

ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
<http://ansijournals.com/ja>

JOURNAL OF AGRONOMY



ANSI*net*

Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Growth Analysis of Soybean as Influenced by GA₃ and IAA and their Frequency of Application

Pulak Kumar Sarkar, Md. Shahidul Haque and M. Abdul Karim

Department of Crop Botany, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

Abstract: The experiment was carried to investigate the effect of plant growth regulators on the growth of soybean. Soybean (cv. BS-3) plants were sprayed with 0, 100 or 200 ppm of GA₃ and IAA at three different times (20 and/or 42 days after sowing). The results indicate that physiological characters e.g. leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were influenced by the application of the growth regulators. GA₃ and IAA at 100 ppm significantly increased LAI, CGR, RGR and NAR. IAA at 200 ppm increased NAR. Double spraying at 20 and 42 DAS performed better than single spraying at 20 DAS and spraying at 42 DAS. Double spraying with GA₃ and IAA had the highest CGR, NAR, LAI. On the other hand, single spraying with GA₃ produced highest RGR and 200 ppm of IAA produced highest NAR. Spraying at 42 DAS of GA₃ and IAA produced highest leaf area index and CGR over the single and double spraying. LAI, RGR, CGR and NAR progressed in similar patterns, regardless of the treatments. The treated plants attained high LAI, RGR, CGR and NAR than the control. This study clearly shows that 100 ppm of GA₃ and IAA treated plants performed better than control and other treated plants.

Key words: GA₃, *Glycine max* (L.) Merrill, growth analysis, IAA, frequency 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 has a high nutritive value containing about 42-45% protein and 20-25% edible oil. A variety of soya products are becoming familiar as food to the people of Bangladesh (Smith, 1975). Some soybean varieties can be profitably used as green manure and fodder also.

There exists a great opportunity, to grow soybean in Bangladesh in the rabi season instead of growing a part of the wheat, pulses and other rabi crops. In the northern part, it can also be grown in summer without affecting the production of transplant aman rice. Even it can be grown in the 'Char' and 'Haor' areas after the recession of flood water with no tillage and minimum inputs. Thus, it can contribute a lot to the economy and human health minimizing the big gap between the current requirements and present production of the oil crops. In Bangladesh, the yield of soybean is very discouraging compared to other soybean producing countries, mainly due to the use of low yield potential varieties and poor cultivation techniques and lack of knowledge about modern production technologies.

Plant growth regulator like indoleacetic acid (IAA) can increase plant height, number of leaves per plant, fruit size with consequent enhancement in seed yield in different crops like groundnut (Lee, 1990), cotton (Kaggate *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, gibberellic acid (GA₃) was reported to stimulate stem elongation (Harrington *et al.*, 1996), increase dry matter accumulation (Hore *et al.*, 1988) as well as total yield (Deotale *et al.*, 1998; Maske *et al.*, 1998). Unfortunately, very limited works have been carried out in Bangladesh in this regard. In the preceding paper, we have reported that yield and yield components of soybean were affected by the application of IAA and GA₃. Here we report the effects of IAA and GA₃ on various physiological growth

parameters 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 November 2000 to February 2001. The seeds of soybean (BS-3) were collected from the Department of Genetics and Plant Breeding, BAU. The 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 ha⁻¹ and 6 t ha⁻¹, 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 L 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. The selected plants of each plot were uprooted carefully ensuring maximum root extraction and they were carried to the laboratory in labeled polyethylene bags preventing 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 leaves, stems and roots. 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 (TDM) was determined by accumulating the dry weight of each portion of the plant. The 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 following formula (Hunt, 1978):

$$\text{LAI} = \frac{\text{LA}}{\text{P}}$$

$$\text{CGR} = \frac{\frac{I}{P} \cdot \frac{W_2 - W_1}{T_2 - T_1}}{\text{mg m}^{-2} \text{ d}^{-1}}$$

$$RGR = \frac{I}{W_1} \cdot \frac{W_2 - W_1}{T_2 - T_1} \text{ mg g}^{-1} \text{ d}^{-1}$$

$$NAR = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{\ln LA_2 - \ln LA_1}{LA_2 - LA_1} \text{ mg cm}^{-2} \text{ d}^{-1}$$

