Original Research Article

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

ABSTRACT

The experiment was conducted on ~~in~~ the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during Rabi season to determine ~~find out~~ 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 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.

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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 has been found to be 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

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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. MATERIAL 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 ~~from~~ sea level [6]. The soil was shallow red-brown and high land in texture. The soil was having the texture of sandy loam with p^H 5.6.

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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. G_0- control, G_1- NAA (40 ppm), G_2 – Cytokinin (10 ppm) and Factor-B had three different levels of application method viz.M_1- Seed soaking with plant growth regulators for 6 hours, M_2- Foliar spray with plant growth regulators at vegetative stage, M_3- 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 ~~find out~~ 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.)

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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

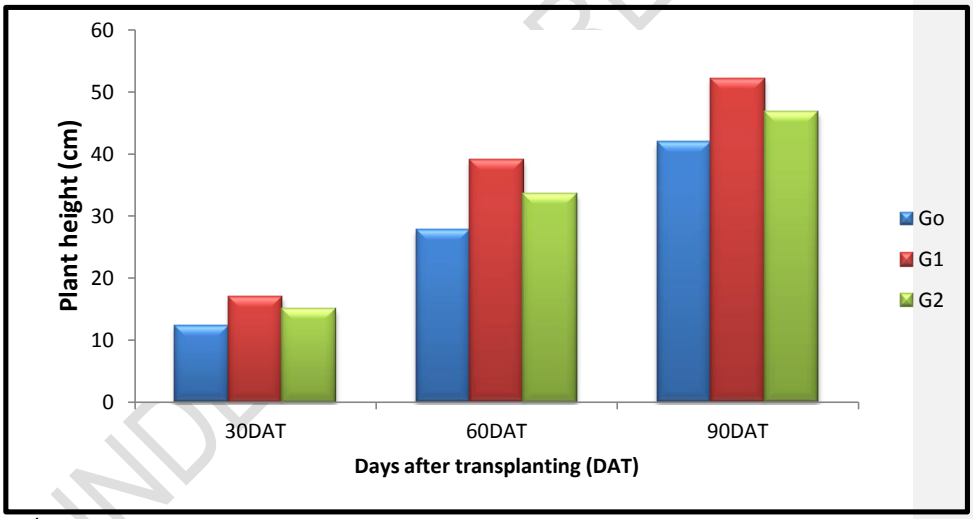
means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability.

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 G_1 treatment, while the shortest plant (41.83 cm) was found from G_0 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 M_2 treatment, while the shortest plant (44.97 cm) was found from M_3 treatment (Fig 2 and Table 3).

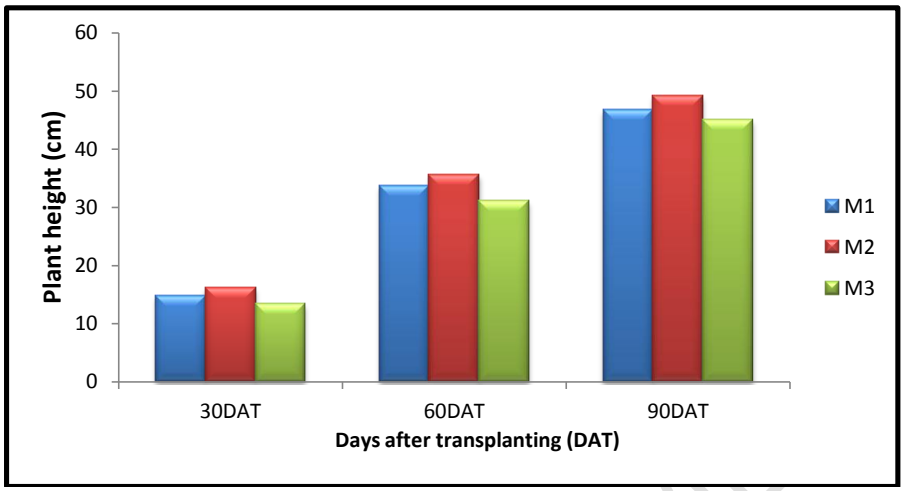
The combined effect showed that the tallest plant (54.50 cm) was observed from G_1M_2 treatment combination and the shortest plant (40.00 cm) was recorded from G_0M_3 treatment combination (Table 4). Increasing plant height was observed with the application of different concentration of auxin as foliar sprays (NAA 50 ppm) in capsicum under



Where, G_0= Control, G_1 = NAA (40 ppm) G_2 = Cytokinin (10 ppm)

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

protected condition in Garhwal region, Himachal Pradesh [9].



