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Effects of GA₃ and IAA and their Frequency of Application on Morphology, Yield Contributing Characters and Yield of Soybean

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Abstract: Effect of plant growth regulators on yield of soybean was investigated. Plants of soybean cv BS-3 were sprayed at three different times with two concentrations (100 and 200 ppm) of gibberellic acid (GA₃) and indole acetic acid (IAA). GA₃ at 100 ppm had regulatory effect to enhance the plant height, number of branches, number of leaves, leaf area per plant, number of flowers, number of pods, percentage of fruit set, number of seed per plant, seed yield per plant, 100-seeds weight and seed yield (t haG¹). On the other hand, 100 ppm IAA produced the highest plant height, number of flowers, number of pods, percentage of fruit set, number of seed per plant, seed yield per plant and seed yield (t haG¹), as compared to other plant growth regulators and control. IAA at 200 ppm increased number of branches, number of leaves, leaf area per plant, 100-seeds weight and net assimilation rate.

Key words: GA₃, *Glycine max* (L.) Merrill, growth regulators, IAA, mode of application

Introduction

Soybean [*Glycine max* (L.) Merrill] is an important widely used oil seed and protein crop of the world. It is a good source of unsaturated fatty acids, minerals like Ca and P including vitamin A, B, C and D can meet up different nutritional needs (Rahman, 1982). It is referred to "the protein hope of the future" as well as "the miracle golden bean" because of its high nutritive value containing about 42-45% protein and 20-25% edible oil. A variety of soya products as food like soya dal, soya chatni, soya-khichuri, soya-milk, soya-curd, soya-flour and roasted soybean snacks are becoming familiar to the people of Bangladesh (Smith, 1975). Some soybean varieties can be profitably used as green manure and fodder. Soybean also helps to improve the soil fertility and productivity by fixing atmospheric nitrogen through *Rhizobium* bacteria that lives in root nodules.

In Bangladesh, research and extension works on soybean have been started in 1972-73 by Mannonite Central Committee (MCC) and subsequently by Bangladesh Agricultural Research Council (BARC). 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 lack of knowledge about modern production technologies i.e. lack of judicious application of irrigation water, seed rate, fertilizer, growth regulators, etc.

Indole acetic acid (IAA) and gibberellic acid (GA₃) can manipulate a variety of growth and developmental phenomena in various crops. IAA has been found to increase the plant height, number of leaves per plant, fruit size with consequent enhancement in seed yield in groundnut (Lee, 1990), cotton (Kapgata *et al.*, 1989), cowpea (Khalil and Mandurah, 1989) and rice (Kaur and Singh, 1987). It also increases the flowering, fruit set, the total dry matter of crops (Gurdev and Saxena, 1991). Likewise, GA₃ stimulated stem elongation (Harrington *et al.*, 1996), increase dry matter accumulation (Hore *et al.*, 1988) and enhance total yield (Deotale *et al.*, 1998; Maske *et al.*, 1998).

Very limited works have been carried out regarding the use of growth regulators on soybean in Bangladesh. However, studies on the effects of growth regulators in it climatic condition could provide useful information regarding manipulation of growth and improvement of yield. Therefore, this experiment was designed to study the effect of IAA and GA₃ in modifying the morphology, yield contributing characters and yield of soybean.

