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Influence of GA_3 and MH and Their Time of Spray on Morphology, Yield Contributing Characters and Yield of Soybean

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Abstract: The experiment was conducted to study the effect of plant growth regulators and their time of spray on morphology, yield and yield contributing characters of soybean. Plants of soybean Cv. PB-1 were sprayed three times (T_1 = spray at 15 DAS, T_2 = spray at 30 DAS and T_3 = spray at 45 DAS) with two concentrations (100 and 200 ppm) of gibberellic acid (GA_3) and maleic hydrazide (MH). Significant variations exist among the concentrations of growth regulators and with their time of application in respect of morphological, yield and yield contributing characters of soybean. T_2 followed by T_3 produced the tallest plant with the highest number of branches, leaves, flowers, pods per plant, number of seeds per pod, seed yield per plant, 100-seed weight and seed yield (t ha^{-1}). T_1 produced the least of them. GA_3 was more effective than MH. GA_3 at 100 ppm followed by GA_3 at 200 ppm produced the highest number of branches, leaves, flowers, pods per plant, number of seeds per pod, seed yield per plant, 100-seed weight and seed yield (t ha^{-1}) while 200 ppm MH was least effective to produce them. The present study clearly shows that almost all the plants treated with growth regulators performed better than control. However, interaction effect indicated that 100 ppm GA_3 treated plants sprayed at 30 DAS (T_2C_3) showed the best performance.

Key words: Gibberellic acid (GA_3), Maleic hydrazide (MH), morphology, soybean (*Glycine max* L.), yield

INTRODUCTION

Soybean is one of the most important economic food legumes cultivated world wide because of its higher nutritional and industrial values. It is an introduced crop in Bangladesh and usually used as ingredient of poultry, dairy and fish feeds. The multipurpose use of soybean is gradually increasing in our country. Besides oil, soybean seeds are used for producing many of the foods like soya-milk, soya-dal, soya-curd, soya-flour, soya-khichuri, soya-chatni, baby food, confectioneries and roasted soybean snacks which are becoming familiar to the people of Bangladesh. Soybean contributes more than 41% of the total oil seed production of the world[1]. According to the planning commission of the People's Republic of Bangladesh, about 1,82,000 tons of edible oil is necessary every year whereas the indigenous production is only 54,990 tons[2]. Under this circumstances, a large amount of foreign currency is being spent every year for buying the deficit amount of oil. So, it is essential to increase soybean cultivation in Bangladesh.

In Bangladesh, among all the oil seed crops, mustard tops the list in terms of area, while soybean is treated as such a very minor pulse and oil crop concentrated only in few districts and locations that the reference of soybean does not appear in the regular national statistics. The statistical information is rare regarding production and acreage of soybean in Bangladesh. It was estimated to cover about 5000 hectares with approximately 7500 tons of production all over the country in 1997[3]. Research and extension works on soybean have been started in 1972-73 by Mannonite Central Committee and subsequently by Bangladesh Agricultural Research Council. But still the yield of soybean here is very discouraging compared to other soybean producing countries. This is mainly due to the use of low yield potential varieties and poor cultivation techniques, especially due to lack of knowledge about modern production technique i.e., lack of judicious application of irrigation water, fertilizer, growth regulators etc. GA_3 and MH are two plant growth regulators which can manipulate a variety of growth and developmental phenomena in various crops. Foliar application of GA_3 has been found to increase stem diameter, promote stem elongation and leaf formation, accelerated flowering, increase the length of the flower stalk and number of flowers or inflorescence[4] as well as total yield[5-7]. It was also reported that soybean yield was increased by the application of MH[8].

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Studies in other countries of the world provided useful information regarding the use of growth regulators on soybean. Unfortunately, very limited works have been carried out in Bangladesh in this regard. Studies on the effects of growth regulators in our climatic condition could provide useful information. Therefore, the present work was designed to study the influence of GA_3 and MH on the morphological and yield contributing characters of soybean and to know the most suitable time of spraying of growth regulators to improve its production.

MATERIALS AND METHODS

The experiment was conducted at the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, during the period from December, 2001 to March, 2002. A single variety of soybean (*Glycine max* L. Cv. PB-1) was used in the present study. The two-factor experiment {Factor A (growth regulators): C_0 = Control, C_1 = 100 ppm MH, C_2 = 200 ppm MH, C_3 = 100 ppm GA_3, C_4 = 200 ppm GA_3 and Factor B (time of spray): T_1 = 15 days after sowing (DAS), T_2 = 30 DAS, T_3 = 45 DAS} was laid out in split plot design with 4 replications. The size of the unit plot was 1x1 m and the distance between plots was 0.5 m. The plots were raised up to 15 cm from the soil surface.

