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EFFECT OF PLANT GROWTH REGULATORS ON THE PERFORMANCE OF LADY'S FINGER (*Abelmoschus esculentus* L.)

M. MONIRUZZAMAN[1] AND R. KHATOON[2]

Abstract

Field experiments were conducted at the Plant Physiology Field of Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI), Gazipur during the summer seasons of 2022 and 2023 to study the effect of plant growth regulators (PGRs) on the growth and yield of lady's finger. Two okra varieties, namely BARI Dheros-2 and OK-1820 were sprayed with seven PGRs treatments *viz.*, two levels (100 and 200 ppm) of naphthalene acetic acid (NAA), two levels (100 and 200 ppm) gibberellic acid (GA_3) and two levels (200 and 400 ppm) of chlorocholine chloride (CCC) concentrations at 4 weeks after seed sowing, first flowering and 3 weeks after first flowering stages. The control plots were treated with tap water. The experiment was conducted in a split-plot design with three replications allocating varieties in main plot and PGR treatments in sub plots. The plant height, leaf area index (LAI), dry weight/plant, fruit length, fruit diameter, individual fruit weight, number of fruits/plant and weight of fruits/plant were the maximum for 100 ppm GA_3 followed by 200 ppm GA_3 in both BARI Dheros-2 and OK-1820 in two years. The highest fruit yield per hectare (21.10 t in BARI Dheros-2 and 21.74 t in OK-1820 during 2022, and 29.11 t/ha in BARI Dheros-2 and 29.22 t/ha in OK-1820 during 2023) was recorded with the application of 100 ppm GA_3 which was followed by 200 ppm GA_3 (19.88 t/ha in BARI Dheros-2 and 20.87 t/ha in OK-1820 during 2022, and 28.37 t/ha in BARI Dheros-2 and 28.75 t/ha during 2023) and 400 ppm CCC (27.03 t/ha in BARI Dheros-2 and 26.88 t/ha in OK-1820 during 2023). The BARI Dheros-2, recorded the maximum average fruit yield for 100 ppm GA_3 (25.11 t/ha) followed by 200 ppm GA_3 (24.13 t/ha) and 400 ppm CCC (21.34 t/ha) while in OK-1820, 25.48, 24.81 and 23.25 t/ha average fruit yield were found in 100 ppm GA_3, 200 ppm GA_3 and 400 ppm CCC, respectively. Both the varieties provided with the maximum gross margin while treated with GA_3 @ 100 ppm (Tk. 4, 52,237/ha from BARI Dheros-2 and Tk. 4, 61,612/ha from OK-1820). The highest BCR (3.94) was recorded for CCC @400 ppm in OK-1820 and BCR 3.62, 3.67 and 3.58 were for 400 ppm CCC, 200 ppm CCC and 100 ppm GA_3 from BARI Dheros-2, respectively. It might be recommended that spraying of 400 ppm CCC or 100 ppm GA_3 singly in 3 equal sprays at 4 weeks after sowing, at flowering and 3 weeks after first flowering would be optimum for maximum fruit yield and highest return of lady's finger.

Keywords: Lady's finger, *Abelmoschus esculentus*, GA_3, NAA, CCC, Yield, BCR

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[1]Chief Scientific Officer, Planning and Evaluation Wing, Bangladesh Agricultural Research Institute (BARI), Gazipur, and [2]Senior Scientific Officer, Plant Physiology Section, HRC, BARI, Gaizpur, Bangladesh.

Introduction

Okra [*Abelmoschus esculantus* (L.) Moench] is a very popular summer vegetable crop widely cultivated all over Bangladesh. It is locally known as “Dheros” which belongs to the family Malvacae and can be grown under a high temperature range of 24-27°C. However, it is extremely sensitive to frost and temperature below 12°C and seeds germinate poorly at ground temperature of 20 °C or less (Anon., 2012). Okra pod contains good amount of potassium, calcium, magnesium, phosphorus, vitamin 'A' and 'C'. One hundred gram of fresh pod of okra has around; 1.9 g of protein, 0.2 g fat, 6.4 g carbohydrate, 0.7 g minerals and 1.2 g fiber (Tiwari *et al*., 1998). In the year 2022-23, the total production of okra was 96 thousand tons from 12.56 thousand hectares of land with an average yield of 7.64 t ha^{-1} (BBS, 2024).

