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VEGETATIVE GROWTH, YIELD AND QUALITY OF BROCCOLI AS INFLUENCED BY APPLICATION OF GIBBERELLIC ACID

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Abstract

Field experiments on broccoli cv. 'BARI Broccoli-1' was carried out during two consecutive *rabi* seasons of 2014-15 and 2015-16 at the field of Plant Physiology Section of HRC, BARI. 30 days old seedlings were treated before transplanting by dipping their roots for 24 h in different concentrations of GA_3 (Gibberellic acid) viz., 20, 40, 60, 80 and 100 ppm along with control (distilled water). The experiment was laid out in a Randomized complete block Design with three replications. GA_3 concentrations significantly influenced the growth parameters, yield and yield attributes and quality parameters of broccoli. In regard to the average data of two years, GA_3 @ 60 ppm gave the maximum leaf length (46.58 cm), spread diameter (52.38 cm), head circumference (38.2cm cm), head length (16.60 cm), head diameter (15.45 cm), primary and secondary head weight/plant (289.85 g and 192.80 g). The maximum head yield (18.82 t/ha in 2014-15 and 21.39 t/ha in 2015-16) with an average of 20.11 t/ha was recorded at GA_3 @ 60 ppm followed by GA_3 @ 40 ppm. Application of GA_3 @ 60 ppm also produced the highest head compactness index (18.77 g/cm), maximum vitamin C (82.88 mg/100 g FW), vitamin A (601.90 IU/100 g FW) contents and the highest total soluble solid (10.10%). From the investigation it was also observed that application of more than 60 ppm GA_3 reduced the yield attributes and yield of broccoli.

Keywords*:* Broccoli, gibberellic acid, growth, vitamin A, vitamin C and TSS.

Introduction

Broccoli *(Brassica oleracea* var. *italica* L.) is a member of cole crops belonging to the family *Brassicaceae*. It is an important vegetable crop and has high nutritional and good commercial value. At present, this crop is cultivated in limited area in Bangladesh. However, due to increasing its consumption by consumers, there is a trend to increase cultivation by farmers. Broccoli is rich in dietary fiber, minerals, vitamins, and anti-oxidants. Fresh broccoli is a storehouse of many phytonutrients such as thiocyanates, indoles, sulforaphane, isothiocyanates, and flavonoids like beta-carotene, cryptoxanthin, lutein, and zeaxanthin which help protect against prostate, colon, urinary bladder, pancreatic, and breast cancers. Now-a-days, broccoli attracted more attention due to its multidimensional use and great nutritional value (Rangkadilok *et al*., 2004).

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Growth regulators are organic substances besides nutrients, synthesized in plants, causing alteration in their cellular metabolism. Synthesis of some plant hormones is adversely affected by environmental factors, which causes restriction on physiological processes of the plant and ultimately, limits their growth potential. The application of these hormones in low concentration regulates growth, differentiation and development, either by promotion or inhibition (Naeem *et al*.. 2004), and allows physiological processes to occur at their normal rate. Plant growth regulators modify the physiological processes of the plant, which ultimately affect the yield and quality of the crop. Among plant growth regulators, GA_3 exhibited beneficial effect in cole crops such as in cabbage (Chaurasiya *et al.*, 2014), cauliflower (Kaur and Mal, 2018) and broccoli (Chanwala *et al*., 2019; Reza *et al*., 2015). In other crops GA_3 had also positive influence on growth and yield attributes. GA_3 significantly enhanced fruit yield in okra (Baraskar *et al.*, 2018), seed germination rate in brinjal and tomato (Islam *et al*., 2006), fiber yield in cotton (Copur *et al*., 2010) and other growth parameters in other crops. Gibberellins stimulate cell division, cell enlargement or both (Nickell, 1982). Such type of investigation is very scanty in Bangladesh. Therefore, the experiment was conducted to evaluate the response of GA_3 on yield and quality improvement of broccoli.