Where,
 LA = total leaf area
 W₁ = total dry weight at time T₁,
 W₂ = total dry weight at time T₂,
 P = ground area
 LA₁ = Total leaf area at time T₁
 LA₂ = Total leaf area at time T₂
 ln = Natural logarithm

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

Leaf area index (LAI): The growth regulators exhibited a significant effect on the leaf area index of soybean at all stages of plant growth (Table 1). The data revealed that both GA₃ and IAA significantly increased leaf area index at both concentrations applied. The highest LAI (10.16) was recorded with 100 ppm GA₃ (C₁) followed by 100 ppm IAA (C₃) (7.54) at 80 DAS. It is clear from these results that 100 ppm both of GA₃ and IAA had significantly higher LAI throughout the growth stages over their respective higher concentrations and the controls. A comparative study reveals that GA₃ is more efficient in leaf development than IAA as was observed by its relatively higher LAIs at all sampling dates (Table 1).

The highest leaf area index (9.50) was obtained at 80 DAS with the application of GA₃ at T₃ time (single spray at 42 DAS) (Table 2). The highest LAI among the application times of IAA application was found at 80 DAS (7.50) due to the single application on 42 DAS. However, IAA was less effective than GA₃.

The interaction effects of time of application and different concentrations of growth regulators were significant (Tables 3, 4). The highest combined effect (12.5) was found with 100 ppm GA₃ (C₁) and single spray at 42 DAS (T₃) (C₁T₃). Among IAA

interactions, 100 ppm IAA x T₃ (C₃T₃) had the highest effect (9.20) obtained at 80 DAS. LAI is the index of leafiness and leaves are the site of photosynthesis. The result of this study clearly reflected that 100 ppm both of GA₃ and IAA increased leaf area index at later stage i.e., before maturity. GA₃ is more effective in leaf development than IAA. An identical result was reported by Fasheun and Dennett (1982). Shen *et al.* (1990) reported a slight increase of LAI in soybean by GA₃ treatment. LAI of the treated plants maximized earlier than the control plants in this study. The highest yield per plant was attributed to the earlier attainment of the high CGR and LAI (Kumari and Balasubramanian, 1990).

Crop growth rate (CGR): Crop growth rate (CGR) was measured between growth stages (40 to 80 DAS) as an estimate of net canopy photosynthesis. The application of GA₃ had significant effect on crop growth rate of soybean at 40, 60 and 100 DAS (Table 1). Initially, CGR was lower in treated as well as control plants. It gradually increased, maximized and thereafter declined slightly due to aging of the crop. The CGR maximized earlier (60 DAS) in GA₃ treated plants. The data revealed the highest CGR (0.89 mg dm⁻² day⁻¹) at 100 ppm GA₃ at 60 DAS. It is also clear that the treated plants always had a higher CGR over the control (Table 1). Effect of IAA on CGR was almost same as that of GA₃. The treated plant had higher values of CGR at all sampling dates except 40 DAS (Table 1). However, the higher CGR of the treated plants was significant at only 60 DAS. The CGR maximized at 60 and 80 DAS in treated and control plants, respectively. Comparative study indicates that GA₃ treated plants had higher CGR than the IAA treated plants (Table 1).

The analysis of variance indicated that the CGR differed significantly at all stages except 80 DAS, due to different times of application of GA₃ and IAA (Table 2). The highest crop growth rate (0.749 mg dm⁻² day⁻¹) was attained at 60 DAS by the double application of GA₃ (Table 2). The trend of the CGR at various stages of plant growth due to the frequency of GA₃ and IAA application (Table 2) was similar to that of their concentrations (Table 1). The CGR increased and reached its peak at 60 DAS and thereafter gradually decreased.

The results of the interaction of times and different concentrations of the growth regulators were found statistically significant at all stages except 80 DAS (Tables 3, 4). C₁T₂ had the higher CGR (1.12 mg dm⁻² day⁻¹) than any other GA₃ combinations, while C₃T₂ (0.695 mg dm⁻² day⁻¹) was superior to the other IAA combinations. At the early stage (60 DAS), CGR was highest (1.12