The plots were fertilized with cowdung, urea, triple super phosphate (TSP), muriate of potash (MP) and gypsum @ 6 t ha^{-1}, 50, 150, 100 and 80 kg ha^{-1}, respectively. Total amount of cowdung, urea, TSP, MP and gypsum were applied as basal dose during land preparation. The seeds of soybean were sown on December 11, 2001 with a spacing of 20x10 cm and 2 seeds were placed in each point at 2-3 cm depth from the soil surface. At 15 DAS, seedlings were thinned to one per point. Intercultural operations were done as and when required.

Preparation and application of growth regulators: Plant growth regulators were prepared following the procedure mentioned below and spraying was done at noon by using a hand sprayer.

Gibberellic acid: A 100 ppm solution of GA_3 was prepared by dissolving 100 mg of GA_3 in a small quantity of ethanol prior to dilution with distilled water. Then distilled water was added to make the volume of 1 L to get 100 ppm solution. In a similar way, solutions of 200 ppm were prepared. An adhesive namely, tween 20 @ 0.01% was added (2 drops/100 mL) to each solution[9].

Maleic hydrazide: Solutions of MH were prepared in a similar process followed for the preparation of GA_3 solutions.

Distilled water (control): A corresponding amount of ethanol was added to distilled water making the final volume 1 L for application to the control plants. The adhesive, tween 20 @ 0.01%, was added to the control one.

Crop sampling and data collection: The first crop sampling was done on 20 DAS and it was continued at an interval of 20 days till physiological maturity at 100 DAS. At the time of each harvest, three plants were selected randomly from each plot. The height of the plants was ascertained by measuring with a graduated scale placed from ground level to top of the leaves. Number of branches and leaves per plant were recorded separately at each harvest. Total leaf area of individual sample was measured by an electronic leaf area meter (LI 3000, USA). Yield and yield contributing characters like number of flowers, pods per plant, number of seeds per pod, seed yield per plant, 100-seed weight and seed yield (t ha^{-1}) were also recorded. Data of the experiment were analyzed statistically and the differences between pairs of means were compared by DMRT.

RESULTS AND DISCUSSION

Morphological characters

Plant height: The effect of time of spray on plant height was found significant at all sampling dates except at 20 and 100 DAS (Fig. 1). At all growth stages, T_2 produced the tallest plant and the shortest by the T_1. T_3 was intermediately effective to enhance the height of the plant. Application of growth regulators influenced the plant height significantly at all stages of growth except 20 DAS (Fig. 2). GA_3 applied @ 100 ppm produced the tallest plants and the shortest by control at all growth stages. The interaction effect between time and growth regulators on plant height was significant at all growth stages (Table 1). The tallest plant was produced by T_2C_3 followed by T_2C_4 and the shortest plant was found in T_1C_0. 100 ppm MH was found better to enhance plant height than 200 ppm.

The increase in plant height due to GA_3 application might be due to its effect on elongation of internodes[10]. GA_3-induced highest plant height was observed in soybean[6], okra[11], rice[12] and groundnut[13].

Number of branches per plant: Different times of spray showed significant differences in number of branches per plant except at 80 DAS (Fig. 3). At all growth stages, T_2

Table 1: Interaction effect of plant growth regulators and their time of spray on plant height of soybean at different days after sowing

Treatments	Plant height (cm) 20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1C_0	10.67f	20.21c	32.93g	46.58f	53.62e
T_1C_1	11.19ef	23.92c	42.81ef	60.28c-e	64.38cd
T_1C_2	11.30ef	23.71c	39.66ef	58.75c-e	62.63c-e
T_1C_3	12.75b-e	24.63c	46.29c-e	67.84a-c	68.75a-c
T_1C_4	12.70b-e	24.63c	46.03c-f	67.04a-d	68.75a-c
T_2C_0	11.04f	22.54c	39.92ef	54.92d-f	62.50c-e
T_2C_1	12.33c-f	24.13c	46.03c-f	64.81b-e	68.50a-c
T_2C_2	11.64d-f	23.25c	45.56c-f	63.43b-e	67.63a-d
T_2C_3	14.79a	38.71a	64.35a	76.25a	78.00a
T_2C_4	14.31ab	36.29a	56.56b	73.83ab	74.25ab
T_3C_0	10.93f	23.83c	39.54f	53.33ef	58.63de
T_3C_1	12.32c-f	23.87c	44.86d-f	63.46b-e	67.50a-d
T_3C_2	11.33ef	23.79c	45.12c-f	61.62b-e	65.00b-d
T_3C_3	13.56a-c	35.63ab	51.59bc	71.06a-c	71.00a-c
T_3C_4	13.16b-d	31.84b	50.46cd	69.38a-c	69.25a-c
Sig. level	**	**	*	**	*