The average yield of okra in our country is very low compared to the other okra growing countries such as India (12.18 t/ha), Pakistan (11.19 t/ha), Egypt (13.84 t/ha) and Ghana (21.35 t/ha) (Anon., 2022; Vanitha *et al*., 2013). Plant growth regulators (PGRs) can profoundly influence the growth and differentiation of various parts of plant. The activities of PGs depend on their concentration and environmental factors affecting their absorption and plant’s physiological state. PGRs have the ability to effect cell division, cell structure, cell expansion, cell function, and mediate environmental stress even at low concentrations (Shagufta *et al*., 2019). Its use in crop promotes growth along the longitudinal area, increase number of branches, early flower initiation, fruit set, fruit quality and subsequently contributes towards higher production when applied at various concentrations (Maity *et al*., 2016). Among the several growth substances, gibberellic acid (GA_3) naphthalene acetic acid (NAA) and chlorocholine chloride (CCC) are found very promising and these are being used in Okra (Gadade *et al*., 2017; Meena *et al.*, 2017; Bhagure and Tambe, 2013; Maity *et al*., 2016; Pateliya *et al*., 2014; Mondal *et al*., 2012). The role of GA_3 in cell elongation in plant has been well established which resulted in increasing the plant height. Contrary to GA_3 and NAA, CCC has been found to retard plant growth by reducing internodes length (Moulana *et al*., 2020) who observed 17% decrease in internode length at 90 days after sowing (DAS). However, there is little information available on the effect of growth regulators on the growth and yield of okra in Bangladesh. In view of the above facts, the present experiment was conducted to find out a suitable dose of GA_3, NAA and CCC on the growth, yield and quality of okra with economic return.

Materials and Methods

The experiment was conducted at the research field of plant physiology section of HRC (23°59′33″ N latitude and 90°24′37.95″ E longitude) during the summer season of 2022 and 2023. The experiment was laid out in a split plot design with three replications. The experiment consisted of 7 PGRs treatments *viz.*, T_1 = tap water as control, T_2 = 100 ppm naphthalene acetic acid (NAA), T_3 = 200 ppm

NAA, T_4 = 100 ppm gibberellic acid (GA_3), T_5 = 200 ppm GA_3, T_6 = 200 ppm chlorocholine chloride (CCC) and T_7 = 400 ppm CCC and two varieties *viz.*, V_1 = BARI Dheros-2 and V_2 = Ok-1820 (Ispahani). The treatment 200 ppm GA_3 was selected as one of the treatments after reviewing the literature cited in different journals according to Shahid *et al.* (2013), Gadade *et al* (2017) and Baraskar *et al*. (2018) who all selected 200 ppm GA_3 as one of the treatments for their experiments on okra. The unit plot size was 2.00 m x 2.00 m (4.0 m^2) having 16 plants. Manures and fertilizers were applied to the soil @ 5000 kg Cowdung, 200 kg N, 150 kg P, 150 kg K, and 20 kg S per hectare. The source of N, P, K and S were Urea, TSP, MoP and gypsum. The total amount of cowdung, TSP, gypsum and one-fourth quantity of urea and MoP were applied prior to planting seeds and the remaining three- fourth quantity of Urea and MoP was top dressed into three equal installments 30, 45 and 60 days after transplanting. Seeds of two okra varieties were dibbled at the rate of 2 seeds/hill on 12 April 2022 and 16 April 2023 maintaining 50 x 50 cm plant spacing. Prior to planting, seeds were soaked in tap water for 24 hours for uniform and better germination. After germination the seedlings were thinned out to one seedling in each hole. The harvesting of green fruits was done every alternate day. The experiments were completed on 22 July 2022 and 26 July 2023. The control plants were sprayed with tap water, whereas aqueous solutions of NAA, CCC and GA_3 were sprayed thrice on the plants i.e. at 4 weeks after sowing, 1^{st} flowering and three weeks after 1^{st} flowering. Trix was added to the solutions as a surfactant for the uniform spread of chemicals and moisture on leaves. In the first year, both varieties were attacked by Jassids 35 days after sowing (DAS) and by red mite 55 DAS. To control Jassids Admire (ai: Imidacloprid 70% WG) was sprayed @ 1.0 ml/L of water thrice at 10 days interval starting from the infestation; whereas, to control red mite Vertimec 1.8 EC (ai: Abamectin) was sprayed two times at an interval of 15 days starting from the infestation. In the 2^{nd} year no infestation of insect and mites was seen because admire and omite (ai: Propargite 57% EC) were sprayed to the crops thrice at 15 days interval starting from 30 DAS. The data were recorded on plant height at the last harvest, leaf area index, dry weight/plant, fruit length, fruit diameter, individual fruit weight, number of fruits/plants, weight of fruits/plant, and fruit yield/ha. Plot yield was converted to per hectare yield. The following equation was used to calculate the leaf area (LA) of each leaf: $LA\ (m^2) = L \times W \times k$ (1) Where, L =leaf length (m) W = leaf width (m). k= 0.62 for okra (Musa and Usman, 2016). To obtain the total leaf area per plant, the specific leaf area LA was multiplied by the number of leaves counted. The LAI was then determined by dividing the leaf area by the ground area of the plant.

