



Growth and Yield of Chilli as Influenced by Plant Growth Regulators and Its Method of Application

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Authors' contributions

This work was carried out in collaboration among all authors. Authors TM and KK planned the experiment and lead the research. Authors IS, TM and KK designed and carried out the research. Authors MEH performed the statistical analysis. Authors IS and IAS carried out the research on the field. Authors IS, SA, SM and AG collected the data. Authors IS and MEH wrote the manuscript. Authors IAS, SA, SM and AG managed the literature searches. All authors provided critical feedback and helped shape the research, analysis and manuscript.

Article Information

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- Complete Peer review History: <http://www.sdiarticle4.com/review-history/51501>

Original Research Article

Received 12 August 2019

Accepted 18 October 2019

Published 23 October 2019

ABSTRACT

The experiment was conducted on the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during Rabi season to determine the growth, yield and economic benefit of chilli as influenced by plant growth regulators. The experiment consisted of two factors. Factor A: Plant growth regulators (three levels) as G0: Control, G1: NAA (40 ppm), G2: Cytokinin (10 ppm) and Factor B: Application method (three levels) as M1: Seed soaking with plant growth regulators for 6 hours, M2: Foliar spray of plant growth regulators at vegetative stage, M3: Foliar spray of plant growth regulators at flower bud initiation stage. The experiment was laid out in a Randomized

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Complete Block Design with three replications. In the case of plant growth regulators, the highest yield (33.56 t/ha) was found from G1 treatment, whereas the lowest (13.85 t/ha) from G0 treatment. For the application method, maximum yield (27.12 t/ha) was recorded from M3 treatment, while the minimum yield (19.92 t/ha) from M1 treatment. Due to combined effect, the highest yield (38.10 t/ha) with net income (1075498) and BCR (3.39) was observed from G1M3 treatment combination, while the lowest yield (11.22 t/ha) with net income (147131) and BCR (1.49) from G0M1 treatment combination. So, the economic analysis revealed that the G1M3 treatment combination appeared to be the best for achieving the higher growth, yield and economic benefit of chilli.

Keywords: Application method; Chilli; growth regulators and yield.

1. INTRODUCTION

Chilli (*Capsicum frutescens*) is one of the important spices which belong to the family Solanaceae. It is the second most important Solanaceous crop after tomato throughout the world [1]. Green chillies are rich in vitamin A and C and the seed contains traces of starch [2,3]. Also, peppers are a good source of vitamin-B and vitamin B6, carbohydrate, carotene, thiamine, riboflavin and niacin [4]. The production of chilli is governed not only by the inherent genetic yield potential but also it is greatly influenced by several environmental factors and cultivation practices. But the production of chilli is reduced due to flower and fruit drop, which is caused by physiological and hormonal imbalance in the plants, particularly under unfavourable environments. There is a huge potential to increase the yield of chilli by reducing flower drops and by increasing fruit set. Studies revealed that the application of NAA is effective in reducing the flower and fruit drops thereby enhancing the production of chilli per unit area and per unit time. It also plays an important role in stimulating cellular elongation in the shoot, apical bud dominance and root initiation [5]. Another plant growth regulator, cytokinin stimulates cell-division, induce cell-enlargement, break dormancy, shoot initiation and rejuvenation of mature shoots. Although plant growth regulators have great potential for growth improvement their application has to be planned sensibly in terms of optimal concentration, stage of the application and proper application method. Plant growth regulators can be used through different application methods such as foliar spray, seed soaking, drenching, etc. Foliar spray and seed soaking methods are very useful for using these chemicals. But specific information based on research work on many aspects of chilli crop more particularly the application method is still lacking in the literature. The present study was

undertaken to evaluate the performance of plant growth regulators and its application method on growth, yield and economic return of chilli in Bangladesh.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period of rabi season from October 2017 to March 2018. The experimental site is situated between 23°75' N latitude and 90°34' E longitude and at an elevation of 8.4 m above sea level [6]. The soil was shallow red-brown and highland in texture. The soil was having the texture of sandy loam with pH 5.6.

