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Influence of GA_3 and MH and Their Time of Spray on Dry Matter Accumulation and Growth Attributes of Soybean

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Abstract: A study was conducted to investigate the effect of plant growth regulators on dry matter production and growth attributes 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). The results of the experiment revealed that significant variations exist with the time of application in respect of dry matter production in root, stem, leaf and total dry matter per plant and growth attributes like Leaf Area Index (LAI), Crop Growth Rate (CGR), Relative Growth Rate (RGR) and Net Assimilation Rate (NAR). CGR and NAR were increased up to 80 DAS and thereafter decreased due to maturity with respect of time of spray and concentration of growth regulators. However, LAI and RGR were maximized at 100 and 60 DAS, respectively. T_2 produced the highest root, stem, leaf and total dry matter, LAI, CGR, RGR and NAR followed by T_3 and T_1 produced the least of them. All growth regulators had positive effect in dry matter production and growth of soybean over non-sprayed control plants. GA_3 was more effective than MH. However, 100 ppm GA_3 had the most regulatory effect to enhance root, stem, leaf and total dry matter, LAI, CGR, RGR and NAR followed by 200 ppm GA_3. 200 ppm MH was least effective among the treatments. Interaction between T_2C_3 (spray at 30 DAS × 100 ppm GA_3) brought about the best improvement in dry matter production and growth of soybean.

Key words: Gibberellic Acid (GA_3), Maleic Hydrazide (MH), dry matter, growth attributes, soybean, *Glycine max* L.

INTRODUCTION

Soybean, an important grain legume is making headway in Bangladesh agriculture to meet the protein and oil requirement. It is an excellent source of major nutrients including vitamins A, B and D, unsaturated fatty acids and minerals like Ca and P that can meet up different nutritional needs[1]. It contains about 42-45% protein, 20-25% edible oil and 42-46% carbohydrate.

Soybean contributes more than 41% of the total oil seed production of the world. According to the estimation of FAO[2], 50,293 thousand hectares of land in the world is under soybean cultivation and the production is near about 80,941 thousand tons. More than 90% of production comes from only three countries like USA, China and Brazil. As for feed and food crop soybean is gaining an important position in the agriculture of tropical and sub-tropical countries including India, Sri Lanka, Thailand and Bangladesh. But the area and yield of soybean in Bangladesh are very low that the reference of soybean does not appear in the regular national statistics. Efforts have been made to raise its yield by adopting various agricultural practices among which exogenous application of growth regulators is one approach to improve crop productivity[3]. Gibberellic Acid (GA_3) and maleic hydrazide (MH) are two plant growth regulators which can manipulate a variety of growth and developmental phenomena in various crops. Treatment with GA_3 was found to increase dry matter accumulation[4] as well as total yield[5-7]. Likewise MH has a good effect on the yield of soybean[8]. Many research works have investigated the effects of GA_3 on various crops while reports on the use of MH are quite meager. The present investigation was an attempt to gain further information on the effects of GA_3 and MH and their time of spray on dry matter accumulation and growth attributes of soybean.

MATERIALS AND METHODS

The experiment was conducted at the field laboratory of the Department of Crop Botany, Bangladesh

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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 and C_4 = 200 ppm GA_3 and Factor B (time of spray): T_1 = 15 days after sowing (DAS), T_2 = 30 DAS and T_3 = 45 DAS} was laid out in split plot design with 4 replications. The whole area was divided into 4 blocks and each block into 15 unit plots. 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 according to Rahman *et al.*[9]. 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. The plants were sprayed with 100 and 200 ppm of GA_3 and MH. Control plants were sprayed with same amount of distilled water.

Crop sampling and recording of data: 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 selected plants of each plot were uprooted carefully by a 'khurpi' in order to ensure maximum root extraction and they were carried to the laboratory keeping in properly labelled polythene bags to prevent transpiration and respiration losses. Then the harvested plants were washed in running tap water to remove soil and blotted with blotting paper to remove the adhering water on them. The plants were separated into roots, stems and leaves. Total leaf area of individual sample was measured by an electronic leaf area meter (LI 3000, USA). The components were oven dried at 80±2°C for 48 h to record constant dry weights. Total dry matter was determined by accumulating the dry weight of each portion of the plant. Growth parameters like Leaf Area Index (LAI), Crop Growth Rate (CGR), Relative Growth Rate (RGR) and Net Assimilation Rate (NAR) were computed from the above data using the formulae rendered by Hunt[10].