Where,M_1: Seed soaking with plant growth regulators for 6 hours, M_2: Foliar spray of plant growth regulators at vegetative, M_3: Foliar spray of plant growth regulators at flower bud initiation stage

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

3.2. Number of branches per plant

At 90 DAT, the maximum number of branches per plant (17.33 cm) was recorded from G_1 treatment, while the minimum number (14.11 cm) was found from G_0 treatment which was statistically identical to G_2 (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 M_2 treatment, while the shortest plant (15.44 cm) was found from M_1 and M_3 (Table 3). The maximum number of branches per plant (18.33 cm) was recorded from G_1M_2 treatment combination which was statistically similar with G_1M_1 (17.00 cm), G_1M_3 (16.67 cm), G_2M_1 (15.33 cm) and G_2M_3 (16.00 cm) treatment combinations. On the other hand, the minimum number of branches per plant (13.67 cm) was observed from G_0M_3 treatment combination (Table 4) which was statistically similar to G_0M_1 (14.00 cm), G_0M_2 (14.67 cm) and G_2M_2 (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 G_1 treatment, while the maximum (63.00 days) from G_0 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 M_2 treatment, while the maximum (59.33 days) was attained from M_3 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 G_1M_2 treatment combination, while the maximum (64.00 days) was observed from G_0M_3 treatment combination (Table 4). From 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 G_1 treatment, while the maximum days (103.67 days) was attained from G_0 (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 M_3 treatment, while the maximum days (98.83 days) was recorded from M_1 treatment, which was statistically identical to M_2 (Table 6). The minimum days from transplanting to50%flowering (87.50 days) was showed in G_1M_3 treatment combination, while the maximum days (105.50 days) was found from G_0M_1 treatment combination which was statistically identical to G_0M_2 (Table 7).

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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 1st flowering
	30 DAT	60 DAT	90DAT	30 DAT	60 DAT	90DAT	
G_0	12.3c	27.8c	41.83c	3.56c	8.78c	14.11b	63.0a
G_1	16.9a	38.9a	52.18a	6.11a	12.56a	17.33a	50.8c
G_2	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 1st flowering
	30 DAT	60 DAT	90DAT	30DAT	60 DAT	90DAT	
M_1	14.76b	33.68ab	46.66b	5.00	10.78ab	15.44b	57.33b
M_2	16.17a	35.57a	49.14a	5.55	11.44a	16.00a	55.41c
M_3	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 the similar letter(s) are statistically similar and those having the dissimilar letter(s) differ significantly at 0.05 level of probability

Table 4. 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 1st
	30 DAT	60DAT	90DAT	30 DAT	60 DAT	90DAT	

							flowering
G_0M_1	12.33e	28.53de	41.90f	3.67	9.00de	14.00bc	63.00b
G_0M_2	13.93d	30.40cd	43.60e	4.00	9.67cd	14.67bc	62.00c
G_0M_3	10.67f	24.67e	40.00g	3.00	7.67e	13.67c	64.00a
G_1M_1	16.77b	38.73ab	51.90b	6.00	12.33ab	17.00ab	51.00h
G_1M_2	18.60a	40.80a	54.50a	7.00	13.33a	18.33a	48.50i
G_1M_3	15.47c	37.33ab	50.13c	5.33	12.00ab	16.67abc	53.00g
G_2M_1	15.20c	33.80bc	46.20d	5.33	11.00bc	15.33abc	58.00e
G_2M_2	16.00bc	35.53c	49.33c	5.67	11.33bc	15.00bc	55.50f
G_2M_3	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 the similar letter(s) are statistically similar and those having the dissimilar letter(s) differ significantly at 0.05 level of probability

3.5. Number of flowers per plant

The maximum number of flowers per plant (434.12) was recorded from G_1 treatment, whereas the minimum number (136.62) was obtained from G_0 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 M_3 treatment, while the minimum number (234.44) was found from M_1 treatment (Table 6). The highest number of flowers per plant (500.29) was recorded from G_1M_3 treatment combination, while the lowest number (106.69) was found from G_0M_1 treatment combination (Table 7). It can be said that plant growth regulators modify plant physiological process when used ~~using~~ in small amounts and plays an essential role in plant growth, elongation and flower development.