Materials and Methods

The experiment was conducted at the Field Laboratory of the Department of Crop Botany, Bangladesh Agricultural University (BAU), Mymensingh during the period from November 2000 to February 2001. Seeds of soybean (BS-3) were collected from the Department of Genetics and Plant Breeding, BAU. Land of the experimental site was ploughed and cross-ploughed three times followed by laddering. Then all the stubbles and uprooted weeds were removed and the land was made ready. Urea, triple superphosphate (TSP), muriate of potash (MP) and well decomposed cowdung (CD) were applied as basal dose during land preparation to the plots @ 50, 150, 50 kg haG¹ and 6 t haG¹, respectively. The two factorial experiment comprised of the growth regulators and their times of application was laid out in randomized complete block design (RCBD). The whole area was divided into three blocks and each block into 15 unit plots. The size of the unit plot was 1 x 1 m² and the distance between plots was 0.5 m. The seeds were shown in rows made by hand plough. The distances between rows and seeds were 25 and 10 cm, respectively and two seeds were placed in each point at 2-3 cm depth from the soil surface. The gaps where seeds failed to germinate were filled up within two weeks after germination of seeds. Irrigation was done as per necessity by watering cans to the young plants and by flow irrigation afterwards to maintain soil moisture at field capacity. A 100 ppm solution of IAA or GA₃ was prepared by dissolving 100 mg of IAA or GA₃ in a small quantity of ethanol prior to dilution with distilled water. Then distilled water was added to make the volume 1 liter to get 100 ppm solution. In a similar way, solutions of 200 ppm were made. A corresponding amount of ethanol was added to distilled water making the final volume 1L for application to the control plants. Soybean plants were sprayed with the solutions of GA₃ and IAA on 20 days after sowing (DAS) and/or 42 DAS by a hand sprayer.

The first crop sampling was done on 20 DAS and it was continued at an interval of 20 days till physiological maturity on 80 days. At the time of each harvest, five plants were selected randomly from each plot and leaf area was measured. The height of the plants was ascertained by measuring with a scale placed from ground level to top of the leaves. Numbers of leaves and branches per plants were recorded separately at each harvest. Plant height, number of leaves per plant and number of branches per plant were recorded. Following yield contributing characters were studied: number of flowers/plant, number of pods/plant, number of seeds/plant, seed yield/plant (g), percentage of fruit set, hundred seed weight (g) and seed yield (t haG¹) at the time of final harvest.

The data were analyzed using the MSTAT-computer package program developed by Russell (1986). The differences between pairs of means were compared by least significant difference (LSD) test.

Results and Discussion

Plant height: Plant height increased gradually with the advancement of the growth of the plants in all treatments. The growth regulators had stimulatory effects on plant height. The data revealed that GA₃ at 100 ppm produced the tallest plants at all growth stages. Application of IAA also had stimulatory effects on plant height (Table 1). Both the concentrations had significantly higher plant height over control throughout the growth period. However, 100 ppm was superior to 200 ppm in producing taller plants. GA₃ was more efficient in stem elongation than IAA.

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Table 1: Effect of GA₃ and IAA on morphological characters of soybean

Conc. (ppm)	Plant height (cm) at DAS					Number of branches plant G ¹ at DAS		Number of leaves plant G ¹ at DAS			
	20	40	60	80	100	80	100	20	40	60	80
GA₃											
Control	8.86b	9.74c	17.0c	21.24a	25.11c	1.67a	2.11c	4.67	3.44c	5.22c	6.67b
100	10.31ab	30.94a	38.39a	35.28a	57.10a	4.67ab	6.22a	5.57	5.78a	9.33a	11.89a
200	11.25a	20.31b	30.0b	30.28a	50.67b	3.11b	4.56b	5.33	4.67b	7.78b	11.56a
IAA											
Control	8.86b	9.74c	17.00c	21.23b	25.51c	1.67b	2.11c	4.67a	3.44b	5.22b	6.89b
100	10.97a	19.16a	30.33a	32.61a	47.67a	2.67ab	3.78b	5.22a	4.33a	5.78ab	8.22ab
200	10.83ab	13.22b	26.33b	28.78a	42.33b	3.78a	4.78a	5.89a	4.33a	6.11a	9.22a

Values with different letter (s) within a column differ significantly at 5% of probability (LSD)

Table 2: Effect of time of application of GA₃ and IAA on morphological characters of soybean