Recorded data were statistically analyzed by MSTAT-C and mean separation was done by Tukey W test at 5% level of probability. Cost-return analysis was also done considering the average yield of 2022 and 2023 for each variety.

Results and Discussion

Growth characters

Plant height, Leaf Area Index (LAI) and dry weight/plant were significantly influenced by different plant growth regulator treatments (Table 1). In 2022 the maximum plant height at last harvest was obtained from 100 ppm GA_3 (159.20 cm in BARI Dheros-2 and 142.87 cm in OK-1820 whereas, during 2023, 178.21 cm in BARI Dheros-2 and 168.17 cm in OK-1820. In 2023, in the case of BARI Dheros-2, plant height at 100 ppm GA_3 was identical with that of 200 ppm. The lowest plant height was recorded from 400 ppm CCC in both varieties in both 2022 and 2023 because a spray of 400 ppm CCC produced an inhibitory effect on plant height that produced shorter plant compared to control treatment. Kuswaha *et al*. (2020) reported that highest plant height at 90 DAS (96.17 cm) and maximum number of leaves (23.79/Plant) from 100 ppm GA_3.

In BARI Dheros-2, during 2022, maximum leaf area index was noticed in 100 ppm GA_3 (6.19) which was statistically similar to 200 ppm GA_3 (6.03) and the lowest from control 400 ppm CCC (4.70). In OK-1820, during 2022 maximum leaf area index was recorded from 100 ppm GA_3 (5.71) followed by 200 ppm GA_3 (5.15) and the lowest from 400 ppm CCC. But during 2023, in OK-1820 the highest LAI was observed from 100 ppm GA_3 (8.43 and 7.18, respectively) followed by 200 ppm GA_3 (7.47 and 6.05, respectively) and the lowest LAI from control treatment. Konyeha and Alatise (2013) obtained leaf area index (LAI) of 3.19 to 4.40 for lady's finger at 7 WAP (weeks after planting) at irrigated condition using 60 cm x 30 cm spacing in Nigeria. Baraskar *et. al.* (2018) reported that plant height, number of branches per plant, number of leaves per plant, leaf area, fresh weight per plant.