Materials and Methods

The experiment was conducted at the field of Plant Physiology Section of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI) during the *rab*i seasons from October to January of 2014-15 and 2015-16. The experiment was laid out in a Randomized Complete Block Design with three replications. The experiment was conducted with five gibberellic acid (GA_3) concentrations along with control *viz*., T_0 = Distilled water (control), T_1 = GA_3 @ 20 ppm, T_2 = GA_3 @ 40 ppm, T_3 = GA_3 @ 60 ppm, T_4 = GA_3 @ 80 ppm and T_5 = GA_3 @ 100 ppm. Using electronic balance 250 mg of gibberellic acid was accurately weighed out and dissolved in a few ml of ethyl alcohol (95%). The solution thus prepared was transferred to a 250 ml volumetric flask. Then the volume of the solution was made upto 250 ml with distilled water to get the 1000 ppm stock solution. Finally, the required lower concentrations of GA_3 (20, 40, 60, 80 and 100 ppm) were prepared from the stock solutions by using the formula: $V_1 \times S_1 = V_2 \times S_2$; where. S_1: concentration of stock solution (1000 ppm) of GA_3, V_1 = volume of stock solution of GA_3 (which we have to be calculated), S_2: concentration of GA_3 needed and V_2: amount of solution required for spray. Then calculated amount (V_1) of GA_3 was taken from stock solution and poured into a volumetric flask of known volume and then required amount of distilled water was added into this flask.

The test variety was ‘BARI Broccoli-1’ which is a sprouting type broccoli. Cowdung, urea, TSP, MoP, gypsum, boric acid, zinc sulphate and magnesium sulphate were applied @ 10 t, 240, 150, 150, 55, 12, 11 and 60 kg/ha (Ferdouse Islam, 2015). The entire quantity of cowdung, TSP, gypsum, boric acid, zinc sulphate and magnesium sulphate, one-third of urea and half of MoP were applied during final land preparation. The remaining half of MoP and two-third of urea were applied in three equal installments at 20, 40 and 60 days after transplanting. 30 days old seedlings were transplanted on 19 November 2014 and 11 November 2015 at 60 cm row to row and 40 cm plant to plant distance. The unit plot size was 6.72 m^2 (2.80 m x 2.40 m) having 28 plants. GA_3 was applied to the plants according to treatment schedule. Seedlings were uprooted from seed bed on 18 November 2014 and 10 November 2015 in the afternoon and the total seedlings were divided into six groups and roots of five groups of seedlings were dipped into the desired concentration of GA_3 and one group was dipped in distilled water for twenty four hours. Weeding was done as and when necessary. A total of four irrigations were applied to the crop. There was no attack of insects and incidence of diseases on the crop. Harvesting of primary head was done 21 January to 26 January 2015 and 14 January to 20 January 2016. After harvesting of primary head, 4-5 secondary (lateral) heads were arisen from below the primary head which was also harvested at 6-7 days later of primary head harvest at edible stage. in both years. Data on growth parameters viz. plant height, number of leaves/plant, leaf length, leaf breadth, spread diameter and days to primary head formation were recorded at head initiation stage after transplanting. At first canopy spread of north-south and east-west direction were measured, then these two measures were added and averaged to get spread diameter datum (Hafiz *et al*., 2015). Data on head parameters like head circumference, head length, head diameter, primary head weight, secondary (lateral) head weight, weight of heads/plant, head yield per plot (6.72 m^2) were recorded at harvesting stage. All the growth and head parameters were averaged from randomly selected 10 plants. Per hectare head yield was estimated from plot yield. Data on quality parameters *viz.*, vitamin C, vitamin A content and TSS (%) were recorded from the florets of broccoli. Head compactness index was calculated from the formula: Head compactness index = Primary head weight/plant (g)/Head diameter (cm) (Metwaly, 2016); Vitamin A (IU/100 g FW) was estimated from ß carotene (µg/100 g FW) by dividing 0.6. Vitamin-C (ascorbic acid) in fresh broccoli head was estimated by 2,6-Dichlorophenol-indophenol visual titration method as described by Rangana (1986). The reagents used for the estimation of vitamin-C were as follows: 1) Metaphosphoric acid (6%), 2) standard ascorbic acid solution, 3) 2-6 dichlorophenol-indophenol dye. 20 grams florets of broccoli head were weighed accurately by an electrical balance and blended. The blended sample were then transferred to a 100 mi volumetric flask and the volume was made upto 100 ml. For estimation of vitamin-C, the following steps were followed: Standardization of dye solution, preparation of solution and then titration. The formula of estimating: Vitamin-C content (mg per 100 g of florets) = (T× D×V_1×100)/(V_2 x W); Where, T=Titre, D=Dye factor, V_1 = total volume of blended sample (100 ml), V_2 = Volume of extract taken for estimation (titration) (5 ml) and W = weight of sample taken for estimation (20 g)