Table 2: Interaction effect of plant growth regulators and their time of spray on number of branches per plant of soybean at different days after sowing

Treatments	Number of branches per plant 40 DAS	60 DAS	80 DAS	100 DAS
T_1C_0	0.00	0.92d	2.53	2.75
T_1C_1	0.42	1.59a-d	3.06	3.00
T_1C_2	0.08	1.25d	2.77	2.75
T_1C_3	0.08	1.92a-d	3.34	3.75
T_1C_4	0.00	1.92a-d	3.32	3.25
T_2C_0	0.00	1.42cd	2.63	2.75
T_2C_1	0.00	1.67a-d	3.24	3.25
T_2C_2	0.17	1.59a-d	3.30	3.25
T_2C_3	2.08	2.92a	4.46	4.50
T_2C_4	0.75	2.84ab	3.94	4.00
T_3C_0	0.00	1.25d	2.61	2.75
T_3C_1	0.00	1.58a-d	3.09	3.25
T_3C_2	0.00	1.50b-d	2.99	3.00
T_3C_3	0.00	2.65a-c	3.72	4.00
T_3C_4	0.00	2.00a-d	3.42	3.75
Sig. level	NS	**	NS	NS

Table 3: Effect of time of spray on number of leaves per plant of soybean at different days after sowing

Treatments	Number of leaves per plant 20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1	4.02b	5.25b	9.53b	18.64	21.50
T_2	4.23a	6.63a	11.43a	21.03	23.25
T_3	4.12ab	5.42b	10.51ab	20.85	23.10
Sig. level	**	**	**	NS	NS

Table 4: Effect of plant growth regulators on number of leaves per plant of soybean at different days after sowing

Treatments	Number of leaves per plant 20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
C_0	3.97c	5.42b	9.25c	18.69b	20.08b
C_1	4.03bc	5.67b	10.55b	19.36b	22.08b
C_2	4.06bc	5.47b	10.22bc	19.80b	21.67b
C_3	4.33a	6.47a	11.80a	23.08a	26.33a
C_4	4.22ab	5.80b	10.64b	19.94b	22.92ab
Sig. level	**	**	**	**	*

Table 5: Interaction effect of plant growth regulators and their time of spray on number of leaves per plant of soybean at different days after sowing

Treatments	Number of leaves per plant 20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1C_0	3.83	5.08c	8.16g	17.16	16.50b
T_1C_1	4.00	5.08c	9.66d-g	19.09	21.24b
T_1C_2	4.00	5.17c	9.41b-g	18.33	20.50b
T_1C_3	4.17	5.50c	10.91cd	21.08	23.75ab
T_1C_4	4.08	5.25c	10.75c-e	20.67	24.00ab
T_2C_0	4.00	5.17c	8.67e-g	18.08	18.75b
T_2C_1	4.08	5.6bc	10.42d-f	20.50	22.50b
T_2C_2	4.08	5.67bc	10.08d-g	19.92	22.25b
T_2C_3	4.58	8.91a	14.16a	24.59	32.50a
T_2C_4	4.42	6.75b	13.09ab	22.58	26.24ab
T_3C_0	4.00	5.08c	8.59fg	17.58	18.00b
T_3C_1	4.00	5.50c	9.83d-g	19.25	21.50b
T_3C_2	4.00	5.33c	9.83d-g	19.42	21.50b
T_3C_3	4.33	6.33bc	12.66a-c	22.33	25.50ab
T_3C_4	4.25	6.00bc	11.17b-d	22.08	24.50ab
Sig. level	NS	**	**	NS	*

Table 6: Effect of time of spray on leaf area per plant of soybean at different days after sowing

Treatments	Leaf area per plant (cm^2) 20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1	20.65	111.70	216.83b	406.40	490.53
T_2	24.75	116.00	268.87a	448.07	546.28
T_3	23.97	112.61	234.29b	435.52	494.13
Sig. level	NS	NS	*	NS	NS