2.2 Experimental Framework

The hybrid seed of chilli (Variety-Anmol) was used as planting materials in the experiment. The experiment was laid out in factorial design in Randomized Complete Block with three replications. Factor-A had three levels of plant growth regulators viz. G₀- control, G₁- NAA (40 ppm), G₂- Cytokinin (10 ppm) and Factor-B had three different levels of application method viz. M₁- Seed soaking with plant growth regulators for 6 hours, M₂- Foliar spray with plant growth regulators at vegetative stage, M₃- Foliar spray with plant growth regulators at flower bud initiation stage. There were 27 units of plot in the experiment. The size of each plot was 1.6 m x 1.2 m, which accommodated 12 plants at a spacing 40 cm x 40 cm.

2.3 Application of Manure and Fertilizers

Fertilizers were applied at 210, 330, 200 kg and 10 ton per ha for urea, TSP, MP and cow dung, respectively (Table 1).

Table 1. Manure and fertilizer dose in the main field

Fertilizer	Quantity	Application method
Cow dung	10 t/ha	Basal dose
Urea	210 kg/ha	15, 25 and 35 DAT
TSP	330 kg/ha	Basal dose
MP	200 kg/ha	½ basal dose + rest ½ (15 and 25 DAT)

Source: Razzaket. al., 2011 [7]

2.4 Economic Analysis

The cost of production was calculated to determine the most economic combination of growth regulator and application method. All input cost like the cost for land lease and interests on running capital were computed in the calculation. The interests were calculated @ 13% in simple rate. The market price of chilli was considered for estimating the return. The benefit-cost ratio (BCR) was calculated as follows:

BCR = Gross return per hectare (Tk.) ÷ Cost of production per hectare (Tk.)

2.5 Statistical Analysis

The data collected on different characters were statistically analyzed using MSTAT-C software. The mean values of all the characters were evaluated and analysis of variance was performed by 'F' test. The significance of the difference among the treatments means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

Plant height was significantly influenced by plant growth regulators. At 90 DAT, the tallest plant (52.18 cm) was obtained from G1 treatment, while the shortest plant (41.83 cm) was found from G0 treatment (Fig. 1 and Table 2). It revealed that plant growth hormone increased plant height, which might be due to the regulating effect of exogenous application of PGRs. [8] studied with tomato plants were treated with NAA and supported the results. At 90 DAT, the tallest plant (49.14 cm) was obtained from M2 treatment, while the shortest plant (44.97 cm) was found from M3 treatment (Fig. 2 and Table 3).

The The combined effect showed that the tallest plant (54.50 cm) was observed from G1M2

treatment combination and the shortest plant (40.00 cm) was recorded from G0M3 treatment combination (Table 4). Increasing plant height was observed with the application of different concentration of auxin as foliar sprays (NAA 50 ppm) in capsicum under protected condition in Garhwal region, Himachal Pradesh [9].

3.2 Number of Branches Per Plant

At 90 DAT, the maximum number of branches per plant (17.33 cm) was recorded from G1 treatment, while the minimum number (14.11 cm) was found from G0 treatment which was statistically identical to G2 (15.44 cm) (Table 2). Tiwari and Singh, [10] reported that the number of branches increased by NAA 40 ppm. At 90 DAT, the maximum number of branches per plant (16.00 cm) was obtained from M2 treatment, while the shortest plant (15.44 cm) was found from M1 and M3 (Table 3). The maximum number of branches per plant (18.33 cm) was recorded from G1M2 treatment combination which was statistically similar with G1M1 (17.00 cm), G1M3 (16.67 cm), G2M1 (15.33 cm) and G2M3 (16.00 cm) treatment combinations. On the other hand, the minimum number of branches per plant (13.67 cm) was observed from G0M3 treatment combination (Table 4) which was statistically similar to G0M1 (14.00 cm), G0M2 (14.67 cm) and G2M2 (15.00 cm) treatment combination. It was found in the present study that plant growth regulators increase the number of branches per plant.