ß-carotene was determined following acetone-hexane method as stated by Masayasu and Yamashita (1992). 100 grams of florets of broccoli head was dipped in acetone-hexane (4:6) solution for extraction of the pigment. Then the supernatant was collected in vials and the optical density of the supernatant at 663 nm, 645 nm, 505 nm and 453 nm were measured by spectrophotometer (UV-1800, Shimadju, Japan). From these values, the content of ß-carotene was estimated using the following formula: ß-carotene (mg/100g) = $0.216A_{663}$ - $1.22A_{645}$ -$0.304A_{505}$ + $0.452A_{453}$ (A_{663}, A_{645}, A_{505} and A_{453} are absorbance at 663 nm, 645 nm, 505 nm and 453 nm, respectively)

TSS (%) in fresh broccoli head was estimated by a Hand Refractometer. At first a small amount of fresh florets of broccoli head was pressed to collect juice. This juice was then put on the prism of the refractometer and data was recorded. The MSTAT-C computer package was used to analyze the data and mean separation was done by LSD test at 5% level of probability.

Results and Discussion

Effect of GA_3 on growth characters

Application of GA_3 significantly influenced leaf length, spread diameter and days to primary head formation (Table 1). The maximum leaf length was recorded from T_3 treatment (45.00 cm in 2014-15, 48.15 cm in 2015-16 with the mean 46.58 cm) closely followed by T_2 treatment (43.33 cm in 2014-15, 46.36 cm in 2015-16 and the mean value 44.85 cm) while the lowest leaf length was obtained from T_0 treatment in both years. T_3 treatment gave the maximum spread diameter (51.10 cm in 2014-15 and 53.66 cm in 2015-16 with the mean 52.38 cm) followed by T_2 (47.84 cm in 2014-15, 49.14 cm in 2015-16 with the mean value of 48.89 cm) and the T_0 treatment produced the lowest spread diameter in both the years. The possible reason for increase in leaf length and spread diameter of broccoli plants might be due to optimum dose of the gibberellic acid, which promoted vegetative growth by cell elongation and cell division. Similar results were also found by Kumar and Roy (2000).

The T_0 reatment took the maximum days (63.46 days in 2014-15 and 61.46 days in 2015-16) to reach primary head formation stage and T_3 took the minimum days (56.60 days in 2014-15 and 54.81 days in 2015-16 with the mean 58.71 days) for primary head formation. This is in agreement with the results obtained by Patil *et al.* (1987). Verma *et al*. (2018) reported the minimum days (56.33 days) required to head formation when GA_3 @ 75 ppm was sprayed followed by GA_3 @ 50 ppm (58.51 days).

Table 1. Effect of GA_3 on growth characters and primary head formation of broccoli (var. 'BARI Broccoli-1')

Treatment	Plant height (cm)			Leaves/plant (no.)			Leaf length (cm)		
	Y_1	Y_2	Mean	Y_1	Y_2	Mean	Y_1	Y_2	Mean
T_0	20.41	24.70	22.56	11.60	13.34	12.47	41.67	44.59	43.03
T_1	21.27	25.74	23.51	12.30.	14.15	13.23	42.54	45.52	44.03
T_2	21.67	26.22	23.95	12.41	14.27	13.34	43.33	46.36	44.85
T_3	22.08	26.72	24.40	12.64	14.54	13.58	45.00	48.15	46.58
T_4	21.07	25.49	23.28	12.07	13.88	12.98	41.99	44.93	43.46
T_5	20.46	24.76	22.61	11.95	13.74	12.85	42.11	45.06	43.89
$LSD_{0.05}$	ns	ns	-	ns	ns	-	1.69	1.21	-
CV (%)	4.90	6.76	-	3.90	5.65	-	3.17	4.32	-

Table 1. continued.