Table 7: Effect of plant growth regulators on leaf area per plant of soybean at different days after sowing

Treatments	Leaf area per plant (cm^2) 20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
C_0	18.87	71.41c	208.16c	292.21b	412.16
C_1	21.13	109.38b	231.41bc	429.24ab	540.25
C_2	23.65	90.84bc	241.73b	409.36ab	465.73
C_3	26.51	150.71a	275.57a	542.73a	577.05
C_4	25.46	144.85a	243.12ab	476.44a	556.38
Sig. level	NS	**	**	**	NS

Table 8: Interaction effect of plant growth regulators and their time of spray on leaf area per plant of soybean at different days after sowing

Treatments	Leaf area per plant (cm^2) 20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1C_0	17.17	68.01	184.92f	289.82	307.38
T_1C_1	21.51	89.07	212.95d-f	397.60	456.87
T_1C_2	21.14	87.19	197.82ef	377.90	427.62
T_1C_3	24.22	146.89	244.37c-e	452.58	570.93
T_1C_4	23.86	139.22	244.28c-e	447.99	570.67
T_2C_0	18.30	77.58	195.27d-f	422.65	426.72
T_2C_1	20.78	126.15	237.24c-f	430.90	530.61
T_2C_2	20.21	103.28	241.51c-f	342.28	475.80
T_2C_3	37.25	152.53	372.14a	597.49	732.87
T_2C_4	28.05	149.88	306.35b	591.31	670.19
T_3C_0	18.24	68.66	190.05ef	304.54	398.51
T_3C_1	23.20	98.73	229.87c-f	407.11	466.85
T_3C_2	22.88	96.25	213.08d-f	417.08	464.50
T_3C_3	25.13	148.45	279.15bc	574.85	582.97
T_3C_4	24.94	149.73	250.95b-d	455.85	572.24
Sig. level	NS	NS	**	NS	NS

Table 9: Effect of time of spray on yield and yield contributing characters of soybean

Treatments	No. of flowers/plant	No. of pods/plant	No. of seeds/pod	Seed yield/plant (g)	100-seed wt (g)	Seed yield (t ha^{-1})
T_1	52.48b	39.24c	2.07	6.60b	14.68b	1.93b
T_2	55.49a	48.16a	2.11	7.92a	15.86a	2.16a
T_3	54.30ab	42.83b	2.08	6.69b	15.01b	1.97b
Sig. level	*	**	NS	**	**	*

Table 10: Effect of plant growth regulators on yield and yield contributing characters on soybean

Treatments	No. of flowers/plant	No. of pods/plant	No. of seeds /pod	Seed yield/plant (g)	100-seed wt (g)	Seed yield (t ha^{-1})
C_0	52.44	35.09c	1.86b	5.68c	14.68b	1.68c
C_1	54.33	41.83b	2.11a	7.45a	15.13b	2.07a
C_2	52.66	37.41c	2.15a	6.74b	15.00b	1.94b
C_3	55.65	44.38a	2.19a	7.88a	15.92a	2.25a
C_4	55.38	43.16ab	2.13a	7.59a	15.19b	2.16a
Sig. level	NS	**	**	**	**	*

Table 11: Interaction effect of plant growth regulators and their time of spray on yield and yield contributing characters of soybean at different days after sowing

Treatments	No. of flowers/plant	No. of pods/plant	No. of seeds/pod	Seed yield/plant (g)	100-seed wt (g)	Seed yield (t ha^{-1})
T_1C_0	46.16e	29.62h	1.77e	4.3f	13.69e	1.46g
T_1C_1	50.83c-e	36.91fg	2.05bc	5.8c-e	14.56c-e	1.75fg
T_1C_2	50.74c-e	36.08fg	1.97cd	5.6c-e	14.53c-e	1.72fg
T_1C_3	59.33ab	42.83b-d	2.19ab	8.12b	15.55bc	2.24b-d
T_1C_4	56.24bc	41.49c-e	2.17ab	8.08b	15.51bc	2.19b-d
T_2C_0	48.19de	36.08fg	1.89c-e	5.32d-f	14.23de	1.56g
T_2C_1	54.33b-d	40.66c-f	2.07bc	8.03b	15.44bc	2.10c-e
T_2C_2	52.24c-e	39.83d-f	2.05bc	6.49c	15.27b-d	2.03d-f
T_2C_3	63.33a	49.33a	2.35a	9.49a	17.59a	2.59a
T_2C_4	60.33ab	48.16a	2.32a	9.12ab	16.04b	2.46ab
T_3C_0	47.41de	34.99g	1.85de	5.19c-f	13.80e	1.56g
T_3C_1	51.74c-e	39.24d-g	2.07bc	6.43c	15.38bc	2.03d-f
T_3C_2	51.08c-e	38.66d-g	2.05bc	6.32cd	14.65c-e	1.77e-g
T_3C_3	59.99ab	46.58ab	2.27a	8.83ab	15.96b	2.45ab
T_3C_4	59.41ab	45.16a-c	2.27a	8.81ab	15.59bc	2.42a-c
Sig. level	**	**	**	**	**	**