The data collected on growth parameters under the experiment were statistically analyzed to obtain the level of significance using the MSTAT-computer package programme developed by Russell[11]. The differences between pairs of means were compared by DMRT.

RESULTS AND DISCUSSION

Dry matter accumulation

Root: Root dry weight was recorded from 20 to 100 DAS. The analysis of variance indicates that the root dry weight was statistically significant at 40 and 80 DAS (Table 1) due to different time of spray of growth regulators. At 40 DAS, the highest (0.09 g) root dry matter was found in T_3 and the T_1 and T_2 produced the same amount of root dry matter (0.07 g). At 80 DAS, the highest (0.96 g) root dry matter was found in T_2 and the lowest (0.82 g) was in T_1. At 100 DAS, though the growth was statistically not significant, the highest root dry matter (1.07 g) was found in T_2 followed by T_3(1.03 g). The data reveals a significant difference in root dry matter among various treatments except at 20 DAS (Table 2). GA_3 significantly increased root dry matter accumulation at all growth stages. However, the highest root dry matter was accounted for 100 ppm GA_3 followed by 200 ppm GA_3. The effect of MH was statistically significant only at 100 DAS and both concentrations were almost statistically similar in effect. The interaction result of the present study clearly reflected that root dry matter was statistically significant at all growth stages except at 80 DAS (Table 3). At all growth stages, the highest root dry matter was found in the interaction between T_2C_3 followed by T_2C_4 and the smallest by T_1C_0.

Stem: The average stem dry matter per plant differed significantly at all stages except 20 and 80 DAS due to different time of application (Table 1). The highest stem dry matter was obtained by T_2 at all growth stages followed by T_3. T_1 produced the least amount of stem dry matter per plant. Accumulation of stem dry matter was significantly higher in 100 ppm GA_3 followed by 200 ppm GA_3 at all growth stages (Table 2). The effect of MH was statistically more or less identical to the control in accumulating dry matter in stem. However, 100 ppm MH was superior to produce stem dry matter than 200 ppm MH. Interaction effect of plant growth regulators and their time of spray was significant at all stages except 20 DAS (Table 3). The highest stem dry matters (0.24, 1.46, 5.94 and 11.35 g) were found in the interaction of T_2C_3 at 40, 60, 80 and 100 DAS, respectively and the lowest stem dry matters (0.13, 0.84, 3.59 and 4.84 g) were observed in the interaction of T_1C_0 at the same DAS.

Leaf: The responses due to time of spraying did not show any significant difference on leaf dry matter accumulation except at 100 DAS (Table 4). T_2 produced the highest leaf

Table 1: Effect of time of spray of growth regulators on root and stem dry matter per plant of soybean at different days after sowing

	Root dry matter per plant (g)					Stem dry matter per plant (g)				
Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1	0.03	0.07b	0.28	0.82b	1.00	0.04	0.16c	0.95b	4.74	8.26b
T_2	0.06	0.09a	0.31	0.96a	1.07	0.05	0.20a	1.16a	5.47	10.26a
T_3	0.04	0.07b	0.29	0.90ab	1.03	0.04	0.18b	1.02b	4.85	9.02ab
Sig. level	NS	*	NS	*	NS	NS	**	*	NS	**

Table 2: Effect of growth regulators on root and stem dry matter per plant of soybean at different days after sowing

	Root dry matter per plant (g)					Stem dry matter per plant (g)				
Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
C_0	0.03	0.07b	0.27c	0.81b	0.90c	0.04	0.16b	0.92c	4.55c	7.86b
C_1	0.04	0.07b	0.30a-c	0.89b	1.00b	0.04	0.18ab	1.01bc	4.92bc	9.14a
C_2	0.03	0.07b	0.29bc	0.82b	0.98b	0.04	0.17ab	0.99bc	4.71bc	8.90ab
C_3	0.07	0.09a	0.33a	1.07a	1.14a	0.05	0.21a	1.19a	5.67a	10.08a
C_4	0.06	0.09a	0.31ab	0.90b	1.13a	0.05	0.19ab	1.10ab	5.26ab	9.91a
Sig. level	NS	*	**	**	*	NS	**	**	**	**

