1].

Conclusion

Application of plant growth regulators at different stages plays an important role in soybean growth and yield. All the applied growth regulators increase yield as compared to control but TIBA increase yield as compare to other and over control. Although GA_3, IAA, CCC and MH showed better growth performance of soybean, but yield is the ultimate goal of cultivating any crop. From the above results and discussion it may be concluded that, application of TIBA at flowering stage 35 DAS and pod initiation stage (50 DAS) would be promising practice for soybean yield.

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