3.3 Days from Transplanting to 1st Flowering

The minimum days from transplanting to 1st flowering (50.83 days) was found from G1 treatment, while the maximum (63.00 days) from G0 treatment (Table 2). It is recorded that when NAA has been applied @ 20 ppm the initiation of flowering was earlier by almost one week. A similar finding was recorded by Desai, [11]. The minimum days from transplanting to 1st flowering (55.41 days) was recorded from M2 treatment, while the maximum (59.33 days) was attained from M3 treatment (Table 3). The present result indicated that different application method affects in 1st flowering. The minimum days from transplanting to 1st flowering (48.50 days) was found from G1M2 treatment combination, while the maximum (64.00 days) was observed from

G0M3 treatment combination (Table 4). From the presented data, it can be observed that NAA has a positive effect on early flower initiation.

3.4 Days from Transplanting to 50% Flowering

The minimum days from transplanting to 50% flowering (90.17 days) was found from G1 treatment, while the maximum days (103.67 days) was attained from G0 (Table 5) treatment.

Data recorded on days from transplant to 50% flowering was in agreed with the findings of [12]. The minimum days from transplanting to 50% flowering (94.50 days) was observed

from M3 treatment, while the maximum days (98.83 days) was recorded from M1 treatment, which was statistically identical to M2 (Table 6). The minimum days from transplanting to 50% flowering (87.50 days) was showed in G1M3 treatment combination, while the maximum days (105.50 days) was found from G0M1 treatment combination which was statistically identical to G0M2 (Table 7).

3.5 Number of Flowers Per Plant

The maximum number of flowers per plant (434.12) was recorded from G1 treatment, whereas the minimum number (136.62) was

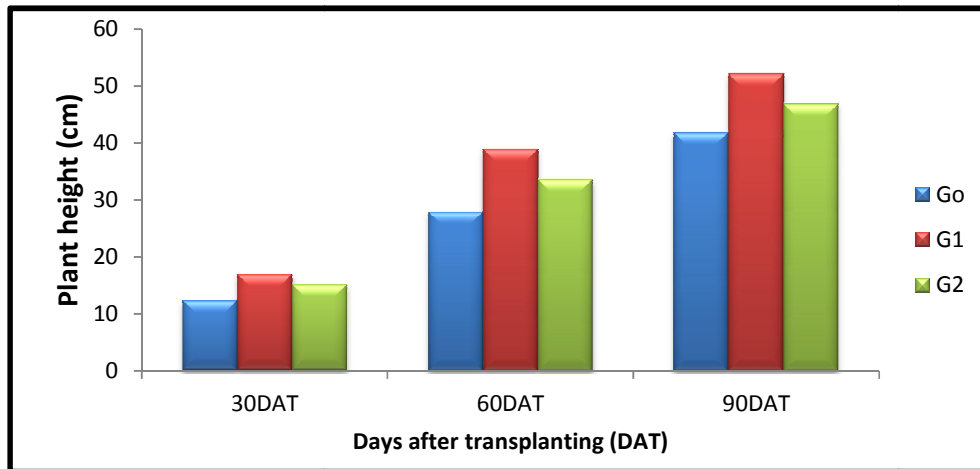


Fig. 1. Effect of plant growth regulators on plant height at different days after transplanting of chilli

Where, G₀= Control, G₁ = NAA (40 ppm) G₂ = Cytokinin (10 ppm)

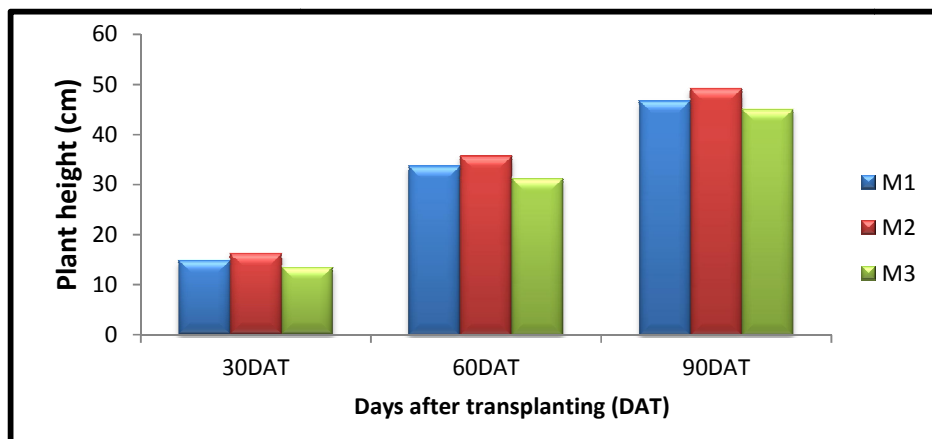


Fig. 2. Effect of application method on plant height at different days after transplanting of chilli