In both the varieties during 2022 and 2023, maximum dry weight/plant was observed from 100 ppm GA_3 (213.10g and 165.3 g in BARI Dheros-2 and 274.31 g and 237.39 g in OK-1820) and the lowest from 400 ppm CCC in BARI Dheros-2 and OK-1820 during 2022, whereas the lowest dry weight/plant was found in 400 ppm CCC treatment in both the varieties during 2023. The increase of growth characters like plant height, LAI and dry weight/plant might be due to that GA_3 could be involved in many aspects of plant growth and development, such as cell enlargement, internodes elongation, stimulated RNA and protein synthesis and thereby leading to enhanced growth and development (Yamaguchi and Kamiya, 2000). The results of better performance of okra under growth regulator treatments might be due to the consequence of growth regulators on cell elongation, stimulated RNA and protein synthesis, and better diversion of food material towards flowering and fruiting. The positive influence of plant growth regulators on growth and yield of okra was in agreement with Kokare *et al*. (2006) and Nawalkar *et al*. (2007). Rajappa *et al*. (2020) obtained highest plant height (102.38 cm), leaf area/plant (1124.87 cm^2) from 150 ppm sprayed 30 days after sowing when 150 ppm GA_3, 150 ppm NAA and 100 ppm IAA were used. Chowdhury *et al*. (2014) reported that application of GA_3 @ 100 ppm produced maximum plant height, number of leaves/plant, number of internodes, fresh weight and dry weight/plant. Kuswaha *et al*. (2020) reported that highest plant height at 90 DAS (96.17 cm) and maximum number of leaves (23.79/Plant) from 100 ppm GA_3.

Fruit yield and yield components

During 2022 maximum fruit length was obtained from 100 ppm GA_3 (13.07 cm in BARI Dheros-2 and 13.40 cm in 2OK-1820) which was closely followed by 200 ppm GA_3 only in BARI Dheros-2 (13.04 cm) (Table 2). The lowest fruit length of BARI Dheros-2 was noted in control treatment. In 2023, the maximum fruit length was recorded from 200 ppm GA_3 (16.40 cm in BARI Dheros-2 and 16.38 cm in OK-1820) which was closely followed by 100 ppm GA_3 (16.07 cm in BARI Dheros-2 and 16.29 cm in OK-1820), 100 ppm NAA (15.83 cm in BARI Dheros-2 and 15.85 cm in OK-1820) and 400 ppm CCC (15.81 cm in BARI Dheros-2 and 15.45 cm in OK-1820) and the lowest from control (Table 2). Application of 400 ppm CCC gave the maximum fruit diameter (15.77 and 15.23 cm in BARI Dheros-2 and OK-1820, respectively during 2022; 15.40 and 15.99 cm in BARI Dheros-2 and OK-1820, respectively during 2023). During 2022 spraying of 100 ppm GA_3 also gave similar fruit diameter (15.15 cm) as 400 ppm CCC recorded (15.23 cm) in OK-1820. In 2023, 100 ppm GA_3 registered fruit diameter (14.96 cm in BARI Dheros-2 and 15.91 cm in Ok-1820, which were identical with 400 ppm CCC and the lowest from control in both varieties during both years. In BARI Dheros-2, during 2022 maximum individual fruit weight was recorded from 100 ppm GA_3 (20.33 g) which was identical to 200 ppm GA_3 (19.93g) and followed by 200 ppm NAA and 400 ppm CCC and the lowest from control, whereas in OK-1820 the highest individual fruit weight was obtained from 100 ppm GA_3 (21.13 g) which was followed by 200 ppm GA_3 (19.73g), 100 ppm NAA (19.60g) and 200 ppm NAA (19.53g) and the lowest from control in BARI Dheros-2.

In 2022 the maximum number of green fruits/plants was harvested with the application of 100 ppm GA_3 (37.90 in BARI Dheros-2 and 45.70 in OK-1820), which was followed by 200 ppm GA_3 (35.70 in BARI Dheros-2 and 42.30 in OK-1820) and 100 ppm NAA in OK-1820, while minimum number of fruits/plants was recorded in control in both varieties (Table 2). In 2023, the highest number of green fruits/plant was obtained from 100 ppm GA_3 (65.30 in BARI Dheros-2 and 66.06 in OK-1820) which was statistically similar to 200 ppm GA_3 only in OK-1820 (63.66/plant) and the lowest number of green fruits was recorded from control in both the varieties. Maximum weight of fruits/plant was recorded from 100 ppm GA_3 (546.0 g in BARI Dheros-2 and 739.5 g in OK-1820 during 2022; 1116.7 g in BARI Dheros-2 and 1146.7 g in OK-1820) which was followed by 200 ppm GA_3 (515.0 g in BARI Dheros-2 and 689.0 g in OK-1820 during 2022; 1050.0 g in BARI Dheros-2 and 1120.0 g in OK-1820 during 2023) and 200 ppm NAA (709.0 g in OK-1820) and 100 ppm NAA (688.0 g) and the minimum weight of fruits/plant from control in both varieties during both years. Maity *et al.* (2016) obtained the highest fruit length and maximum fruit number/plant from the application of 150 ppm GA_3. Bhagure and Tambe (2013) and Singh and Singh (2020) obtained maximum number of fruits/plant (12.29) from 100 ppm GA_3.