Treatment	Leaf breadth (cm)			Spread diameter (cm)			Days to primary head formation		
	Y_1	Y_2	Mean	Y_1	Y_2	Mean	Y_1	Y_2	Mean
T_0	15.97	16.66	16.32	44.30	46.34	45.32	63.46	61.46	62.46
T_1	16.44	17.26	16.85	46.96	49.02	47.49	58.97	57.10	58.04
T_2	16.92	17.66	17.29	47.84	49.94	48.89	58.36	56.51	57.44
T_3	17.27	18.03	17.65	51.10	53.66	52.38	56.60	54.81	55.71
T_4	15.94	16.74	16.34	45.08	47.26	46.17	59.03	57.26	58.15
T_5	15.95	16.71	16.33	44.75	46.70	45.73	58.63	56.97	57.80
$LSD_{0.05}$	ns	ns	-	4.26	3.11	-	2.09	1.65	-
CV (%)	4.49	8.87	-	5,02	6.34	-	5,14	4.87	-

T_0 = Distilled water (control), T_1 = GA_3 @ 20 ppm, T_2 = GA_3 @ 40 ppm, T_3 = GA_3 @ 60 ppm, T_4 = GA_3 @ 80 ppm, T_5 = GA_3 @ 100 ppm; Y_1 = 2014-15, Y_2 = 2015-16; ns = not significant.

Table 2. Effect of GA_3 on primary head of broccoli (var. 'BARI Broccoli-1')

Treatment	Head circumference (cm)			Head length (cm)			Head diameter (cm)		
	Y_1	Y_2	Mean	Y_1	Y_2	Mean	Y_1	Y_2	Mean
T_0	30.68	32.14	31.41	11.44	11.90	11.67	11.41	11.76	11.59
T_1	34.19	35.32	34.76	13.49b	13.93	13.71	13.29	13.91	13.60
T_2	35.64	36.81	36.23	14.17	14.74	14.46	14.38	15.04	14.71
T_3	37.61	38.84	38.23	16.29	16.91	16.60	15.10	15.79	15.45
T_4	33.91	34.82	34.37	12.70	13.31	13.01	12.40	12.86	12.63
T_5	33.12	34.11	33.62	12.60	13.00	12.80	12.14	12.57	12.36
$LSD_{0.05}$	1.33	1.29	-	0.826	0.717	-	1.30	1.26	-
CV (%)	4.15	5.60	-	3.58	4.01		5.47	5.21	-

T_0 = Distilled water (control), T_1 = GA_3 @ 20 ppm, T_2 = GA_3 @ 40 ppm, T_3 = GA_3 @ 60 ppm, T_4 = GA_3 @ 80 ppm, T_5 = GA_3 @ 100 ppm; Y_1 = 2014-15, Y_2 = 2015-16.

Table 3. Effect of GA_3 on head weight/plant and head yield of broccoli (var. 'BARI Broccoli-1')

Treatment	Primary head weight /plant (g)			Secondary head weight /plant (g)			Total head weight /plant (g)		
	Y_1	Y_2	Mean	Y_1	Y_2	Mean	Y_1	Y_2	Mean
T_0	187.80	225.48	206.69	135.20	141.40	138.30	323.00	366.90	345.00
T_1	215.40	258.36	236.83	154.90	162.00	158.40	370.30	420.40	395.20
T_2	249.70	299.88	274.79	179.50	187.70	183.60	429.20	487.60	458.50
T_3	263.20	316.20	289.85	188.50	197.10	192.80	451.70	513.30	482.70
T_4	203.40	244.08	223.74	141.40	147.80	144.60	344.80	391.90	368.30
T_5	195.70	234.84	215.27	137.10	143.40	140.20	332.80	378.20d	355.50
$LSD_{0.05}$	8.07	7.11	-	6.82	6.51	-	21.25	19.81	-
CV (%)	3.55	5.14	-	4.68	3.58		8.01	7.54	-

Table 3.continued.

Treatment	Head yield (kg/plot)			Head yield (t/ha)		
	Y_1	Y_2	Mean	Y_1	Y_2	Mean
T_0	9.04	10.27	9.66	13.46	15.29	14.38
T_1	10.37	11.77	11.07	15.43	17.52	16.47
T_2	12.02	13.66	12.84	17.88	20.32	19.10
T_3	12.65	14.37	13.51	18.82	21.39	20.11
T_4	9.66	10.97	10.32	14.37	16.33	15.35
T_5	9.32	10.59	9.96	13.87	15.76	14.81
$LSD_{0.05}$	1.03	0.98	-	1.41	1.38	-
CV (%)	8.56	6.54	-	9.36	9.54	-

T_0 = Distilled water (control), T_1 = GA_3 @ 20 ppm, T_2 = GA_3 @ 40 ppm, T_3 = GA_3 @ 60 ppm, T_4 = GA_3 @ 80 ppm, T_5 = GA_3 @ 100 ppm; Y_1 = 2014-15, Y_2 = 2015-16; Plot area: 6.72 m^2.