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

Treat- ments (ppm)	Leaf area index (LAI) at DAS				Crop growth rate (RGR) (mg dm ⁻² day ⁻¹) at DAS				Relative growth rate (CGR) (mg g ⁻¹ day ⁻¹) at DAS				Net assimilation rate (mg cm ⁻² day ⁻¹) at DAS		
	20	40	60	80	40	60	80	100	40	60	80	100	40	60	80
GA₃															
0	0.51b	1.98b	3.28b	5.98c	0.063c	0.273c	0.415	0.036b	44.48ab	63.66b	36.03a	2.28b	0.423c	4.392c	11.615a
100	0.78a	3.17a	7.75a	10.16a	0.120a	0.890a	0.375	0.278a	47.81a	88.22a	15.38b	7.98a	1.393a	28.973a	21.168a
200	0.79a	3.16a	7.72a	8.05b	0.090b	0.696b	0.480	0.148ab	43.73b	84.84a	22.32b	5.06ab	0.968b	22.578b	23.648b
IAA															
0	0.51b	1.98c	3.28b	5.98c	0.063	0.273c	0.482	0.123	44.48a	63.66c	40.32a	6.72	0.423b	4.392a	13.506b
100	0.78a	2.67a	6.64a	7.54a	0.060	0.630a	0.501	0.150	29.32b	86.02a	25.14b	5.60	0.589a	17.194b	22.189a
200	0.83a	2.40b	6.49a	6.87b	0.061	0.451b	0.586	0.140	32.62b	74.27b	35.00a	6.00	0.563a	11.636a	24.489a

Table 2: Effect of timing of GA₃ and IAA application on physiological characters of soybean

Treat- ments (ppm)	Leaf area index (LAI) at DAS				Crop growth rate (RGR) (mg dm ⁻² day ⁻¹) at DAS				Relative growth rate (CGR) (mg g ⁻¹ day ⁻¹) at DAS				Net assimilation rate (mg cm ⁻² day ⁻¹) at DAS		
	20	40	60	80	40	60	80	100	40	60	80	100	40	60	80
GA₃															
T ₁	0.66	3.00b	5.57b	7.20b	0.062b	0.548b	0.371	0.087b	41.66b	78.46	23.40	4.00	0.751b	15.512 b	14.854
T ₂	0.73	3.33a	7.35a	7.48b	0.125a	0.749a	0.467	0.263a	56.14a	78.84	25.04	7.22	1.497a	27.708 a	20.229
T ₃	0.70	1.97c	5.83b	9.50a	0.071b	0.663b	0.432	0.112ab	38.23b	79.41	25.30	4.10	0.536b	12.722 c	21.347
IAA															
T ₁	0.69	2.27b	5.37	6.33b	0.060a	0.398c	0.495	0.180a	36.21ab	71.82b	34.20	8.27a	0.495b	9.350b	18.326
T ₂	0.73	2.52a	5.53	6.56b	0.069a	0.511a	0.574	0.126b	38.18a	77.00a	33.75	4.94b	0.627a	13.228a	21.268
T ₃	0.70	2.25b	5.51	7.50a	0.055a	0.446b	0.500	0.108b	32.02b	75.12ab	32.53	5.13b	0.454b	10.643a	20.591

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

Sarkar *et al.*: Growth regulators and soybean growth

Table 3: Interaction effect of GA₃ and time of application on physiological characters of soybean