Table 1. Effect of Plant growth regulators on growth characters of two varieties of okra during 2022 and 2023

Treatment	Plant height at last harvest (cm)				Leaf Area Index (LAI)				Dry weight/plant (g)			
	2022		2023		2022		2023		2022		2023	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
T_1	145.47c	124.87de	137.30d	143.23e	4.89c	4.64c	4.23e	4.39e	140.0d	136.0de	176.49f	130.20f
T_2	149.63b	126.52cd	156.33c	154.77d	5.59b	4.53c	5.23d	4.78de	147.2c	139.6c	229.89c	175.44de
T_3	142.67d	127.79c	146.27d	137.20f	4.49d	3.94de	4.52e	4.31 e	136.0e	138.1cd	213.35de	162.88e
T_4	159.20a	142.87a	178.21a	168.17a	6.19a	5.71a	8.43a	7.18a	213.1a	163.5a	274.31a	237.39a
T_5	150.36b	136.34b	173.10a	162.93b	6.03a	5.15b	7.47b	6.05 b	179.8b	148.9b	243.2 b	221.64b
T_6	145.73c	122.34e	168.88ab	158.20c	4.52d	4.15d	5.94c	5.43c	140.9d	138.9c	206.63e	181.90cd
T_7	136.01e	115.68f	162.07bc	154.78d	4.70cd	3.90e	5.77cd	5.00cd	129.5f	135.5e	217.70d	195.93c
CV (%)	4.37	4.37	6.21	6.21	4.13	4.13	5.45	5.45	2.16	2.46	6.58	6.58

Means within a column, having similar letter (s) are not significantly different by Tukey W test at 5% probability level;

T_1 = control (Tap H_2O spray), T_2 = 100 ppm NAA, T_3 = 200 ppm NAA, T_4 = 100 ppm GA_3, T_5 = 200 ppm GA_3, T_6 = 200 ppm CCC and T_7 = 400 ppm CCC; V_1 = BARI Dheros-2, V_2 = OK-1820 (Ispahani)

Table 2. Effect of plant growth regulators on yield attributes and yield of two varieties of okra during 2022 and 2023

Treatment	Fruit length (cm)				Fruit Diameter (mm)				Individual Fruit weight (g)			
	2022		2023		2022		2023		2022		2023	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
T_1	12.25c	12.44e	14.42c	13.50d	13.52f	13.63d	14.01cd	14.31d	18.35e	18.69c	15.25d	15.27c
T_2	12.63bc	13.10bc	15.83ab	15.85ab	13.75e	14.19c	15.06ab	14.90c	19.03d	19.60 b	17.55c	16.88ab
T_3	12.37c	12.90d	14.62c	14.35cd	13.52f	14.05c	13.96d	14.75c	19.73b	19.53b	15.97d	16.53b
T_4	13.07a	13.40a	16.07a	16.29a	15.44b	15.15a	14.96abc	15.91a	20.33a	21.13a	18.80a	17.04ab
T_5	13.04a	13.20b	16.40a	16.38a	14.98c	14.44b	14.11 bcd	15.16b	19.93ab	19.93b	18.48ab	16.90ab
T_6	12.30c	12.93cd	14.68c	14.78 bc	14.27d	13.61d	14.19bcd	14.29d	19.13c	18.30c	16.97c	16.86ab
T_7	12.65bc	13.12bc	15.81abc	15.45abc	15.77a	15.23a	15.40a	15.99a	19.53bc	18.23c	17.69bc	17.38a
CV (%)	2.37	2.37	5.27	5.27	2.31	2.31	3.37	3.37	2.16	2.16	4.16	4.16

Table 2. continued.