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3.6. Number of fruits per plant

The highest number of fruits per plant (410.60) was attained from G_1 treatment, while the lowest number (83.05) was recorded from G_0 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 number of fruits per plant. The maximum number of fruits per plant (283.31) was obtained from M_3 treatment, while the minimum number (193.06) was obtained from M_1 treatment (Table 6). The highest number of fruits per plant (480.32) was recorded from G_1M_3 treatment combination, while the minimum number (49.35) was found from G_0M_1 treatment combination (Table 7).

3.7. Individual fruit weight (g)

The maximum weight (6.03 g) of individual fruit was recorded from G_1 treatment, while the minimum weight (4.63 g) was observed from G_0 treatment (Table 5). The maximum weight (5.67 g) was found from M_3 treatment while the minimum (4.93 g) was recorded from M_1 treatment which was statistically identical with M_2 treatment (Table 6). The maximum weight (6.86 g) of individual fruit was attained from G_1M_3 treatment combination, while the minimum weight (4.40 g) was found from G_0M_1 treatment combination (Table 7) and it was statistically similar to G_0M_2 and G_0M_3 treatment combination. ~~From the~~ 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

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

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)
G_0	103.67a	136.62c	83.05c	4.63c
G_1	90.17c	434.12a	410.60a	6.03a
G_2	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 similar letter(s) are statistically similar and those having 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)
M_1	98.83a	234.44c	193.06c	4.93b
M_2	97.17a	272.35b	235.14b	5.16b
M_3	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

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Table 7. 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)
G_0M_1	105.50a	106.69i	49.35i	4.40e
G_0M_2	104.50a	134.36h	90.35h	4.68de
G_0M_3	101.00b	168.80g	109.45g	4.82de
G_1M_1	92.50e	381.71c	356.48c	5.42bc
G_1M_2	90.50e	420.36b	395.01b	5.82b
G_1M_3	87.50f	500.29a	480.32a	6.86a
G_2M_1	98.50c	214.92f	173.35f	4.96cd
G_2M_2	96.50cd	262.33e	220.07e	4.99cd
G_2M_3	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

3.8. Length and diameter of fruit (cm)

Application of different plant growth regulators varied significantly on length and diameter of fruit. Maximum fruit length (8.74 cm) and diameter (0.78 cm) of chilli were found in G_1 treatment, whereas minimum fruit length (7.86 cm) and diameter (0.61 cm) were recorded from G_0 treatment (Table 8). Plant growth regulators have the possibility to increase length of fruit. The finding was also supported by Hasanuzzaman et al.,[16]. However, maximum (8.44 cm) fruit length was found in M_3 treatment which was statistically identical to M_2 treatment and maximum diameter (0.72 cm) was found in M_3 treatment, whereas minimum fruit length (8.06 cm) and diameter (0.66 cm) were recorded in M_1 treatment (Table 9). Maximum fruit length (8.98 cm) was recorded in G_1M_3 treatment combination which was statistically identical to G_1M_2 (8.85) and maximum diameter (0.81 cm) also found in G_1M_3 treatment combination, whereas minimum fruit length (7.70 cm) was recorded in G_0M_1 treatment combination which was statistically similar to G_0M_2 (7.86 cm) and G_0M_3 (8.02 cm) and G_0M_1 gave the minimum diameter (0.60 cm) of fruit which was statistically identical to the treatment combination of G_0M_2 (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 G_1 treatment, while the lowest yield per plant (177.25 g) was observed from G_0 treatment (Table 8). The highest yield per plant (401.05 g) was found from M_3 treatment, while the lowest yield per plant (289.33 g) was recorded from M_1 treatment (Table 9). Combined effect showed that the highest yield per plant (583.21 g) was attained from the G_1M_3 treatment combination, while the lowest yield per plant (134.34 g) was found from the G_0M_1 (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.