Inter- actions	Leaf area index (LAI) at DAS				Crop growth rate (RGR) (mg dm ⁻² day ⁻¹) at DAS				Relative growth rate (CGR) (mg g ⁻¹ day ⁻¹) at DAS				Net assimilation rate (mg cm ⁻² day ⁻¹) at DAS		
	20	40	60	80	40	60	80	100	40	60	80	100	40	60	80
C ₀ T ₁	0.52	2.00d	3.20d	5.97e	0.062d	0.276c	0.354	0.051b	49.95c	64.21d	32.75	3.47b-d	0.424c	4.397e	9.855
C ₀ T ₂	0.49	1.93d	3.28d	6.00e	0.062d	0.272e	0.560	0.025b	44.23c	63.48d	44.20	1.05d	0.410c	4.327e	15.577
C ₀ T ₃	0.52	2.01d	6.36d	5.96e	0.064d	0.272e	0.330	0.032b	45.27bc	63.29d	31.14	2.33b-d	0.436c	4.451e	9.413
C ₁ T ₁	0.72	4.19a	6.30c	8.72b-d	0.079cd	0.766c	0.319	0.065b	38.29c-e	91.46a	14.84	2.54b-d	0.980bc	24.543c	15.184
C ₁ T ₂	0.89	4.31a	9.96a	9.20bc	0.205a	1.12a	0.321	0.507a	71.10a	82.33c	10.36	13.02a	2.792a	47.198a	19.146
C ₁ T ₃	0.74	1.01e	7.00bc	12.55a	0.075cd	0.89bc	0.486	0.263ab	34.06e	90.89ab	20.85	8.36ab	0.408c	15.178d	29.173
C ₂ T ₁	0.73	2.82c	7.21bc	6.90de	0.088bc	0.63d	0.441	0.145b	42.74cd	79.72c	22.50	6.00b-d	0.848bc	17.596d	19.524
C ₂ T ₂	0.79	3.75b	8.82ab	7.24c-e	0.108b	0.854b	0.519	0.258ab	53.10b	90.71ab	20.56	7.58a-c	1.291b	31.558b	25.966
C ₂ T ₃	0.85	2.90c	7.12bc	10.00b	0.073cd	0.631d	0.480	0.040b	35.36de	84.07bc	23.89	1.60cd	0.765bc	18.538d	25.456

Table 4: Interaction effect of IAA and time of application on physiological characters of soybean

Inter- actions	Leaf area index (LAI) at DAS				Crop growth rate (RGR) (mg dm ⁻² day ⁻¹) at DAS				Relative growth rate (CGR) (mg g ⁻¹ day ⁻¹) at DAS				Net assimilation rate (mg cm ⁻² day ⁻¹) at DAS		
	20	40	60	80	40	60	80	100	40	60	80	100	40	60	80
C ₀ T ₁	0.52	2.00d	3.20	5.97d	0.062ab	0.276f	0.432	0.133a-c	43.95a	64.20d	37.85	7.61a	0.424a	4.397b	12.019
C ₀ T ₂	0.49	1.93d	3.28	6.00d	0.062ab	0.272f	0.610	0.132a-c	44.22a	63.48d	46.93	6.21a	0.410b	4.327b	16.989
C ₀ T ₃	0.52	2.01d	3.36	5.90bd	0.064ab	0.272f	0.405	0.103a-c	45.27a	63.29d	36.14	6.36a	0.436c	4.451b	11.510
C ₁ T ₁	0.79	2.54b	6.51	6.43cd	0.052b	0.545c	0.495	0.190ab	22.52b	79.19b	27.06	7.49b	0.498bc	14.374a	20.181
C ₁ T ₂	0.77	3.14a	6.72	7.00bc	0.082a	0.695a	0.499	0.188ab	43.46a	88.66a	23.42	6.50c	0.867ab	20.436ac	21.349
C ₁ T ₃	0.78	2.33bc	6.68	9.20a	0.046b	0.651b	0.508	0.073bc	21.98b	90.20a	24.96	2.81bc	0.602ac	16.774bc	25.038
C ₄ T ₁	0.75	2.27c	6.40	6.60b-d	0.068ab	0.372	0.559	0.217a	42.17a	72.07c	37.69	9.70ac	0.562a	9.278a	22.777
C ₄ T ₂	0.93	2.50bc	6.60	6.68b-d	0.061ab	0.566c	0.612	0.055c	26.86b	78.88bc	30.89	2.09b	0.605b	14.924c	25.466
C ₄ T ₃	0.82	2.42bc	6.48	7.33b	0.067b	0.416d	0.586	0.149a-c	28.82b	71.87c	36.45	6.22a-c	0.523c	10.705a	25.225

Values with different letter (s) within a column differ significantly at 5% level of probability (LSD), Co = control, T₁ = Spray at 20 DAS only, C₃ = 100 ppm IAA, T₂ = (T₁ + T₃) Double spraying (spray at 20 DAS and 42 DAS), C₄ = 200 ppm IAA, T₃ = Spray at 42 DAS only

mg dm⁻² day⁻¹) in the C₁T₂ (100 ppm GA₃ x T₂) and the lowest (0.046 mg dm⁻² day⁻¹) in the C₃T₃ (100 ppm IAA x T₃) combination. The CGR increased at all the treatments over control in chickpea (Katiyar, 1980). The result of this study is in agreement with the above report. GA and NAA treatments increased crop growth rate through increasing net assimilation rate (Shen *et al.*, 1990). However, Matsunaga *et al.* (1988) stated that the highest maximum CGR was due to the highest LAI. In this study, we found higher LAI and NAR of the treated plant compared to the control.