Treatment	Fruits/plant (no.)				Weight of fruits/plant (g)				Fruit yield (t/ha)					
	2022		2023		2022		2023		2022		2023		Average of two years	
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
T_1	25.61f	30.03e	35.50f	34.86e	334.3f	451.1e	464.75g	459.23 f	10.70d	14.42d	16.12e	16.17e	13.41f	15.30e
T_2	33.50c	41.50b	38.86e	47.76d	488.5c	688.0b	698.93f	752.18e	15.29c	19.99c	18.96d	20.62d	17.13e	20.31d
T_3	32.30d	40.50c	45.13d	47.92d	477.5cd	709.0b	736.75e	761.16e	16.77d	19.63c	19.4d	19.65d	18.09d	19.64d
T_4	37.90a	45.70a	65.30a	66.06a	546.0a	739.5a	1116.7a	1146.7a	21.10a	21.74a	29.11a	29.22a	25.11a	25.48a
T_5	35.70b	42.30b	61.43b	63.66a	515.0b	689.0b	1050.0b	1120.0b	19.88b	20.87b	28.37a	28.75a	24.13b	24.81
T_6	28.60e	38.90d	56.11c	55.97c	464.0d	576.5d	950.0d	926.7d	15.85c	17.78d	25.67c	25.54c	20.76c	21.66c
T_7	27.90e	38.80d	61.13b	61.32b	421.0e	591.5cd	990.0c	966.7c	15.64c	19.6c2	27.03b	26.88b	21.34c	23.75b
CV (%)	2.23	2.23	4.33	4.33	3.63	3.63	5.43	5.43	5.46	5.46	6.16	6.16	7.12	6.97

Means within a column, having similar letter (s) are not significantly different by Tukey W test at 5% probability level ;

T_1 = control (Tap H_2O spray), T_2 = 100 ppm NAA, T_3 = 200 ppm NAA, T_4 = 100 ppm GA_3, T_5 = 200 ppm GA_3, T_6 = 200 ppm CCC and T_7 = 400 ppm CCC; V_1 = BARI Dheros-2, V_2 = OK-1820 (Ispahani).

In 2022, the highest fruit yield was recorded from the application of 100 ppm GA_3 (21.10 t/ha in BARI Dheros-2 and 21.74 t/ha in OK-1820) which was followed by 200 ppm GA_3 (19.88 t/ha in BARI Dheros-2 and 20.87 t/ha in OK-1820) and the lowest from control in both varieties (Table 2). In 2023, the highest fruit yield was also recorded from 100 ppm GA_3 (29.11 t/ha in BARI Dheros-2 and 28.75 t/ha in OK-1820) which was statistically similar to 200 ppm GA_3 (28.37 t/ha in BARI Dheros-2 and 28.75 t/ha in OK-1820) and followed by 400 ppm CCC (27.03 t/ha in BARI Dheros-2 and 26.88 t/ha in OK-1820). The lowest yield was observed in control treatment in both varieties during both years. The yield performance of okra in 2023 was much better than that of 2022 because of higher plant height, higher dry weight/plant, higher fruit size and higher number of fruits/plant. Besides, the first year crop was infested by Jassids and red mites resulting in poor growth and ultimately the yield performance was lower than the second year crop which was not attacked by insects as insecticides were sprayed to the plants for precautionary measure.