Table 3: Interaction effect of growth regulators and their time of spray on root and stem dry matter per plant of soybean at different days after sowing

	Root dry matter per plant (g)					Stem dry matter per plant (g)				
Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1C_0	0.02b	0.06d	0.22f	0.75	0.75e	0.04	0.13e	0.84e	3.59f	4.84e
T_1C_1	0.02b	0.07c	0.29b-e	0.79	0.89de	0.04	0.17b-e	0.92de	4.59c-f	8.55b-d
T_1C_2	0.02b	0.07cd	0.28b-f	0.78	0.86de	0.04	0.15c-e	0.92de	4.50d-f	8.11cd
T_1C_3	0.03b	0.09bc	0.33a-c	0.99	1.12a-d	0.05	0.20a-d	1.13b-d	5.44a-d	10.17a-c
T_1C_4	0.03b	0.09bc	0.31a-d	0.97	1.10a-e	0.04	0.19a-e	1.06b-e	5.38a-d	10.06a-c
T_2C_0	0.02b	0.06d	0.24ef	0.77	0.84de	0.04	0.15b-e	0.90de	4.48d-f	7.24d
T_2C_1	0.03b	0.08c	0.31a-d	0.92	1.00b-e	0.05	0.19a-e	1.01b-e	5.37a-d	10.01a-c
T_2C_2	0.03b	0.08c	0.31a-d	0.87	0.96c-e	0.05	0.17b-e	0.98c-e	5.07a-d	9.87ac
T_2C_3	0.09a	0.12a	0.38a	1.14	1.42a	0.06	0.24a	1.46a	5.94a	11.35a
T_2C_4	0.07ab	0.09bc	0.34ab	1.07	1.36ab	0.05	0.22ab	1.25ab	5.85a	11.31a
T_3C_0	0.02b	0.06d	0.25b-f	0.76	0.84de	0.04	0.14de	0.86e	4.00ef	6.84de
T_3C_1	0.03b	0.08c	0.29b-f	0.83	0.94c-e	0.04	0.17be	0.97c-e	5.04a-e	9.80a-c
T_3C_2	0.02b	0.07c	0.27c-f	0.84	0.93c-e	0.05	0.15b-e	0.97c-e	4.77b-e	8.77bd
T_3C_3	0.07ab	0.10b	0.34ab	0.99	1.29a-c	0.05	0.21a-c	1.20bc	5.73ab	10.58ab
T_3C_4	0.06ab	0.09bc	0.34ab	0.98	1.17a-d	0.05	0.21a-c	1.15b-d	5.58a-c	10.18a-c
Sig. level	**	*	**	NS	**	NS	**	**	**	**

Table 4: Effect of time of spray of growth regulators on leaf dry matter and total dry matter per plant of soybean at different days after sowing

	Leaf dry matter per plant (g)					Total dry matter per plant (g)				
Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1	0.08	0.31	1.41	4.76	6.45b	0.16	0.57	2.65	10.33	16.23b
T_2	0.08	0.31	1.56	5.17	7.10a	0.19	0.59	3.04	11.61	18.36a
T_3	0.08	0.31	1.52	5.00	6.90a	0.18	0.57	2.84	10.76	16.51b
Sig. level	NS	NS	NS	NS	*	NS	NS	NS	NS	*

Table 5. Effect of growth regulators on leaf dry matter and total dry matter per plant of soybean at different days after sowing

	Leaf dry matter per plant (g)					Total dry matter per plant (g)				
Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
C_0	0.07	0.29b	1.34b	4.67b	5.98b	0.15	0.52	2.61c	10.04c	14.75c
C_1	0.08	0.30b	1.56a	4.83b	7.13a	0.16	0.55	2.66c	10.29bc	16.22bc
C_2	0.08	0.30b	1.45ab	4.75b	6.33ab	0.16	0.56	2.87b	10.64bc	17.28b
C_3	0.08	0.36a	1.57a	5.75a	7.35a	0.21	0.66	3.11a	12.50a	18.58a
C_4	0.08	0.31b	1.57a	4.87b	7.29a	0.19	0.59	2.98ab	11.04b	18.35a
Sig. level	NS	**	**	**	**	NS	NS	**	**	**

Table 6: Interaction effect of growth regulators and their time of spray on leaf dry matter and total dry matter per plant of soybean at different days after sowing