Treatments	Plant height (cm) at DAS					Number of branches plant G ¹ at DAS		Number of leaves plant G ¹ at DAS			
	20	40	60	80	100	80	100	20	40	60	80
GA₃											
T ₁	10.572	21.00a	28.33ab	31.83	43.56ab	3.11	3.89b	5.11	4.56ab	7.00b	9.44
T ₂	9.828	23.34a	30.17a	35.28	48.33a	3.45	5.11a	5.11	5.33a	8.44a	10.89
T ₃	10.017	16.66b	26.89b	30.28	41.39b	2.89	3.89b	5.33	4.00b	6.89b	9.78
IAA											
T ₁	9.96	13.33	25.00ab	26.88	37.89	2.44	3.22b	5.67	4.00	5.44b	7.67a
T ₂	10.97	19.16	26.00a	28.33	40.00	3.11	4.00a	4.78	4.33	6.22a	8.89ab
T ₃	10.83	13.22	22.57b	27.40	37.62	2.56	3.44ab	5.33	3.78	5.44d	7.78b

Values with different letter(s) within a column differ significantly at 5% level of probability (LSD)

T₁ = Spray at 20 DAS only, T₂ = (T₁ + T₃) Double spraying (spray at 20 DAS and 42 DAS), T₃ = Spray at 42 DAS only

Significant variation in plant height at all growth stages was found among different times of spray (Table 2). Double spray of both the chemicals was better than single spray and spray at 42 DAS was better than spray at 20 DAS. GA₃ is well known for stem elongation. GA₃ induced higher plant height was reported earlier in soybean (Deotale *et al.*, 1998), okra (Kumer *et al.*, 1996), sesame (Sontakey *et al.*, 1991), rice (Awan and Alizai, 1989) and groundnut (Lee, 1990).

Number of branches per plant: Number of branches/plant was recorded on 80 and 100 DAS. Both GA₃ and IAA significantly increased the number of branches/plant, especially at the final stage of plant growth (100 DAS) (Table 1). The data revealed that, 100 ppm of GA₃ and 200 ppm of IAA produced the maximum number of branches (6.22 and 4.78) among their respective treatments as was ascertained at 100 DAS. The results showed a clear superiority of the growth regulators over the control in producing branches per plant. Application at different times and frequency also showed significant (Table 2). Double spray of GA₃ produced the maximum number of branches/plant (5.11) at 100 DAS. The interaction effect between times and growth regulators on the number of branches plantG¹ was significant (data not presented). GA₃ has been reported to enhance the number of branches/plant in many crops (Awan and Alizai, 1989; Lee, 1990; Sontakey *et al.*, 1991; Deotale *et al.*, 1998). IAA induced higher number of branches/plant was also reported by Chhipa and Lal (1988). In this study both IAA and GA₃ had stimulatory effect on the number of branches plantG¹ in soybean.

Number of leaves per plant: A significant variation was evident in the number of leaves plantG¹ due to the application of growth regulators at different stages of plant growth (Table 1). The treated plants generated higher number of leaves at the later stages over control (60 and 80 DAS). Among the growth regulator treatments, 100 ppm of GA₃ induced maximum number of leaves (11.89) followed by 200 ppm of IAA (9.22) indicating that GA₃ was better at lower level while IAA at higher level. Among the times, T₂ had higher number of leaves/plant at all the growth stages, especially at 40 and 60 DAS in case of GA₃ and at 60 and 80 DAS in IAA (Table 2). Increase in the number of leaves per plant

was reported in Bell pepper (Abdul *et al.*, 1988). The present finding agreed well with the above reports.

Yield contributing characters: Number of flowers per plant was influenced by the application of GA₃ and IAA (Table 3). Growth regulators applied at different concentrations influenced the number of flowers produced per plant significantly (P < 0.05). The lower concentration (100 ppm) of both the growth regulators greatly increased the number of flowers per plant compared to the control. The higher concentration had lesser flower number but still higher than the control. GA₃ was more efficient than IAA. IAA at 200 ppm had the lowest number of flowers per plant (22.00) among the treatments. The maximum number of flowers (35.44) was found with 100 ppm of GA₃. The total flowers per plant were counted in the field in individual treatment for each time of application. A significant difference due to time of application of GA₃ in number of flowers formed per plant was clearly evident (Table 4). The highest number of flowers per plant was observed in double spray (32.56) followed by the single spray at 42 DAS (27.22) and 20 DAS (22.22), respectively. Similar increase of flower number per plant due to the application of 100 ppm of GA₃ and IAA was reported earlier in groundnut (Lee, 1990).