In respect of average yield of two years, the maximum fruit yield of BARI Dheros-2 was recorded from 100 ppm GA_3 (25.11 t/ha) followed by 200 ppm GA_3 (24.13 t/ha) and 400 ppm CCC (21.34 t/ha) and the minimum yield obtained from control treatment (13.41 t/ha) in the same variety, while the highest fruit yield of OK-1820 was obtained from 200 ppm GA_3 (25.48 t/ha) which was statistically similar to 200 ppm GA_3 (24.81 t/ha) and followed by 400 ppm CCC (23.25 t/ha) and the least yield from control treatment (15.30 t/ha) (Table 2). Meena *et al.* (2017) reported that maximum fruit yield/ha in okra was recorded from the application of 20 ppm NAA and 30 ppm GA_3 among three concentrations of NAA (10, 20 and 30 ppm) and three concentrations of GA_3 (10, 20 and 30 ppm). Bhagure and Tambe (2013) obtained the highest fruit yield/plant grom 100 ppm GA_3, whereas Maity *et al*. (2016) obtained the highest number of fruits (18.20/plant) and maximum fruit yield (324.87 g/plant) from 150 ppm GA_3 followed by 100 ppm GA_3 (17.80/plant; 314.177 g/plant). Pateliya *et al.* (2014) reported that application of 300 ppm CCC produced maximum fruit length, fresh fruit weight, number of fruits/plant and fruit yield both per plant and hectare. Moulana *et al*. (2020) got the highest yield of fruit 13.23 t/ha from 350 ppm CCC application. Kuswaha *et al*. (2020) reported that they got highest number of fruits (22.05/plant), maximum weight of fruits (301.19 g/plant) and fruit yield (16.74 t/ha) from 100 ppm GA_3 among 25, 50 and 100 ppm GA_3 and higher number of fruits (18.01/plant), maximum weight of fruits (212.04 g/plant) and fruit yield (11.78 t/ha) from 750 ppm CCC among 250, 500 and 750 ppm CCC.

In case of GA_3, the increase in fruit yield might be due to greater photosynthesis, higher food accumulation, better plant growth and higher yield attributes. Another probable reason for increasing yield attributes might be due to the increasing growth characters by cell elongation and cell expansion that might have ultimately increased in the fruit yield as a result of GA_3 application in this study. CCC application increased fruit diameter and increased fruit length little in 2023. Kumar *et al*. (2018) reported that 600 ppm CCC gave maximum fruit diameter (16.13 mm) among three concentrations of CCC (200, 400 and 600 ppm). Chowdhury *et al*. (2014) obtained maximum number of pods/plant (33.77), pod length (17.66 cm) and pod diameter (1.77 cm) and yield/ha (16.67 t/ha) from the application of GA_3 @ 100 ppm. Kushwaha *et al*. (2000) reported that foliar spray of GA_3 was found beneficial for increasing maximum number of fruit (22.05), highest fruit yield plant^{-1} (301.19 g) and fruit yield ha^{-1} (16.74 t) was recorded with 100 ppm GA_3.

Economics

Cost-return analysis of okra production with the application of NAA, GA_3 and CCC (average of 2022 and 2023 for BARI Dheros-2 and OK-1820) was presented in Table 3. In BARI Dheros-2, the maximum gross return was recorded at 100 ppm GA_3 (Tk 6,27,625/ha) followed by 200 ppm GA_3 (Tk 6, 03,125/ha) and 400 ppm CCC (Tk 5,33,375/ha) and the minimum from the control (Table 4). This variety gave the highest gross margin (Tk 4, 52,237/ha) at 100 ppm GA_3 followed by 200 ppm GA_3 (Tk 3, 87,737/ha) and 400 ppm CCC (Tk. 3, 85,987/ha OK-1820 gave the maximum gross return (Tk 6,37,000/ha) followed by 200 ppm GA_3 (Tk 6,20,00/ha) and 400 ppm CCC (Tk. 5,81,250/ha). The maximum gross margin was recorded at 100 ppm GA_3 (Tk 4, 61,612/ha) followed by 400 ppm CCC (Tk 4, 33,862/ha) and 200 ppm GA_3 (Tk 4, 04,862/ha), and the lowest in control (Tk 2, 46,987/ha). The maximum benefit cost ratio (BCR) was noted at 200 ppm CCC (3.67) closely followed by 400 ppm CCC (3.62) and then followed by 100 ppm GA_3 (3.58) in BARI Dheros-2, whereas, in OK-1820 BCR was found maximum at 400 ppm CCC (3.94) followed by 200 ppm CCC (3.83) and 100 ppm GA_3 (3.63) and 200 ppm NAA (3.55) and the minimum in control (2.82). Although the higher gross margin was recorded at 100 ppm GA_3 and 200 ppm GA_3 treatments in both varieties, the maximum BCR was not obtained from GA_3 treatments because of the high cost involvement in GA_3 treatments.