	Leaf dry matter per plant (g)					Total dry matter per plant (g)				
Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1C_0	0.07	0.24c	1.19f	4.04e	5.01e	0.14b	0.49d	2.25f	8.79d	12.37d
T_1C_1	0.08	0.29bc	1.37d-f	4.62de	5.97c-e	0.15b	0.55b-d	2.67d-f	10.05cd	14.79cd
T_1C_2	0.07	0.29bc	1.33d-f	4.55de	5.90c-e	0.15b	0.54cd	2.63d-f	9.95cd	14.22cd
T_1C_3	0.08	0.32bc	1.64a-c	5.16b-d	7.76a-c	0.18b	0.60b-d	3.03b-d	11.87ab	18.76ab
T_1C_4	0.08	0.32bc	1.51b-d	4.95cd	7.73a-c	0.16b	0.59b-d	2.93b-d	11.25bc	18.67ab
T_2C_0	0.07	0.27bc	1.30d-f	4.91cd	5.29de	0.15b	0.54cd	2.61d-f	9.88cd	13.49d
T_2C_1	0.07	0.32bc	1.48b-d	4.93cd	7.22a-c	0.16b	0.59b-d	2.86cd	11.21bc	18.35ab
T_2C_2	0.08	0.30bc	1.47d-e	4.52de	7.10a-d	0.16b	0.57b-d	2.71de	11.20bc	17.09bc
T_2C_3	0.09	0.44a	1.87a	6.05a	8.77a	0.30a	0.74a	3.61a	13.05a	21.13a
T_2C_4	0.08	0.36ab	1.77a	5.74ab	8.15ab	0.24ab	0.66ab	3.32ab	12.28ab	20.34a
T_3C_0	0.07	0.27bc	1.22ef	4.48de	5.22de	0.14b	0.50cd	2.38ef	8.99d	13.31d
T_3C_1	0.08	0.29bc	1.48b-d	4.84cd	6.68b-e	0.16b	0.57b-d	2.69de	10.76bc	17.04bc
T_3C_2	0.08	0.29bc	1.43c-f	4.84cd	5.97c-e	0.15b	0.55b-d	2.68de	10.15cd	16.91bc
T_3C_3	0.09	0.35b	1.71ab	5.53a-c	7.76a-c	0.19ab	0.61bc	3.27a-c	12.18ab	19.68ab
T_3C_4	0.08	0.35b	1.70ab	5.46a-c	7.73a-c	0.19ab	0.60b-d	3.04b-d	11.92ab	19.38ab
Sig. level	NS	**	**	*	**	**	**	**	**	**

Table 7: Effect of time of spray of growth regulators on LAI and CGR of soybean at different days after sowing

	LAI					CGR (mg dm^{-2}/d)			
Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1	0.41	2.23	4.34b	8.13	9.81	0.02	0.10	0.38	0.27
T_2	0.50	2.32	5.38a	8.96	10.93	0.02	0.12	0.43	0.33
T_3	0.48	2.25	4.69b	8.71	9.88	0.02	0.11	0.38	0.30
Sig. level	NS	NS	*	NS	NS	NS	NS	NS	NS

Table 8: Effect of growth regulators on LAI and CGR of soybean at different days after sowing

	LAI					CGR (mg dm^{-2}/d)			
Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	40 DAS	60 DAS	80 DAS	100 DAS
C_0	0.38	1.43c	4.16c	5.84b	8.24	0.01b	0.10	0.37c	0.23c
C_1	0.47	2.19b	4.83b	8.58ab	10.80	0.02a	0.10	0.38bc	0.29ab
C_2	0.42	1.82bc	4.63bc	8.19ab	9.31	0.02a	0.11	0.38bc	0.30ab
C_3	0.53	3.01a	5.51a	10.85a	11.54	0.02a	0.12	0.46a	0.36a
C_4	0.51	2.90a	4.86ab	9.53a	11.13	0.02a	0.11	0.40b	0.33ab
Sig. level	NS	**	**	**	NS	*	NS	*	*

Table 9: Interaction effect of growth regulators and their time of spray on LAI and CGR of soybean at different days after sowing