Relative growth rate (RGR): The relative growth rate (RGR) was estimated at 40, 60, 80 and 100 DAS. The results indicate that RGR, from its initial lower value, maximized at 60 DAS followed by a gradual decrease in all treatments (Table 1). A 100 ppm GA₃ had the higher RGR value (88.22 mg g⁻¹ day⁻¹). However, unlike CGR, RGR was found higher in control plants than the treated plants at some stages of plant growth.

Effect for times of application of IAA application on RGR of soybean plant was found significant at 40, 60 and 100 DAS (Table 2). While that of GA₃ was insignificant except 40 DAS. The data revealed that RGR was the highest (78.84 mg g⁻¹ day⁻¹) at 60 DAS in double application of GA₃ (T₂) followed by the double application of IAA (Table 2).

The interaction effect between times of application and concentrations of growth regulators on the RGR was significant except 80 DAS (Tables 3, 4). At 60 DAS, the highest RGR (91.46 and 90.20 mg g⁻¹ day⁻¹) was observed in the C₁T₁ (100 ppm GA₃ x T₁) and C₃T₃ (100 ppm IAA x T₃), respectively. The minimum RGR (2.09 and 1.05 mg g⁻¹ day⁻¹) was observed in C₄T₂ (200 ppm IAA x T₂) (Table 4) and C₀T₂ (control x T₂) (Table 3), respectively. Spray of 100 ppm both GA₃ and IAA was the most effective. We found here that the RGR attained its highest value at 60 DAS due to the application of GA₃ and IAA. RGR was found higher at vegetative (60 DAS) stage in wheat (Karim and Siddique, 1991). This might be due to the initial high NAR of the treated plants. GA₃ has been reported to increase RGR in soybean due to an increase in leaf weight ration (Dijkstra *et al.*, 1990).

Net assimilation rate (NAR): The effect of growth regulators on net assimilation rate varied significantly at 40, 60 and 80 DAS (Table 1). The data revealed that the highest (28.973 and 22.189

mg cm⁻² day⁻¹) NARs were found in 100 ppm GA₃ and 100 ppm IAA at 60 and 80 DAS, respectively. The lowest NAR with GA₃ and IAA was observed in 200 ppm GA₃ at 40 DAS (0.96 mg cm⁻² day⁻¹) and 200 ppm IAA at 40 DAS (0.563 mg cm⁻² day⁻¹). Effect for time of application of GA₃ and IAA on NAR of soybean plants was found significant at 40 DAS and 60 DAS (Table 2). The data revealed that NAR was the highest (27.708 mg cm⁻² day⁻¹) in double spray of GA₃ at 60 DAS and the lowest in (0.454 mg cm⁻² day⁻¹) single spray of IAA at 42 DAS which was statistically identical to T₁ (single spray of IAA and GA₃).

The combined effect of growth regulators and times of application on NAR of soybean was found significantly varied at 40 DAS and 60 DAS (Tables 3, 4). Highest NARs (47.198 and 20.436 mg cm⁻² day⁻¹) were observed in the C₁T₂ (100 ppm GA₃ x T₂) and C₃T₂ (100 ppm IAA x T₂), respectively at 60 DAS. The minimum NARs (0.408 and 0.498 mg cm⁻² day⁻¹) were found in the C₁T₃ (100 ppm GA₃ x T₃) and C₃T₁ (100 ppm IAA x T₁) at 40 DAS. The data revealed that lower concentration and (T₂) time of application had the best effect at vegetative stage (60 DAS). This suggests that the growth regulators and time influenced the NAR independently during the entire growth period. Increased NAR due to increased sink activity by the exogenous application of GA₃ is one of the major factors for promoting initial growth of rice by GA₃ treatment (Katayama and Akita, 1989). They also indicated that initial growth promotion by exogenous GA₃ was due to increased NAR and not due to increased leaf area. We found high initial growth (CGR and RGR) of the treated plants together with high NAR. In conclusion, the growth of soybean could be manipulated by the exogenous application of GA₃ and IAA. The increase of growth parameters, especially LAI and CGR during the early growth stages of the treated plants is indicative of the increased yield that we reported in the preceding article.