Table 4. Effect of GA_3 on quality attributes of broccoli head (var. 'BARI Broccoli-1'

Treatment	Head compactness index (g/cm)			Vitamin C (mg/100 g FW)			Vitamin A (IU/100 g FW)			TSS (%)		
	Y_1	Y_2	Mean	Y_1	Y_2	Mean	Y_1	Y_2	Mean	Y_1	Y_2	Mean
T_0	16.46	19.17	17.84	61.42	60.89	61.16	380.80	383.00	381.90	8.50	8.10	8.30
T_1	16.21	18.57	17.41	72.56	72.87	72.72	400.30	405.80	403.10	9.40	9.60	9.50
T_2	17.36	19.94	18.69	76.68	77.65	77.17	426.30	431.00	428.70	9.50	9.70	9.60
T_3	17.43	20.03	18.77	82.82	82.93	82.88	599.80	604.00	601.90	10.10	10.00	10.10
T_4	16.40	18.98	17.71	82.78	82.60	82.69	580.80	590.30	585.60	9.70	9.60	9.70
T_5	16.12	18.68	17.42	80.15	80.20	80.18	577.80	588.00	582.90	9.80	9.80	9.80
$LSD_{0.05}$	0.76	0.81	-	5.11	4.97	-	17.35	16.98	-	0.39	0.32	-
CV (%)	5.68	6.01	-	4.15	4.65	-	3.69	3.80	-	3.54	3.21	-

T_0 = Distilled water (control), T_1 = GA_3 @ 20 ppm, T_2 = GA_3 @ 40 ppm, T_3 = GA_3 @ 60 ppm, T_4 = GA_3 @ 80 ppm, T_5 = GA_3 @ 100 ppm; Y_1 = 2014-15, Y_2 = 2015-16.

Effect of GA_3 on primary head

Maximum head circumference, head length and head diameter were significantly influenced by different levels of GA_3 (Table 2 and 3). It can also be revealed that each yield attributing characters increased with the increase of GA_3 concentration up to 60 ppm and thereafter the values of those characters declined. Head circumference was found the maximum from T_3 (37.61 cm in 2014-15, 38.84 cm in 2015-16 and the mean was 38.23 cm) followed by T_2 (35.64 cm in 2014-15, 36.81 cm in 2015-16 with the mean of 36.23 cm). The same trend was also followed in case of head length as that of head circumference. Application of T_3 treatment produced the highest head length 16.29 cm and 16.91 cm in 2014-15 and 2015-16 and in mean, respectively and the mean was 16.60 cm. The maximum head diameter was also recorded in T_3 treatment (15.10 cm in 2014-15m, 15.79 cm in 2015-16 with the mean value of 15.45 cm) and it was closely followed by T_2 treatment (14.38 cm in 2014-15 and 15.04 cm in 2015-16 with the mean 14.71 cm).

Reza *et al*. (2015) reported that application of GA_3 @ 50 ppm caused increase in curd (head) length and curd diameter by 46% and 20.73%, respectively compared to control.

Effect of GA_3 on head weight/plant and head yield/hectare

Primary head weight, secondary head weight and total head weight/plant were found significantly as influenced by different levels of GA_3 (Table 3). The maximum primary head weight/plant was recorded from T_3 (263.20 g in 2014-15 and 316.20 g in 2015-16 with the mean 289.85 g) followed by T_2 (249.70 g in 2014-15 and 299.88 g in 2015-16 with the mean of 274.79 g). The treatment T_3 also produced the highest secondary head weight/plant (188.50 g in 2014-15, 197.10 g in 2015-16 with the mean of 192.80 g) and it was followed by T_2. The maximum total head weight/plant was recorded from T_3 (451.70 g in 2014-15, 513.30 g in 2015-16 and the mean was 482.7 g) followed by T_2 (429.2 g in 2014-15, 487.6 g in 2015-16 with the mean of 458.50 g). Hussain *et al.* (2016) obtained secondary (lateral) head weight/plant in the range of 49.33 g to 200.70 g/plant.