	LAI					CGR (mg dm^{-2}/d)			
Treatments	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1C_0	0.34	1.36	3.70	5.60	6.15	0.01c	0.08f	0.27f	0.15d
T_1C_1	0.43	1.37	4.26	7.95	9.29	0.02b	0.10d	0.37de	0.23cd
T_1C_2	0.42	1.74	4.60	7.56	8.55	0.02b	0.09e	0.36de	0.17d
T_1C_3	0.48	2.07	4.74	9.05	11.44	0.02b	0.11c	0.43a-d	0.36bc
T_1C_4	0.46	1.97	4.26	8.96	11.41	0.02b	0.11c	0.42a-d	0.36bc
T_2C_0	0.36	1.55	3.80	6.85	8.53	0.01c	0.09e	0.36de	0.17d
T_2C_1	0.46	1.93	4.60	8.62	10.61	0.02b	0.10d	0.42a-d	0.33bc
T_2C_2	0.42	2.07	4.89	8.45	9.52	0.02bc	0.10d	0.42a-d	0.31b-d
T_2C_3	0.75	3.05	7.44	11.95	14.66	0.03a	0.15a	0.50a	0.55a
T_2C_4	0.56	3.00	6.13	11.83	13.40	0.02b	0.13b	0.47ab	0.46ab
T_3C_0	0.37	1.37	3.96	6.09	7.97	0.01c	0.09e	0.31f	0.17d
T_3C_1	0.40	2.94	4.89	8.34	9.34	0.02b	0.10d	0.39b-e	0.25cd
T_3C_2	0.47	2.52	4.83	8.14	9.14	0.02b	0.10d	0.38c-e	0.24cd
T_3C_3	0.50	2.97	5.58	11.50	11.66	0.02b	0.13b	0.46a-c	0.42ab
T_3C_4	0.48	2.99	5.02	9.12	11.42	0.02b	0.12c	0.44a-d	0.37bc
Sig. level	NS	NS	*	NS	NS	*	**	**	**

Table 10: Effect of time of spray of growth regulators on RGR and NAR of soybean at different days after sowing

	RGR (mg g^{-1}/d)				NAR (mg cm^{-2}/d)			
Treatments	40 DAS	60 DAS	80 DAS	100 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1	33.98	39.02	35.71	16.12	0.35	0.66	1.19b	0.68
T_2	35.52	40.39	37.56	18.23	0.39	0.72	1.49a	0.85
T_3	34.24	39.41	36.81	17.65	0.38	0.72	1.28b	0.77
Sig. level	NS	NS	NS	NS	NS	NS	*	NS

Table 11: Effect of growth regulator on RGR and NAR of soybean at different days after sowing

	RGR (mg g^{-1}/d)				NAR (mg cm^{-2}/d)			
Treatments	40 DAS	60 DAS	80 DAS	100 DAS	40 DAS	60 DAS	80 DAS	100 DAS
C_0	33.44	38.97	36.02	15.43c	0.31c	0.58b	1.20	0.60
C_1	34.93	39.88	36.84	16.79a-c	0.36bc	0.72ab	1.31	0.69
C_2	33.49	39.52	36.31	16.12bc	0.32c	0.60b	1.27	0.69
C_3	35.57	39.88	37.38	19.53a	0.47a	0.86a	1.51	1.08
C_4	35.46	39.78	36.92	18.81ab	0.42ab	0.74a	1.31	0.78
Sig. level	NS	NS	NS	*	**	**	NS	NS

Table 12: Interaction effect of growth regulators and their time of spray on RGR and NAR of soybean at different days after sowing

	RGR (mg g^{-1}/d)				NAR (mg cm^{-2}/d)			
Treatments	40 DAS	60 DAS	80 DAS	100 DAS	40 DAS	60 DAS	80 DAS	100 DAS
T_1C_0	26.85	36.21	31.07	11.63	0.24	0.43e	1.01	0.24c
T_1C_1	29.25	38.77	34.80	13.58	0.33	0.64b-e	1.18	0.49c
T_1C_2	32.87	38.97	35.33	14.79	0.31	0.63b-e	1.16	0.48c
T_1C_3	36.43	40.25	38.23	19.97	0.45	0.74b-d	1.45	0.92a-c
T_1C_4	35.87	40.47	37.99	17.84	0.39	0.71b-d	1.41	0.91a-c
T_2C_0	33.94	38.59	35.16	12.07	0.30	0.62c-e	1.08	0.47c
T_2C_1	35.90	39.83	36.86	17.37	0.39	0.70b-d	1.36	0.80a-c
T_2C_2	35.97	39.57	37.18	17.58	0.38	0.69b-d	1.36	0.79a-c
T_2C_3	37.72	41.75	39.00	26.43	0.49	1.04a	1.68	1.50a
T_2C_4	37.15	41.73	38.83	23.83	0.48	0.87ab	1.65	1.33ab
T_3C_0	33.63	38.32	35.28	11.87	0.28	0.54de	1.07	0.42c
T_3C_1	34.30	39.53	36.80	13.98	0.35	0.65b-e	1.24	0.64bc
T_3C_2	34.90	39.04	36.61	16.80	0.34	0.65b-e	1.20	0.59bc
T_3C_3	37.02	40.55	38.76	21.08	0.46	0.83a-c	1.46	1.00a-c
T_3C_4	36.87	40.51	38.54	21.22	0.46	0.75b-d	1.4	0.94a-c
Sig. level	*	*	*	*	NS	**	NS	**