Where, M₁: Seed soaking with plant growth regulators for 6 hours, M₂: Foliar spray of plant growth regulators at vegetative, M₃: Foliar spray of plant growth regulators at flower bud initiation stage

Table 2. Effect of plant growth regulators on growth parameters at different growth stages of chilli

Treatments	Plant height (cm)			No. of branches per plant			Days from transplanting to 1 st flowering
	30 DAT	60 DAT	90DAT	30 DAT	60 DAT	90DAT	
G0	12.3c	27.8c	41.83c	3.56c	8.78c	14.11b	63.0a
G1	16.9a	38.9a	52.18a	6.11a	12.56a	17.33a	50.8c
G2	15.0b	33.5b	46.76b	5.00b	11.00b	15.44b	58.1b
CV %	6.42	8.67	8.25	12.68	11.58	8.45	12.84
LSD (0.05)	0.55	2.98	0.99	0.69	1.03	1.76	0.41

In a column means having a similar letter(s) are statistically similar and those having the dissimilar letter(s) differ significantly at 0.05 level of probability

Table 3. Effect of application method on growth parameters at different growth stages of chilli

Treatments	Plant height (cm)			No. of branches per plant			Days from transplanting to 1 st flowering
	30 DAT	60 DAT	90DAT	30DAT	60 DAT	90DAT	
M1	14.76b	33.68ab	46.66b	5.00	10.78ab	15.44b	57.33b
M2	16.17a	35.57a	49.14a	5.55	11.44a	16.00a	55.41c
M3	13.40c	31.13b	44.97c	4.11	10.11b	15.44b	59.33a
CV %	6.42	8.67	8.25	12.68	11.58	8.45	12.84
LSD (0.05)	0.49	2.76	0.77	NS	0.98	0.48	0.73

In a column means having a similar letter(s) are statistically similar and those having the dissimilar letter(s) differ significantly at 0.05 level of probability

Table 4. The combined effect of plant growth regulators and application method on growth parameters at different growth stages of chilli

Treatments	Plant height (cm)			No of branches per plant			Days from transplanting to 1 st flowering
	30 DAT	60DAT	90DAT	30 DAT	60 DAT	90DAT	
G0M1	12.33e	28.53de	41.90f	3.67	9.00de	14.00bc	63.00b
G0M2	13.93d	30.40cd	43.60e	4.00	9.67cd	14.67bc	62.00c
G0M3	10.67f	24.67e	40.00g	3.00	7.67e	13.67c	64.00a
G1M1	16.77b	38.73ab	51.90b	6.00	12.33ab	17.00ab	51.00h
G1M2	18.60a	40.80a	54.50a	7.00	13.33a	18.33a	48.50i
G1M3	15.47c	37.33ab	50.13c	5.33	12.00ab	16.67abc	53.00g
G2M1	15.20c	33.80bc	46.20d	5.33	11.00bc	15.33abc	58.00e
G2M2	16.00bc	35.53c	49.33c	5.67	11.33bc	15.00bc	55.50f
G2M3	14.07d	31.40cd	44.77e	4.00	10.67bcd	16.00abc	61.00d
CV %	6.42	8.67	8.25	12.68	11.58	8.45	12.34
LSD (0.05)	0.96	5.20	1.42	NS	1.79	3.06	0.71

In a column means having a similar letter(s) are statistically similar and those having the dissimilar letter(s) differ significantly at 0.05 level of probability

obtained from G0 treatment (Table 5). It was noticed that the application of NAA enhanced flower production, reduced flower abscission that contributed the maximum number of flowers per plant compared to plants that treated with others hormone and control. Plant growth regulators play an essential role in flower development [13]. The maximum number of

flowers per plant (322.75) was attained from M3 treatment, while the minimum number (234.44) was found from M1 treatment (Table 6). The highest number of flowers per plant (500.29) was recorded from G1M3 treatment combination, while the lowest number (106.69) was found from G0M1 treatment combination (Table 7). Results show that plant growth regulators modify

plant physiological process when used in small amounts and play an essential role in plant growth, elongation and flower development.