The head yield/plot increased significantly with the increase of GA_3 concentration up to 60 ppm and beyond that head yield declined (Table 3). Each GA_3 treatment maintained a lead over control in respect of head yield both per plot (6.72 m_2) and hectare. The highest head yield per plot was recorded from T_3 (12.65, 14.37 and 13.51 kg/plot in 2014-15, 2015-16 and in mean, respectively) followed by T_2 (12.02 kg/plot in 2014-15, 13.66 kg/plot in 2015-16 with the mean 12.84 kg/plot). Same trend was also followed in case of head yield/hectare. The maximum head yield was obtained from T_3 (18.82 t/ha in 2014-15, 21.39

t/ha in 2015-16 and 20.11 t/ha in mean) followed by T_2 (17.88 t/ha in 2014-15, 20.32 t/ha in 2015-16 and the mean was 19.10 t/ha) and it was the lowest in control (13.46, 15.29 and 14.38 t/ha in 2014-15, 2015-16 and in mean, respectively). The effects of gibberellic acid on broccoli were studied by Wang and Yang (2008) and reported that inflorescence differentiation and head yield was increased. Reza *et al*. (2015) obtained the highest head yield of broccoli from 50 ppm GA_3. Chanwala *et al.* (2019) obtained 19.96 t/ha head yield from 75 ppm GA_3 being statistically similar with 50 ppm GA_3 (18.87 t/ha).

Effect of GA_3 on quality attributes

Head compactness index was recorded the maximum from T_3 (17.43, 20.03 and 18.77 g/cm in 2014-15, 2015-16 and in mean, respectively) closely followed by T_2 (17.36, 19.94 and 18.69g/cm in 2014-15, 2015-16 and in mean, respectively). The highest Vitamin C content was obtained from T_3 (82.82, 82.93 and 82.88 mg/100 g FW in 2014-15, 2015-16 and in mean, respectively) closely followed by T_4 (82.78 mg/100 g FW in 2014-15, 82.60 mg/100 g FW in 2015-16 and 82.69 mg/100 g FW in mean) while its lowest value was in control. Maximum vitamin A content was recorded from T_3 (599.80 IU in 2014-15, 604.00 IU in 2015-16 and 601.90 IU in mean). In 2015-16, there was no significant difference among T_3, T_4 and T_5 treatments regarding vitamin A content. The lowest vitamin A content was observed in the control in both years. TSS was found the maximum in T_3 (10.10% in 2014-15, 10.00% in 2015-16 and 10.10% in mean) and the lowest TSS was recorded in control treatment (8.5% in 2014-15, 8.16% in 2015-16 and 8.3% in mean).

Hussain *et al*. (2017) found head compactness index in the range of 12.93g/cm-18.61 g/cm in nitrogen fertilizer related experiment of broccoli. They also found vitamin C and ß-carotene content in the range of 55.71-94.73 mg/100 g FW and 0.187-0.400 mg/100 gm FW (311.67-666.67 IU/100 g FW), respectively in broccoli (var. Premium Crop'). Chanwala *et al.* (2019) reported that GA_3 @ 75 ppm produced 82.82 mg/100 g FW ascorbic acid which was identical with 50 ppm GA_3 (77.06 mg/100 g FW) in broccoli in India.

Conclusion

Based on the above discussion, it might be concluded that different growth parameters were significantly affected by different GA_3 solutions. GA_3 @ 60 ppm had the maximum influence over other treatments in respect of leaf length, spread diameter, days to primary head formation, head circumference, head length, head diameter, primary and secondary head weight, total soluble solid (TSS), vitamin C and vitamin A content. Therefore, GA_3 @ 60 ppm might be recommended for use in broccoli cultivation.

References

Baraskar, T. V., P. P. Gawande, N. V. Kayande, S. S .Lande and M. S. Naware. 2018. Effect of plant growth regulators on growth parameters of okra (*Abelmoschus esculentus* L. Moench). *Int. J. Chem. Studies*. **6** (6): 165-168.

Chanwala, P., A. K. Soni, D. Sharma and G. Choudhary. 2019. Effect of foliar spray of plant growth regulators on growth and quality of sprouting broccoli (*Brassica oleracea* var *italica* L.) *Int. J. Curr. Microbiol. App. Sci.* **8**(8): 1846-1852.