The growth regulators had highly significant effect on the number of pods per plant. It is interesting to note that the lower concentration (100 ppm) of IAA and GA₃ increased the number of pods better than the higher concentration (200 ppm) (Table 3). The highest number of pods (26.00) was recorded with 100 ppm of GA₃, while 200 ppm of IAA produced the lowest number of pods (16.78) in comparison to the other treatments. Different times of application differed in inducing pods (Table 4). The highest number of pods/plant (23.22) was observed in double spray of GA₃, while the lowest number of pods/plant (15.33) was observed in single spray of IAA at 42 DAS. Increase in the number of pods per plant has been reported in groundnut, rice and gram by the application of 100 ppm IAA and GA₃ (Lee, 1990; Awan and Alizai, 1989; Mange, 1971). The present finding supports these reports. The growth regulators have highly varied effect on the percentage of fruit set. The lower concentration (100 ppm) of IAA and GA₃ resulted in increased percentage of fruit set more efficiently than the higher concentration (200 ppm) and the control. The highest

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Table 3: Effect of GA₃ and IAA on yield and yield contributing characters of soybean

Treatment	Number of flowers plant G ¹	Number of pods plant G ¹	Percentage of fruit set	Number of seeds plant G ¹	Seed yield plant G ¹ (g)	100-seed weight (g)	Seed yield (t ha G ¹)
GA₃							
Control	16.78c	12.67b	64.06c	26.56c	1.69c	6.41b	0.67c
100 ppm	35.44a	26.00a	77.64a	54.22a	5.87a	10.76a	2.34a
200 ppm	29.78b	22.00a	71.33b	46.78a	4.58b	9.68a	1.83b
IAA							
Control	16.78b	12.67b	64.06b	26.56a	1.69b	6.41b	0.67b
100 ppm	24.67a	19.11a	71.97a	39.67a	3.56a	8.82a	1.42a
200 ppm	22.00a	16.78ab	69.50a	36.44b	3.30a	8.94a	1.32a

Table 4: Effect for time of application of GA₃ and IAA on yield and yield contributing characters of soybean

Treatment	Number of flowers plant G ¹	Number of pods plant G ¹	Percentage of fruit set	Number of seeds plant G ¹	Seed yield plant G ¹ (g)	100-seed weight (g)	Seed yield (t ha G ¹)
GA₃							
T ₁	22.22b	17.44b	71.22ab	41.67b	3.71b	8.49b	1.48b
T ₂	32.56a	23.22a	73.64a	48.89a	5.09a	9.66a	2.03a
T ₃	27.22b	20.0ab	68.17b	37.0c	3.33b	8.70b	1.33b
IAA							
T ₁	20.67	16.22	68.35	33.0	2.30b	7.52b	1.00b
T ₂	22.22	17.00	68.31	37.89	3.57a	9.02a	1.42a
T ₃	20.56	15.33	68.86	31.78	2.48b	7.63ab	0.99b

Values with different letter(s) within a column differ significantly at 5% level of probability (LSD)

T₁ = Spray at 20 DAS only, T₂ = (T₁ + T₃) Double spraying (spray at 20 DAS and 42 DAS), T₃ = Spray at 42 DAS only

percentage of fruit set (77.64) was recorded with 100 ppm GA₃, while 200 ppm of IAA produced the lowest percentage of fruit set (69.50). Times of application differed in terms of fruit set (Table 4). The highest percentage of fruit set was found in double spray of GA₃ (73.64). While, the lowest percentage (68.17) of fruit set was observed in single spray of GA₃ at 42 DAS. Increase in the percentage of fruit set has been reported in pineapple by the application of 100 ppm IAA (Going, 1956).