3.6 Number of Fruits Per Plant

The highest number of fruits per plant (410.60) was attained from G1 treatment, while the lowest number (83.05) was recorded from G0 treatment (Table 5). A maximum number of fruit was found

in plant growth regulators (NAA) treated plants compared to control. Deb et al., [14] found a significant response of NAA concerning the number of fruits per plant. The maximum number of fruits per plant (283.31) was obtained from M3 treatment, while the minimum number (193.06) was obtained from M1 treatment (Table 6). The highest number of fruits per plant (480.32) was recorded from G1M3 treatment combination, while the minimum number (49.35) was found from G0M1 treatment combination (Table 7).

Table 5. Effect of plant growth regulators on growth and yield contributing parameters at harvest stage of chilli

Treatments	Days from transplanting to 50% flowering	Number of flowers per plant	Number of fruits per plant	Individual fruit weight (g)
G0	103.67a	136.62c	83.05c	4.63c
G1	90.17c	434.12a	410.60a	6.03a
G2	96.67b	258.81b	217.86b	5.09b
CV %	10.75	8.32	9.56	9.56
LSD (0.05)	1.16	5.03	8.14	0.28

In a column means having a similar letter(s) are statistically similar and those having the dissimilar letter(s) differ significantly at 0.05 level of probability

Table 6. Effect of application method on growth and yield contributing parameters at harvest stage of chilli

Treatments	Days from transplanting to 50% flowering	Number of flowers per plant	Number of fruits per plant	Individual fruit weight (g)
M1	98.83a	234.44c	193.06c	4.93b
M2	97.17a	272.35b	235.14b	5.16b
M3	94.50b	322.75a	283.31a	5.67a
CV %	10.75	8.32	9.56	9.56
LSD (0.05)	1.22	4.76	3.87	0.38

In a column means having a similar letter(s) are statistically similar and those having the dissimilar letter(s) differ significantly at 0.05 level of probability

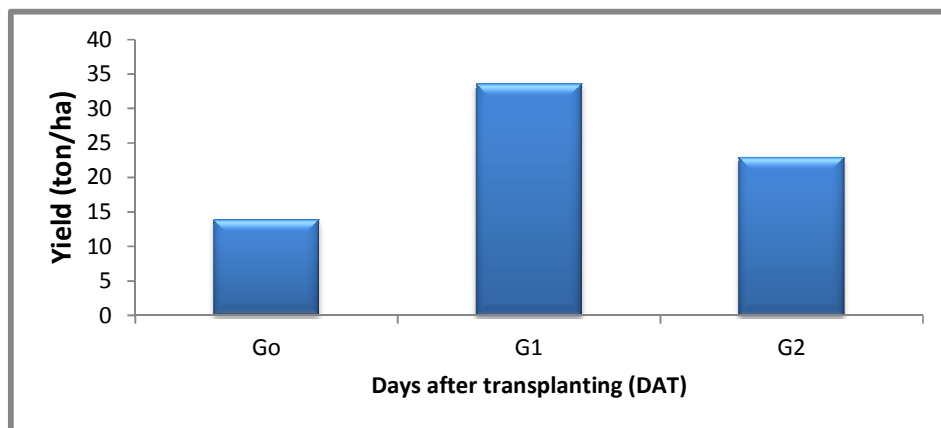


Fig. 3. Effect of plant growth regulators on yield per hectare (ton) at different days after transplanting

Where, G₀= Control G₁ = NAA (40 ppm) G₂ = Cytokinin (10 ppm)

3.7 Individual Fruit Weight (g)

The maximum weight (6.03 g) of individual fruit was recorded from G1 treatment, while the minimum weight (4.63 g) was observed from G0 treatment (Table 5). The maximum weight (5.67 g) was found from M3 treatment while the minimum (4.93 g) was recorded from M1 treatment which was statistically identical with M2 treatment (Table 6). The maximum weight (6.86 g) of individual fruit was attained from G1M3 treatment combination, while the minimum weight (4.40 g) was found from G0M1 treatment combination (Table 7) and it was statistically similar to G0M2 and G0M3 treatment combination. The results of the present study indicated that combined effect of NAA 40 ppm with foliar spray at flower bud initiation stage

might have induced better growth condition and ultimately led to increase individual fruit weight per plant. Similar results were noticed by Revanappa, [15].