Table 3. Cost-return analysis of lady's finger production with the application of NAA, CCC and GA_3 (Average of two years for each variety of BARI Dheros-2 and Ok-1820)

Treatment	Mean pod yield (t/ha)	Gross return (Tk/ha)	Cost of treatment Tk/ha)	Total cost of cultivation (Tk/ha)	Gross margin (Tk/ha)	Benefit-cost ratio (BCR)
BARI Dheros-2						
T_1	13.41	335250	16500	135388	199862	2.48
T_2	17.13	428125	18000	136888	291237	3.13
T_3	18.09	452125	19500	138388	313737	3.27
T_4	25.11	627625	56500	175388	452237	3.58
T_5	24.13	603125	96500	215388	387737	2.80
T_6	20.76	519000	22500	141388	377612	3.67
T_7	21.34	533375	28500	147388	385987	3.62

Treatment	Mean pod yield (t/ha)	Gross return (Tk/ha)	Cost of treatment Tk/ha)	Total cost of cultivation (Tk/ha)	Gross margin (Tk/ha)	Benefit-cost ratio (BCR)
OK-1820						
T_1	15.30	382375	16500	135388	246987	2.82
T_2	20.31	507625	18000	136888	370737	3.71
T_3	19.64	491000	19500	138388	352612	3.55
T_4	25.48	637000	56500	175388	461612	3.63
T_5	24.81	620250	96500	215388	404862	2.88
T_6	21.66	541500	22500	141388	400112	3.83
T_7	23.25	581250	28500	147388	433862	3.94

T_1 = control (Tap H_20 spray), T_2 = 100 ppm NAA, T_3 = 200 ppm NAA, T_4 = 100 ppm GA_3, T_5 = 200 ppm GA_3, T_6 = 200 ppm CCC and T_7 = 400 ppm CCC; V_1 = BARI Dheros-2, V_2 = OK-1820 (Ispahani)

Basic cost of cultivation: Tk. 118888.00;1 kg produce: Tk 25.00.

Cost of PGRs:

1. Naphthalene Acetic Acid (NAA):Tk 3000.00/100 g
2. Cycocel (CCC): Tk 6000.00/100 g
3. Gibberellic acid: 800.00/g

Conclusion

The results indicated that application of GA_3 @100 ppm yielded 21.10 and 21.74 t/ha in BARI Dheros-2 and OK-1820, respectively while GA_3 @ 200 ppm gave the second highest yield 19.88 t/ha of BARI Dheros-1 and 20.87 t/ha of OK- 1820 followed by NAA @ 200 ppm (16.77 t/ha in BARI Dheros-1 and 19.63 t/ha in OK 1820 during 2022. In 2023, spraying of GA_3 @ 100 ppm recorded the highest fruit yield 29.11 t/ha in BARI Dheros-2 and 29.22 t/ha in OK-1820, which was identical with 200 ppm GA_3 (28.37 t/ha in BARI Dheros-2 and 28.75 t/ha in OK-1820. Application of 200 ppm NAA and 400 ppm CCC also performed well with respect to fruit yield in two varieties. In Ok-1820, the maximum gross margin was found from 400 ppm CCC followed by 200 ppm CCC and 100 ppm GA_3, whereas in BARI Dheros-2, the highest BCR from 200 ppm CCC followed by 400 ppm CCC and 100 ppm GA_3 in both BARI Dheros-2 and OK-1820. Application of 100 ppm GA_3 or 200-400 ppm CCC independently in 3 equal sprays at 4 weeks after sowing, first flowering and 3 weeks after first flowering would be optimum for maximum fruit yield and highest return of lady’s finger.

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