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

dry matter per plant (7.10 g) followed by T_3 (6.90 g). The lowest leaf dry matter was found at T_1 (6.45 g). Accumulation of dry matter in leaves due to spraying of growth regulators were significant at all growth stages except 20 DAS (Table 5). GA_3 was more effective in producing leaf dry matter than MH. At all growth stages 100 ppm GA_3 produced the highest leaf dry matter followed by 200 ppm GA_3 and the lowest by the control. Interaction effect of plant growth regulators and their time of spray on leaf dry matter was significant at all growth stages except 20 DAS (Table 6). The highest amount of dry matters (0.44, 1.87, 6.05 and 8.77 g) were produced in the interaction of T_2C_3 at 40, 60, 80 and 100 DAS, respectively. The lowest dry matter of leaf was found in the interaction of T_1C_0 at the same DAS.

Plant leaves are the main organs where the photosynthates are produced. So the amount of leaf dry matter increases with the increasing leaf area and the number of leaves with the time course. In present experiment, increase in leaf dry matter due to the application of growth regulators might be due to the increase in the number of leaves and the area of leaves per plant[9].

Total dry matter per plant: Total dry matter is the sum of dry weight of roots, stems and leaves. The analysis of variance indicated that total dry matter was significant only at 100 DAS. T_2 had superiority in accumulating dry matter over T_3 followed by T_1 throughout the entire growing season (Table 4). The effect of different doses of growth regulators on total dry matter production was significant except at 20 and 40 DAS (Table 5). 100 ppm GA_3 produced the highest total dry matter at all growth stages followed by 200 ppm GA_3 and the minimum was from the control. The response due to time of application and concentrations of growth regulators on total dry matter production was found significant at all stages of growth (Table 6). At 100 DAS, the highest amount of dry matter (21.13 g) was produced by T_2C_3 that was statistically similar to T_2C_4 (20.34 g) and the lowest (12.37 g) was produced by T_1C_0 that was statistically similar to T_3C_0 (13.31 g) and T_2C_0 (13.49 g).

In our experiment, total dry matter was increased due to the application of GA_3 and MH. GA_3 induced increase in total dry matter production were recorded in green gram[12], faba bean[13], soybean[6] and mustard[14]. Calsiz *et al.*[15] observed that MH increased total dry matter in potato.

Growth attributes

Leaf Area Index (LAI): Effect of different time of spray on LAI of soybean was statistically significant only at 60 DAS (Table 7). LAI increased with the advancement of growth stages. T_2 produced the highest (5.38) LAI and the lowest LAI was produced by T_1 (4.34) which was statistically similar to that of T_3 (4.69) at 60 DAS. The

various concentrations of growth regulators had statistically significant influence on LAI at 40, 60 and 80 DAS (Table 8). The maximum LAI was observed by 100 ppm GA_3 at all growth stages followed by 200 ppm GA_3 and the minimum was in the non-sprayed control plants. The results of the interaction of times of spray and different concentrations of growth regulators were found significant only at 60 DAS (Table 9). The highest (7.44) LAI was found by the application of 100 ppm GA_3 (T_2C_3) and the lowest (3.7) by the control (T_1C_0) at 60 DAS.