3.8 Length and diameter of fruit (cm)

Application of different plant growth regulators varied significantly in length and diameter of fruit. Maximum fruit length (8.74 cm) and diameter (0.78 cm) of chilli were found in G1 treatment, whereas minimum fruit length (7.86 cm) and diameter (0.61 cm) were recorded from G0 treatment (Table 8). Plant growth regulators can increase the length of fruit. The finding was also supported by Has anuzzaman et al.,[16]. However, maximum (8.44 cm) fruit length was found in M3 treatment which was

Table 7. The combined effect of plant growth regulators and application method on growth and yield contributing parameters at harvest stage of chilli

Treatments	Days from transplanting to 50%flowering	Number of flowers per plant	Number of fruits per plant	Individual fruit weight (g)
G0M1	105.50a	106.69i	49.35i	4.40e
G0M2	104.50a	134.36h	90.35h	4.68de
G0M3	101.00b	168.80g	109.45g	4.82de
G1M1	92.50e	381.71c	356.48c	5.42bc
G1M2	90.50e	420.36b	395.01b	5.82b
G1M3	87.50f	500.29a	480.32a	6.86a
G2M1	98.50c	214.92f	173.35f	4.96cd
G2M2	96.50cd	262.33e	220.07e	4.99cd
G2M3	95.00d	299.17d	260.16d	5.33bc
CV %	10.75	8.32	9.56	9.56
LSD (0.05)	2.01	2.06	1.24	0.48

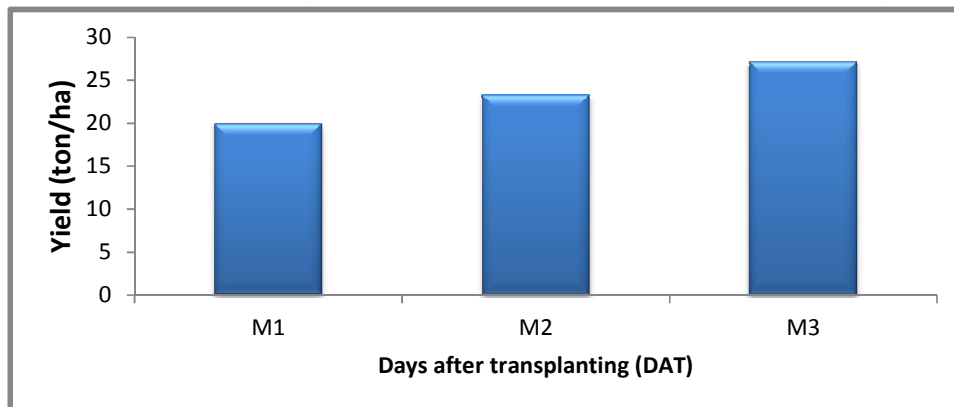


Fig. 4. Effect of application method on yield per hectare (ton) at different days after transplanting

Where, M₁: Seed soaking with plant growth regulators for 6 hours, M₂: Foliar spray of plant growth regulators at the vegetative stage, M₃: Foliar spray of plant growth regulators at flower bud initiation stage

Table 8. Effect of plant growth regulators on growth and yield contributing parameters at harvest stage of chilli

Treatments	Length of fruit (cm)	The diameter of fruit (cm)	Yield per plant (g)	Yield per hectare (ton)
G0	7.86c	0.61c	177.25c	13.85c
G1	8.74a	0.78a	516.66a	33.56a
G2	8.23b	0.68b	332.44b	22.89b
CV %	11.43	9.27	10.78	10.38
LSD (0.05)	0.21	0.05	9.06	2.02

In a column means having a similar letter(s) are statistically similar and those having the dissimilar letter(s) differ significantly at 0.05 level of probability

Table 9. Effect of application method on growth and yield contributing parameters at harvest stage of chilli