The lower concentration of GA₃ and IAA could increase the number of seeds more efficiently than the higher concentration (Table 3). The highest number of seed (54.22) was recorded with 100 ppm GA₃, while 200 ppm of IAA produced the lowest number of seeds/plant (36.44). Different times of application of GA₃ had significant effect on the production of seeds (Table 4). The highest number of seeds per plant (48.89) was obtained by double spray of GA₃. While, the lowest number of seeds per plant (37.0) was observed in single spray of GA₃ at 42 DAS. However, the influence of time of IAA application was insignificant.

Results clearly showed that growth regulator application increased 100-seed weight in soybean (Table 3). Among the concentrations of GA₃ and IAA, the highest 100-seeds weight (10.76 g) was found with 100 ppm GA₃ and lowest 100-seeds weight (8.82 g) was recorded in 100 ppm of IAA. Different times of application had varied effect on 100-seeds weight (Table 4). The highest 100-seeds weight (9.66 g) was obtained by double spray of GA₃. While, the lowest 100-seeds (7.63 g) was obtained in single spray of IAA at 42 DAS. Application of 100 ppm GA₃ was reported to increase 100-seed weight in groundnut and sorghum (Lee, 1990; Shinde *et al.*, 1989). Present study clearly shows that GA₃ has (100 ppm) the potentiality to increase 100-seeds weight in soybean also.

Yield: The analysis of variance showed that growth regulators exerted highly varied influence on seed yield per plant (Table 3). The highest seed yield per plant (5.87 g) was obtained by 100 ppm of GA₃ followed by 100 ppm IAA (3.56 g) and the lowest seed yield/plant (3.30 g) was observed with 200 ppm of IAA. The data indicates that the lower concentration of IAA and GA₃ increased seed yield more efficiently than the higher concentrations. The highest seed yield per plant (5.09 g) was obtained by double spray of GA₃, while the lowest seed yield per plant (2.30 g) was observed in single spray of IAA at 20 DAS (Table 4). The interaction effects of time and different concentrations of growth regulators were found statistically varied (data not presented). Application of 100 ppm GA₃ increased seed yield per plant in rice and okra (Awan and Alizai, 1989; Kumer *et al.*, 1996).

Both IAA and GA₃ significantly increased the seed yield calculated in terms of t haG¹ (Table 3). The highest seed yield (2.34 t haG¹) was obtained by 100 ppm GA₃ followed by 100 ppm IAA (1.42 t haG¹). The lowest seed yield (1.3 t haG¹) was observed with 200 ppm IAA. It is clear from this study that 100 ppm both of IAA and GA₃ had promotive effect on seed yield. The average yield differed significantly due to different times of spray (Table 4). The highest seed yield (2.03 t haG¹) was obtained by double spray of GA₃ and the lowest seed yield (0.99 t haG¹) was obtained with single spray of IAA at 42 DAS. The results of the interaction of time and different concentrations of growth regulators were found statistically significant (data not presented). This result is in agreement with those of Awan and Alizai (1989), Sontakey *et al.* (1991) and Reena *et al.* (1999) who reported that 100 ppm IAA increased the seed yield in rice, sesame and soybean, respectively. There are much information regarding the increase of seed yield by GA₃. Application of 100 ppm GA₃ increased seed yield in rice (Awan and Alizai, 1989), soybean (Deotale *et al.*, 1998; Maske *et al.*, 1998), bell pepper (Abdul *et al.*, 1988) and onion (Hore *et al.*, 1988). The result of the present study clearly reflected that 100 ppm GA₃ increased seed yield in soybean.

Experimental results mentioned above revealed that the morphological and yield contributing characters of soybean could be modified by GA₃ and IAA applied at all developmental stages. GA₃ and IAA brought about an improvement in the growth, flowering, fruit setting and yield contributing characters of soybean when applied twice (double spray) at 100 ppm. Late spray (single spray at 42 DAS) at 100 ppm of both the growth regulators had better performance over the control and early spray (single spray at 20 DAS). Further investigations may be undertaken with lower concentrations than 100 ppm and concentrations between 100 and 200 ppm which may contribute better effect in modifying the growth, flowering, fruit setting and yield contributing characters of soybean.

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