NS= Not significant, *,**, significant at 1 and 5% level, respectively. Figures in a column with same letter(s) do not differ significantly as per DMRT

produced the maximum number of branches followed by T_3 and T_1. However, the effect of T_1 was statistically similar to that of T_3. Figure 4 shows significant differences among the concentrations of growth regulators at 40, 60 and 80 DAS. 100 ppm GA_3 produced the maximum number of branches followed by 200 ppm GA_3. Growth regulators had the superiority over control in increasing the number of branches at all growth stages. The interaction effect between times and growth regulators on the number of branches was significant only at 60 DAS (Table 2). Maximum number of branches was found in T_2C_3 and the minimum was observed in the interaction between T_1C_0 indicating early spray (spray at 15 DAS) is least effecting to produce branches in soybean plant.

In the present study, both GA_3 and MH had stimulatory effect on the number of branches per plant. GA_3-induced higher number of branches was found in soybean[6]. MH-induced higher number of branches was also reported in fenugreek by Alagukannan and Vijayakumar[14].

Number of leaves per plant: Number of leaves per plant was recorded from 20 DAS to 100 DAS. Among the times of spray, T_2 produced significantly higher number of leaves at 20, 40 and 60 DASs followed by T_3 and T_1 (Table 3). At 80 and 100 DAS, T_2 also produced the maximum number of leaves per plant, however, the result was statistically not significant. The results revealed a significant variation in number of leaves due to the effect of growth regulators applied at different phenophases of soybean (Table 4). The treated plants generated significantly higher number of leaves per plant. At 100 DAS, 100 ppm GA_3 induced maximum number of leaves (26.33) followed by 200 ppm (22.92) indicating that GA_3 was better at lower level than its higher level. Control plants had the minimum number of leaves. Interaction effect between time of spray and growth regulators on the number of leaves was significant at 40, 60 and 100 DASs (Table 5). Non-sprayed control plants performed worst than the sprayed plants. At all growth stages, T_2C_3 produced maximum number of leaves followed by T_2C_4.

In this experiment, the treated plants generated significantly higher number of leaves per plant. Satheeshan and Mohan Kumaran[15] reported that 100 ppm MH increased the number of leaves in *Costus speciosus*. Similarly, GA_3-induced higher number of leaves was reported in wheat[16], soybean[6], faba bean[17] and bell pepper[18].

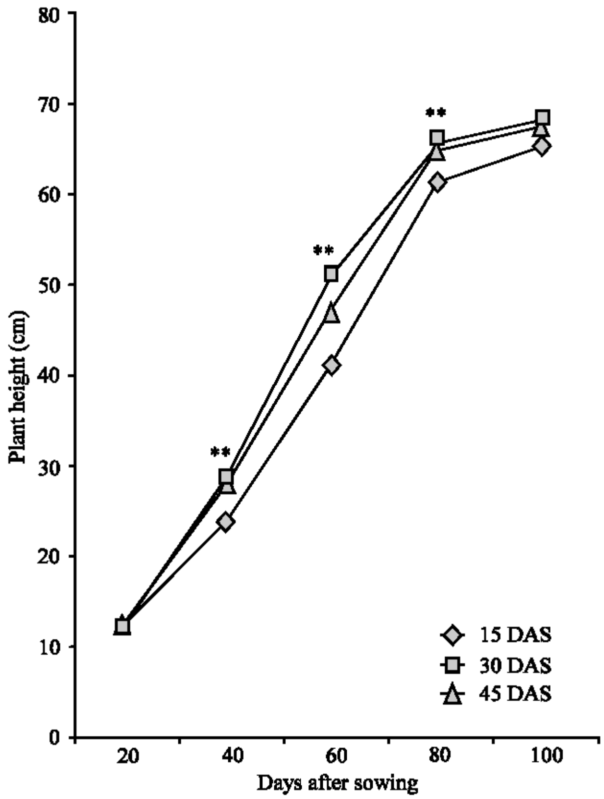

Fig. 1: Effect of time of spray of growth regulators on plant height of soybean at different days after sowing. **, significant at 1% level