Treatments	Length of fruit (cm)	Diameter of fruit (cm)	Yield per plant (g)	Yield per hectare (ton)
M1	8.06b	0.66c	289.33c	19.92c
M2	8.32a	0.70b	335.97b	23.26b
M3	8.44a	0.72a	401.05a	27.12a
CV %	11.43	9.27	10.78	10.38
LSD (0.05)	0.19	0.03	7.21	1.34

In a column means having a similar letter(s) are statistically similar and those having the dissimilar letter(s) differ significantly at 0.05 level of probability

Table 10. The combined effect of plant growth regulators and application method on growth and yield contributing parameters at harvest stage of chilli

Treatments	Length of fruit (cm)	Diameter of fruit (cm)	Yield per plant (g)	Yield per hectare(ton)
G0M1	7.70d	0.60e	134.34i	11.21i
G0M2	7.86cd	0.61e	168.03h	13.85h
G0M3	8.02bcd	0.63d	229.38g	16.50g
G1M1	8.39b	0.73b	456.48c	29.22c
G1M2	8.85a	0.79a	510.30b	33.36b
G1M3	8.98a	0.81a	583.21a	38.10a
G2M1	8.11bc	0.64d	277.17f	19.34f
G2M2	8.24bc	0.70c	329.59e	22.57e
G2M3	8.33b	0.71bc	390.55d	26.78d
CV %	11.43	9.27	10.78	10.38
LSD (0.05)	0.37	0.02	2.10	0.14

In a column means having a similar letter(s) are statistically similar and those having the dissimilar letter(s) differ significantly at 0.05 level of probability

statistically identical to M2 treatment and maximum diameter (0.72 cm) was found in M3 treatment, whereas minimum fruit length (8.06 cm) and diameter (0.66 cm) were recorded in M1 treatment (Table 9). Maximum fruit length (8.98 cm) was recorded in G1M3 treatment combination which was statistically identical to G1M2 (8.85) and maximum diameter (0.81 cm) also found in G1M3 treatment combination, whereas minimum fruit length (7.70 cm) was recorded in G0M1 treatment combination which was statistically similar to G0M2 (7.86 cm) and

G0M3 (8.02 cm) and G0M1 gave the minimum diameter (0.60 cm) of fruit which was statistically identical to the treatment combination of G0M2 (0.61) (Table10).

3.9 Yield Per Plant (g)

Yield is the main achievement for performing the production of a crop. Highest and quality yield is the main target of producing a crop. Under the present study, the highest yield per plant (516.66 g) was found from G1 treatment, while the

lowest yield per plant (177.25 g) was observed from G0 treatment (Table 8). The highest yield per plant (401.05 g) was found from M3 treatment, while the lowest yield per plant (289.33 g) was recorded from M1 treatment (Table 9). The combined effect showed that the highest yield per plant (583.21 g) was attained from the G1M3 treatment combination, while the lowest yield per plant (134.34 g) was found from the G0M1 (Table 10) treatment combination. This result also is in agreement with the findings of Bhalekar et al., [17] where he revealed that NAA spray at flowering stage recorded higher fruit yield compared to control.

3.10 Yield Per Hectare (ton)

Application of different plant growth regulators significantly affects the yield of chilli. The highest yield per hectare (33.56 ton) was observed from G1 treatment, while the lowest yield per hectare (13.85 ton) was recorded from G0 treatment (Fig 3 and Table 8). Pargi, [18] conducted a pot experiment on tomato and found a maximum yield of tomato with NAA @ 40 ppm followed by NAA @ 30 ppm. These results proved that the maximum growth, yield and yield attributes were found with plant growth regulators compared to the control. In case of application method, the highest yield per hectare (27.12 ton) was recorded from M3 treatment, while the minimum yield per hectare (19.92 ton) was observed from M1 treatment (Fig 4 and Table 9). The maximum yield per hectare (38.10 ton) was recorded from G1M3 treatment combination, while the minimum yield per hectare (11.21 ton) was found from G0M1 treatment combination (Table10).

4. CONCLUSION

Considering the above result of this experiment it can be concluded that plant growth regulator (NAA 40 ppm) was superior to the others. The application method played a vital role in the growth and yield of chilli. In respect of all, foliar spray of plant growth regulators at flower bud initiation stage showed better performance than others. The combined application of NAA with foliar spray at flower bud initiation stage is more suitable for chilli crop production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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