In present experiment, the growth regulators significantly increased LAIs in soybean which might be due to increased number of leaves[9] and vigorous growth of the plant[16]. GA_3-induced acceleration of vegetative growth resulted in an extensive photosynthetic apparatus and relative increases in LAIs were recorded in green gram[12]. Seedlings of onion Cv. N-2-4-1 were sprayed or dipped or both with GA_3 at 60 ppm before transplanting had increased LAI[17].

Crop Growth Rate (CGR): Different times of application of growth regulators had no significant influence on CGR (Table 7). This suggests that different times of application influenced CGR independently during the entire growth period. However, the maximum CGR was obtained at T_2 followed by T_1 and T_3 at 100 DAS. CGR was lower at initial growth stages and attained its maximum at 80 DAS and then gradually declined. Growth regulators significantly regulated CGR of soybean plants at different growth stages (Table 8). The data revealed that at 40 DAS all the growth regulators significantly increased CGR over the control. At 80 and 100 DAS, 100 ppm GA_3 significantly increased the CGR. The 200 ppm GA_3 increased CGR that is statistically similar to MH. The lowest CGR was found in the control. The results of the interaction of time of spray and different concentrations of growth regulators were found statistically significant at all growth stages (Table 9). The highest CGR (0.55 mg dm^{-2}/d) was observed in the interaction of T_2C_3 at 100 DAS and the lowest (0.15 mg dm^{-2}/d) was obtained in the interaction of T_1C_0 that is statically similar to the interaction of T_1C_2, T_2C_0 and T_3C_0 at the same DAS.

In present experiment, plant growth regulators increased CGR over the control. This is in agreement with the findings of Khan[16]. Increase in CGR due to the application of growth regulators was certainly the result of increase in dry matter production with time course. Brar and Singh[18] made similar observation with GA_3 in cotton.

Relative Growth Rate (RGR): The RGR was estimated at 40, 60, 80 and 100 DAS. Time of application of growth regulators did not show any significant difference on RGR at any stage (Table 10). However, maximum RGR was obtained with T_2 followed by T_3 and the minimum was with T_1. The effect of growth regulators indicate that RGR, from its initial lower value, maximized at 60 DAS followed by a gradual decrease in all treatments (Table 11). 100 ppm GA_3 had the highest RGR value (19.53 mg dm^{-2}/d) and the control had the lowest (15.43 mg dm^{-2}/d) at 100 DAS. The interaction effect between times of spray and growth regulators on the RGR was significant at all growth stages (Table 12). At 60 DAS, the highest RGR (41.73 mg g^{-1}/d) was observed in the T_2C_3 (100 ppm GA_3) that is statistically similar to the interaction between T_2C_4 (200 ppm GA_3). The minimum RGR (38.32 mg g^{-1} /d) was observed in T_1C_0 (control).

Net Assimilation Rate (NAR): Effect of time of application of plant growth regulators on NAR of soybean plants was found significant only at 80 DAS (Table 10). The data revealed that NAR was the highest (1.49 mg cm^{-2}/d) in T_2 and the lowest in (1.19 mg cm^{-2}/d) T_1 that was statistically identical to T_3. NAR from its initial lower value, maximized at 80 DAS followed by a gradual decrease in all treatments (Table 10-12). The effect of growth regulators on NAR was varied significantly at 40 DAS and 60 DAS (Table 11). Both at 40 and 60 DAS, the highest NAR was found at 100 ppm GA_3 that was statistically similar to 200 ppm GA_3 and the lowest was in the control that was statistically similar to 200 ppm MH. The combined effect of growth regulators and their time of spray on NAR of soybean was found significant at 60 DAS and 100 DAS (Table 12). The highest NARs were observed in the T_2C_3 followed by T_2C_4 at all stages of growth and minimum NARs were found almost always under early sprayed control plants (T_1C_0).

In present experiment, NAR maximized at 80 DAS followed by a gradual decrease in all treatments. It was established that NAR became higher during vegetative stage and then declined rapidly as season progressed[19-20] possibly for mutual leaf shading and increase of old leaves which could have lower photosynthetic efficiency[21]. NAR tended to increase with GA_3 treatment at pod filling stage might be related to the increased sink demand and pod photosynthesis[22].

In conclusion, dry matter production and the growth attributes of soybean may be enhanced by the application of GA_3 and MH at all developmental stages. GA was more effective than MH. 100 ppm GA_3 brought about the best improvement in dry matter production and growth of soybean when applied at 30 DAS (T_2). However, late spray (T_3) of 100 ppm of both the regulators had better performance over the control and early spray (T_1).