References

- Deotale, R.D., V.G. Maske, N.V. Sorte, B.S. Chimurkar and A.Z. Yerne, 1998. Effect of GA₃ and NAA on morpho-physiological parameters of soybean. J. Soils Crops, 8: 91-94.
- Dijkstra, P., H.T. Reegen and P.J.C. Kuiper, 1990. Relation between relative growth rate, endogenous gibberellins and the response to applied gibberellic acid for *Plantago major*. Physiol. Pl., 79: 629-634.
- Fasheun, A. and D.M. Dennett, 1982. Interception of radiation and growth efficiency in field beans (*Vicia faba* L.). Agril. Meteorol., 26: 221-219.

Sarkar *et al.*: Growth regulators and soybean growth

- Gurdev, S. and O.P. Saxena, 1991. Seed treatments with bioregulators in relation to wheat productivity. In: New Trends in Plant Physiology, Proceed., National Symposium on Growth and Differentiation in Plants. New Delhi, India, pp: 201-210.
- Harrington, J.F., L. Rappaport and K.J. Hood, 1996. The influence of gibberellins on stem elongation and flowering on endive. *Sci.*, 125: 601.
- Hore, J.K., N.C. Paria and S.K. Sen, 1988. Effect of pre-sowing seed treatment on germination, growth and yield of (*Allium cepa*) var. Red Globe. *Hararyana J. Hort. Sci.*, 17: 83-87.
- Hunt, R., 1978. Plant Growth Analysis. Studies in Biology No. 96. Edward Arnold Ltd., London, pp: 67.
- Kapgate, H.G., N.N. Potkile, N.G. Zode and A.M. Dhopte, 1989. Persistence of physiological responses of upland cotton to growth regulators. *Ann. Plant Physiol.*, 3: 188-195.
- Karim, M.M. and K.A.M. Siddique, 1991. Crop growths and relative growth rates of old and modern wheat cultivars. *Aust. J. Agril. Res.*, 42: 13-20.
- Katayama, K. and S. Akita, 1989. Effect of exogenously applied gibberellic acid (GA_3) on initial growth of rice cultivars. *Japan. J. Crop Sci.*, 58: 217-224.
- Katiyar, R.P., 1980. Development changes in leaf area index and other growth parameters in chickpea. *Indian J. Agric. Sci.*, 50: 684-691.
- Kaur, J. and G. Singh, 1987. Hormonal regulation of grain filling in relation to peduncle anatomy in rice cultivars. *Indian J. Expl. Biol.*, 25: 63-65.
- Khalil, S. and H.M. Mandurah, 1989. Growth and metabolic changes of cowpea plants as affected by water deficiency and Indoleacetic acid. *J. Agron. Crop Sci.*, 163: 160-166.
- Kumari, A.N. and M. Balasubramanian, 1990. Physiological analysis of growth in soybean. *Indian J. Plant Physiol.*, 33: 248-252.
- Lee, H.S., 1990. Effects of pre-sowing seed treatments with GA_3 and IAA on flowering and yield components in groundnuts. *Korean J. Crop Sci.*, 35: 1-9.
- 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 soyabean. *J. Soils Crops*, 8: 20-21.
- Matsunaga, R., A. Hamid and A. Hashem, 1988. Dry matter production and yield performance of summer and winter pulses in Bangladesh. *J. Fac. Agric. Kyushu Univ.*, 33: 221-118.
- Rahman, L., 1982. Cultivation of Soybean and its Uses. City Press, Dhaka, Bangladesh, pp: 5-7.
- Russell, D.F., 1986. MSTAT-C package programme. Crop and Soil Science Department, Michigan State University, USA.
- Shen, Y., Y. Ishii, K. Ito and H. Numaguchi, 1990. Effects of plant growth regulators on the dry matter productivity in green fodder sorghum *Sorghum bicolor* Moench. *J. Jananese Soc. Grass. Sci.*, 36: 276-284.
- Smith, R.G., 1975. Composition of Foods: Raw, Processed and Prepared, Agriculture Hand Book No. 8. Agric. Res. Sevr. Washington, D.C. Revised, 1993. Compiled and Written by R. G. Smith, Home Economist, M.C.C., pp: 42-45.