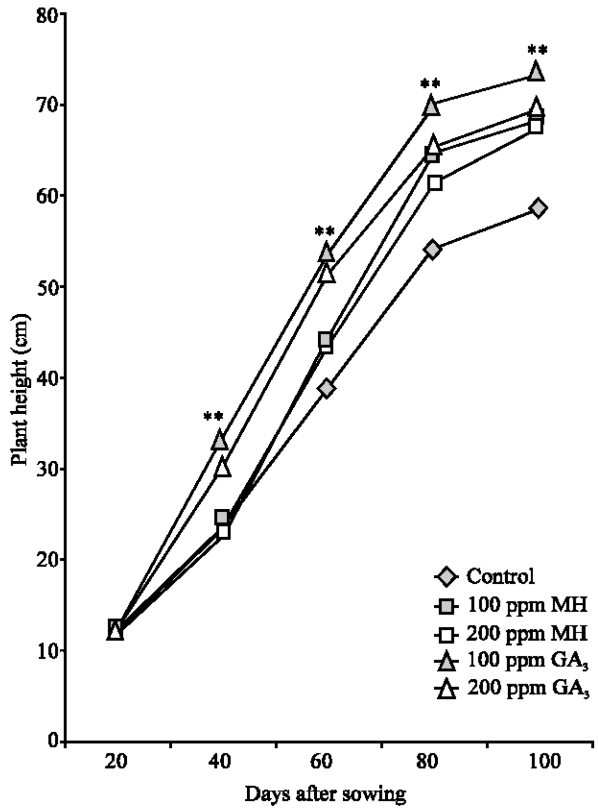

Fig. 2: Effect of plant growth regulators on plant height of soybean at different days after sowing. **, significant at 1% level

Leaf area per plant: Effect of time of spray on leaf area per plant was significant only at 60 DAS (Table 6). T_2 produced the maximum leaf area (268.87 cm^2) followed by T_3 and T_1. However, T_1 and T_3 were statistically similar in effect. The effect of growth regulators on the leaf area was significant at different growth stages except 20 and 100 DASs (Table 7). All the growth regulators increased leaf area with the advancement of growth stages. At 100 DAS, 100 ppm GA_3 produced the maximum leaf area per plant (577.05 cm^2) followed by 200 ppm GA_3 (556.38 cm^2) and the minimum (412.16 cm^2) was observed in the control. Interaction effect between the time of spray and growth regulators on the leaf area was significant only at 60 DAS (Table 8). At all growth stages, the maximum leaf area was found in T_2C_3 and the minimum was observed in the interaction between T_1C_0.

The results of the present experiment supports the findings of Naidu and Swamy[19]. Leaf area depends on the size and number of leaves. Therefore, the increase in leaf area due to the application of growth regulators might be due the increase in the number of leaves per plant in present experiment.

Yield and yield contributing characters

Number of flowers per plant: The total number of flowers per plant was counted in the field in individual treatment for each time of application. The difference due to time of application of growth regulators in relation to the number of flowers formed per plant was statistically significant (Table 9). The highest number of flowers was observed in T_2 (55.49) and the lowest was in T_1 (52.48). T_3 produced the intermediate number of flowers per plant (54.30). Table 10 showed that there was no significant difference on number of flowers per plant within the treatments although the growth regulators had positive effect over the control. 100 ppm GA_3 produced the maximum number of flowers (55.65) followed by 200 ppm GA_3 (55.38) and the control had the lowest (52.44). Interaction effect of different levels of growth regulators and their time of spray showed significant variations on number of flowers per plant (Table 11). The highest number of flowers (63.33) was produced by T_2C_3 followed by T_2C_4 (60.33). The interaction of T_1C_0 had the lowest number of flowers per plant (46.16).