Chaurasiya, J., M. L. Meena, H. D. singh, A. Adarshand and P. K. Mishra. 2014. Effect of GA_3 and NAA on growth and yield of cabbage (*Brassica oleracea* var. *capitata* L.)

Ferdouse Islam, L. Akter and M. H. Al-Mamun. 2015. Advanced yield trial of selected broccoli lines. Research report on horticultural crops 2014-2015. Olericulture Divisionm, HRC, BARI, Gazipur. pp. 69-70

Hafiz, M. A., A. Biswas, M. Zakaria, J. Hassan and N. A. Ivy. .2015. Effect of planting dates on the yield of broccoli genotypes. *Bangladesh J. Agril. Res.* 40 (3): 465-478

Hussain, M. J., A. J. M. S. Karim, A. R. M. Solaiman, M. s. Islam and M. Rahman. 2017. Effect of different levels on urea super granule and prilled urea on the crop quality, nutrient uptake and soil nutrient status of broccoli. *The Agriculturists*. **15**(2): 24-39.

Hussain, M. J., A. J. M. S. Karim, A. R. M. Solaiman, M. S. Islam and M. Rahman. 2016. Effect of urea super granule and prilled urea on yield and yield attributes of Broccoli (*Brassica oleracea* var. *italica* L.). *The Agriculturists*. **14**(2): 95-112.

Islam, M. O., M. S. Islam and A.K.M. A. Prodhan. 2006. Seed germination and seedling growth of brinjal, tomato and chilli treated with GA_3 and GABA. *J. Bangladesh Agril. Univ.* **4**(1): 43-49.

Kaur, P. and D. Mal. 2018. Effect of foliar spray of NAA and GA_3 on the growth, curd formation and yield of cauliflower (*Brassica oleracea var.* botrytis L. *J. Pharm. Phytochem*. **7**(3): 2805-2807

Kumar, V. and N. Roy. 2000. Effect of plant growth regulators on cauliflower cv. Pant Subhra. *Orissa J. Hort*. **28**(1): 65-67.

Masayasu, N and U. Yamashita. 1992. Simple method for simultaneous determination of chlorophyll and carotenoids in tomato fruit. *J. Japan Soc. Food Sci Tech*. **9**(100: 935-928.

Metwaly, E. E. 2016. Effect of nitrogen and boron fertilization on yield and quality of broccoli. *J. Plant Production.* **7**(12): 1395 -1400

Naeem, M, I. Bhatti, R. H. Ahmad and M. Y. Ashraf. 2004. Effect of some growth hormones (GA_3, IAA and Kinetin) on the morphology and early or delayed initiation of bud of lentil (*Lens culinaris* Medik). *Pakistan J. Bot.* **36**: 801-809.

Nickell, L.G. 1982. Plant Growth Regulators, Springer- *Verlag Berlin Heidelberg, New York. pp*. 1-3.

Patil, A. A., S. M. Maniur and U. G. Nalwadi. 1987. Effect of GA_3 and NAA on growth and yield of cabbage. *South Ind. Hort.* **35** (5): 393-394.

Rangana, S. 1986. Handbook of Analysis and Quality control for Fruit and Vegetable products. Tata McGraw Hill Pub. Co. Ltd., New Delhi, India. 1143 pp.

Rangkadilok, N., M. E. Nicolas, R. N. Bennett, D. R. Eagling, R.R. Premier and W.J. Taylor. 2004. The effect of sulfur fertilizer on glucoraphanin levels in broccoli (*B. oleracea* L. var. *italica)* at different growth stages. *J. Agric. Food Chem.* **52**: 2632-2639.

Reza, M., M. Islam, A. Haque, R. K. Sikder, H. Mehraj and A. F. M. J. Uddin. 2015. Influence of different GA_3 concentrations on growth and yield of broccoli. *Ame-Urasian J. Sci. Res.* **10**(5): 332-335.

Verma, S., S. Sengupta, B. K. Agarwal, K.K. Jha, S. Mishra, R. Rajak and V. Rani. 2018. Foliar application of boron, urea and GA_3 influences earliness of curd production in broccoli (*Brassica oleracea* var. italica). *Int. J. Agril. Sci*. **14**(1): 149-153.

Wang, T. and X. Yang. 2008. The Effects of gibberellin on inflorescence differentiation, photosynthesis characteristics and quality in broccoli. *Northern Hort*. **01**: 10-12.