REFERENCES

1. Rahman, L., 1982. Cultivation of soybean and its uses. City Press, Dhaka, pp: 5-7.
2. FAO., 1981. Production Year Book. Food and Agriculture Organizations of the United Nations, Rome, Italy, 50: 110-112.
3. Pando, S.B. and G.C. Srivastava, 1985. Physiological studies on seed set in sunflower. III. Significance of dwarfening of plant size using growth regulators. Indian J. Physiol., 28: 72-80.
4. Stowe, B.B. and T. Yamaki, 1957. The history and physiological action of the gibberellins. Ann. Rev. Plant Physiol., 8: 181.
5. Atal, C.K. and J.K. Sethi, 1961. Increase fibre content in hemp by application of gibberellines. Curr. Sci., 30: 177.
6. Deotale, R.D., V.G. Maske, N.V. Sorte, B.S. Chimurkar and A.Z. Yerne, 1998. Effect of GA_3 and NAA on morpho-physiological parameters of soybean. J. Soils and Crops, 8: 91-94.
7. Maske, V.G., R.D. Deotale, N.V. Sorte, H.B. Goramnagar and C.N. Chore, 1998. Influence of GA_3 and NAA on growth and yield contributing parameters of soybean. J. Soils and Crops. 8: 20-21.
8. Mehetre, S.S. and S.K. Lad, 1995. Effect of foliar applications of growth substances on growth and yield of soybean. Soybean Genet. Newslett., 22: 132-134.
9. Rahman, M.S., N.I.M.A. Tahar and M.A. Karim, 2004. Influence of GA_3 and MH and their time of spray on morphology, yield contributing characters and yield of soybean. Asian J. Plant Sci., 3: 602-609.
10. Hunt, R., 1978. Plant Growth Analysis. Studies in Biology No. 96. Edward Arnold Ltd., London, pp: 67.
11. Russel, D.F., 1986. MSTAT-C package programme. Crop and Soil Science Department, Michigan State University, USA.
12. Suma Bai, D.I., A.T. Abraham and S.T. Mercy, 1987. Hormonal influence on crop performance in green gram. Legume Res., 10: 49-52.
13. Cors, F. and A. Falisse, 1987. The effect of growth regulators on two spring legumes, protein peas and field beans. Mededelingen van de Facultiet Landbouwwetenschappen, Rijksuniversiteit Gent., 52: 1259-1266.
14. Khan, N.A., H.R. Ansari and Samiullah, 1998. Effect of gibberellic acid spray during ontogeny of mustard on growth, nutrient uptake and yield characteristics. J. Agron. Crop Sci., 181: 61-63.
15. Calsiz, D.O., L.V. Fernandez and M.H. Inchausti, 2001. Maleic hydrazide effects on tuber yield, sprouting characteristics and French fry processing quality in various potato (*Solanum tuberosum* L.) cultivars grown under Argentinian conditions. American J. Potato Res., 78: 119-128.
16. Khan, M.A.H., 1981. The effect of carbon dioxide enrichment on the pattern of growth and development in rice and mustard plants. Ph.D. Thesis. Royal Vet. Agril. Univ. Copenhagen, pp: 104.
17. Nirmal, S.V., B.P. Deore and R.C. Patill, 1994. Effect of growth substances on yield and yield contributing traits in onion. J. Maharashtra Agril. Univ., 19: 136-137.
18. Brar, Z.S. and M. Singh, 1983. Effect of plant growth regulators on biomass and productivity of cotton. Indian J. Ecol., 10: 254-259.
19. Kollar, H.R., W.E. Nyquist and I.S. Chorush, 1970. Growth analysis of the soybean community. Crop Sci., 10: 407-412.
20. Haloi, B. and B. Baldev, 1986. Effect of irrigation on growth attributes in chickpea when grown under different dates of sowing and population pressure. Indian J. Plant Physiol., 29: 14-27.
21. Pandey, R.K., M.C. Saxena and V.B. Singh, 1978. Growth analysis of black gram genotypes. Indian J. Agric. Sci., 48: 466-473.
22. Pandey, R.K. and V.B. Singh, 1980. Vegetative growth of dry matter production and seed yield of field pea (*Pisum sativum* L.). Legume Res., 3: 1-6.