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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 G_1 treatment, while the lowest yield per hectare (13.85 ton) was recorded from G_0 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 ~~than~~ control. In case of application method, the highest yield per hectare (27.12 ton) was recorded from M_3 treatment, while the minimum yield per hectare (19.92 ton) was observed from M_1 treatment (Fig 4 and Table 9). The maximum yield per hectare (38.10 ton) was recorded from G_1M_3 treatment combination, while the minimum yield per hectare (11.21 ton) was found from G_0M_1 treatment combination (Table 10).

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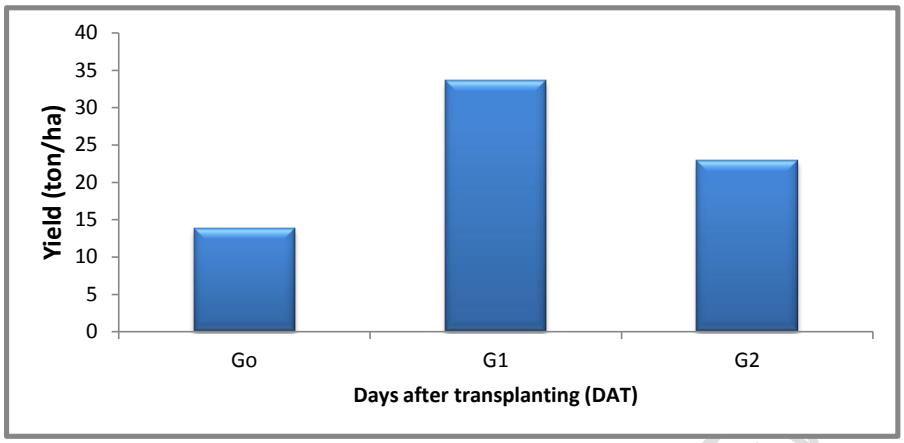
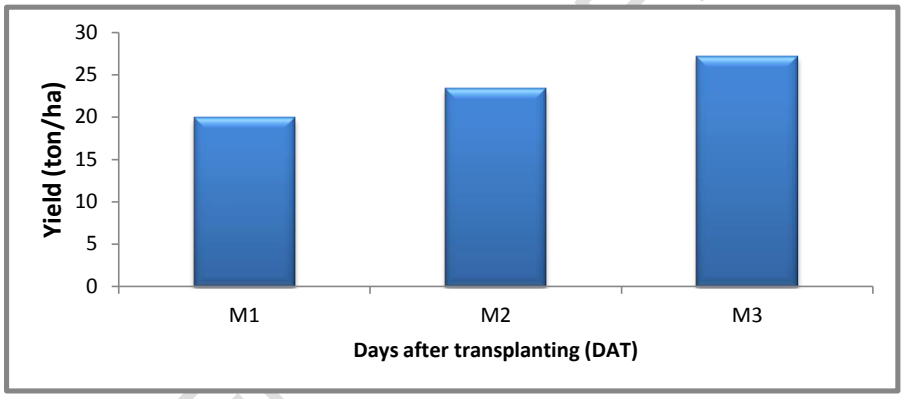


Where, G_0= Control G_1 = NAA (40 ppm) G_2 = Cytokinin (10 ppm)

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



Where, M_1: Seed soaking with plant growth regulators for 6 hours, M_2: Foliar spray of plant growth regulators at the vegetative stage, M_3: Foliar spray of plant growth regulators at flower bud initiation stage

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

Table 8. Effect of plant growth regulators 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)
G_0	7.86c	0.61c	177.25c	13.85c
G_1	8.74a	0.78a	516.66a	33.56a
G_2	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 the 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 similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Table 10. 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 similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

4. CONCLUSION

Considering the above result of this experiment it can be concluded ~~said~~ 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.

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COMPETING INTERESTS

The authors have declared that no competing interests exist.

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