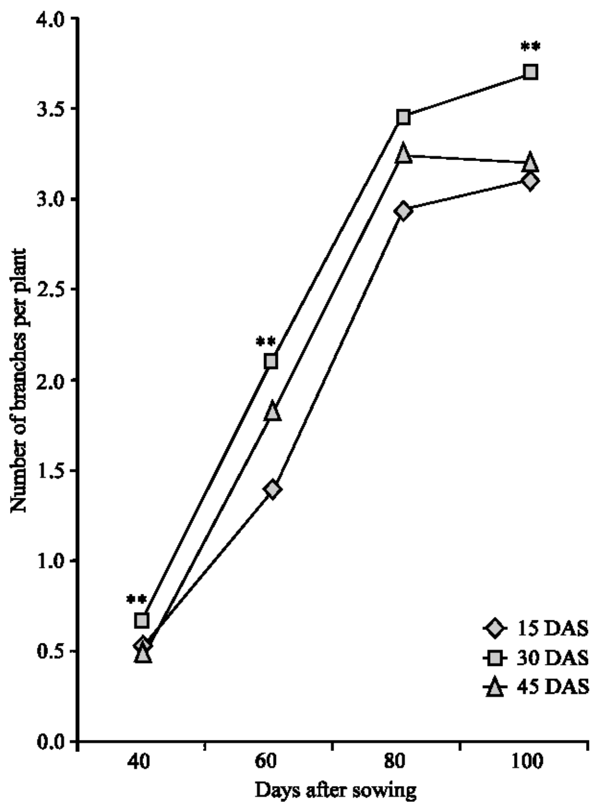

Fig. 3: Effect of time of spray of growth regulators on number of branches per plant of soybean at different days after sowing.**, significant at 1% level

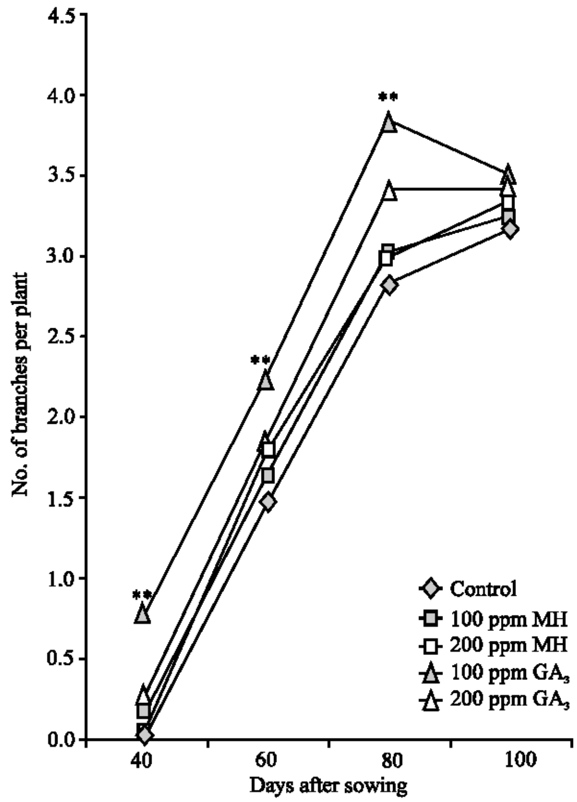

Fig. 4: Effect of plant growth regulators on number of branches per plant of soybean at different days after sowing.**, significant at 1% level

Similar increase of flower number per plant due to the application of 100 ppm of GA_3 was reported earlier in groundnut[13] and onion[20].

Number of pods per plant: Different times of application of growth regulators differed significantly in their inherent characters to produce pod per plant (Table 9). The highest number of pods (48.16) was observed in T_2 while the lowest (39.24) was in T_1. Growth regulators had highly significant effect on the number of pods per plant. Both concentrations of GA_3 and lower concentration of MH significantly increased the number of pods over the control (Table 10). The highest number of pods (44.38) was recorded with 100 ppm of GA_3 followed by 200 ppm GA_3 (43.16) while the control plants had the lowest (35.09). Growth regulators in combination with different times of application showed significant variations on number of pods per plant (Table 11). The highest number of pods per plant (49.33) was obtained by T_2C_3 followed by T_2C_4 (48.16) and the lowest (29.62) was observed in the interaction of T_1C_0.

In present experiment, 100 ppm GA_3 significantly increased the number of pods per plant. Similar increase in the number of pods has been reported in groundnut[13] and chickpea[21] by the application of 100 ppm of GA_3.

Number of seeds per pod: Different times of application failed to exert a significant influence on the number of seeds per pod. However, T_2 had the superiority over T_3 followed by T_1 (Table 9). Growth regulators exerted highly varied influence on the number of seeds per pod (Table 10). All growth regulators were statistically similar in effect. However, 100 ppm of GA_3 produced the highest number of seeds (2.19) and the lowest (1.86) was produced by the control. The interaction effect between different times of application and concentrations of growth regulators were found to be statistically significant (Table 11). The highest number of seeds (2.35) was obtained by T_2C_3 followed by T_2C_4 (2.32) and the lowest (1.77) was in T_1C_0.

In the present study, both GA_3 and MH produced higher number of seeds per pod compared to the control. These results are in consistence with the findings of

Abdel *et al.*[22] who noted that number of seeds per pod was increased in flax by 10^{-5} M GA_3.

Seed yield per plant: Different times of application varied differently to produce seed yield per plant (Table 9). The highest seed yield (7.92 g) was obtained by T_2 while the lowest (6.60 g) was observed in T_1 which was statistically similar to T_3 (6.69 g). Growth regulators exerted highly varied influence on seed yield per plant (Table 10). The highest seed yield (7.88 g) was produced by 100 ppm GA_3 that is statistically similar to 200 ppm GA_3 (7.59 g) and 100 ppm MH (7.45 g) and the lowest (5.68 g) was in the control. The data indicated that the lower concentrations of GA_3 and MH were more effective than their higher concentrations. The results of the interaction effect of spraying time and different concentration of growth regulators were found statistically significant (Table 11). The highest seed yield (9.49 g) was obtained by T_2C_3 followed by T_2C_4 and the lowest (4.3 g) was in the interaction of T_1C_0.

Present study clearly shows that GA_3 (100 ppm) has the potentiality to increase the seed yield per plant in soybean. Application of 100 ppm GA_3 increased seed yield in rice[12,23], okra[11] and tomato[23]. In present experiment, the increase in seed yield might be attributed to the superior values of morphological (viz., plant height, leaf area, number of leaves and branches per plant) and yield contributing characters (viz., number of flowers and pods per plant and the number of seeds per pod) in plants treated with growth regulators.

Hundred seed (100-seed) weight: Hundred seed weight varied significantly with different time of application of growth regulators (Table 9). The highest 100-seed weight (15.86 g) was obtained in T_2 while the lowest (14.68 g) was in T_1 which is statistically similar to T_3 (15.01 g). Application of growth regulators significantly influenced the 100-seed weight in soybean (Table 10). Among the concentrations of GA_3 and MH, the significantly highest 100-seed weight (15.92 g) was found with 100 ppm GA_3. Though the control produced the lowest 100-seed weight (14.68 g), the effect was statistically similar to the other treatments. Interaction effect showed that the highest 100-seed weight (17.59 g) was obtained by T_2C_3 followed by T_2C_4 (16.04 g) and the lowest (13.69 g) was observed by the interaction of T_1C_0 (Table 11).

Application of 100 ppm GA_3 was reported to increase 100-seed weight in groundnut[13]. This result is inconsistence with the findings of our present experiment.

Seed yield (t ha^{-1}): Average seed yield differed significantly with the time of spray (Table 9). The highest seed yield (2.16 t ha^{-1}) was obtained by T_3 and the lowest (1.93 t ha^{-1}) by T_1. Both GA_3 and MH significantly increased seed yield over the control (Table 10). The highest seed yield (2.25 t ha^{-1}) was obtained by 100 ppm GA_3 followed by 200 ppm GA_3 and the lowest (1.68 t ha^{-1}) was in the control. It is clear from this study that GA_3 has more promotive effect on seed yield than MH. Lower concentration of MH was more effective than its higher concentration. The result of the interaction of different concentrations of growth regulators and their time of spray on seed yield was found statistically significant (Table 11). The highest seed yield (2.59 t ha^{-1}) was obtained by T_2C_3 and the lowest (1.46 t ha^{-1}) was in the interaction of T_1C_0.

GA_3 increased seed yield of soybean in this experiment. GA_3-induced increase in seed yield have been reported in rice[12,23], soybean[6,7], bell pepper[22] and onion[25].

In conclusion, experimental results mentioned above revealed that both GA_3 and MH brought about an improvement in morphological and yield contributing characters of soybean. Late spray (T_3) of both regulators had better performance over the control and early spray (T_1). However, interaction effect indicated that 100 ppm GA_3 treated plants sprayed at 30 DAS (T_2C_3) showed the best performance. Further investigation may be undertaken with lower concentrations than 100 ppm and concentrations between 100 and 200 ppm which may contribute better effect in changes the morphological and yield contributing characters of soybean.

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