

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

ABSTRACT

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

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 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

37 chilli crop more particularly the application method is still lacking in the literature. The
38 present study was undertaken to evaluate the performance of plant growth regulators and
39 its application method on growth, yield and economic return of chilli in Bangladesh.

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41 2. MATERIAL AND METHODS

42 2.1. Experimental site

43 The experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural
44 University, Dhaka-1207 during the period of rabi season from October 2017 to March
45 2018. The experimental site is situated between 23°75' N latitude and 90°34' E longitude
46 and at an elevation of 8.4 m from sea level [6]. The soil was shallow red-brown and
47 high land in texture. The soil was having the texture of sandy loam with p^H 5.6.

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49 2.2 Experimental framework

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

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60 2.3 Application of manure and fertilizers

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

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64 **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)

65 **Source:** Razzaket. al., 2011 [7]

66 2.4. Economic analysis

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

72 $BCR = \text{Gross return per hectare (Tk.)} \div \text{Cost of production per hectare (Tk.)}$

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74 2.5. Statistical analysis

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

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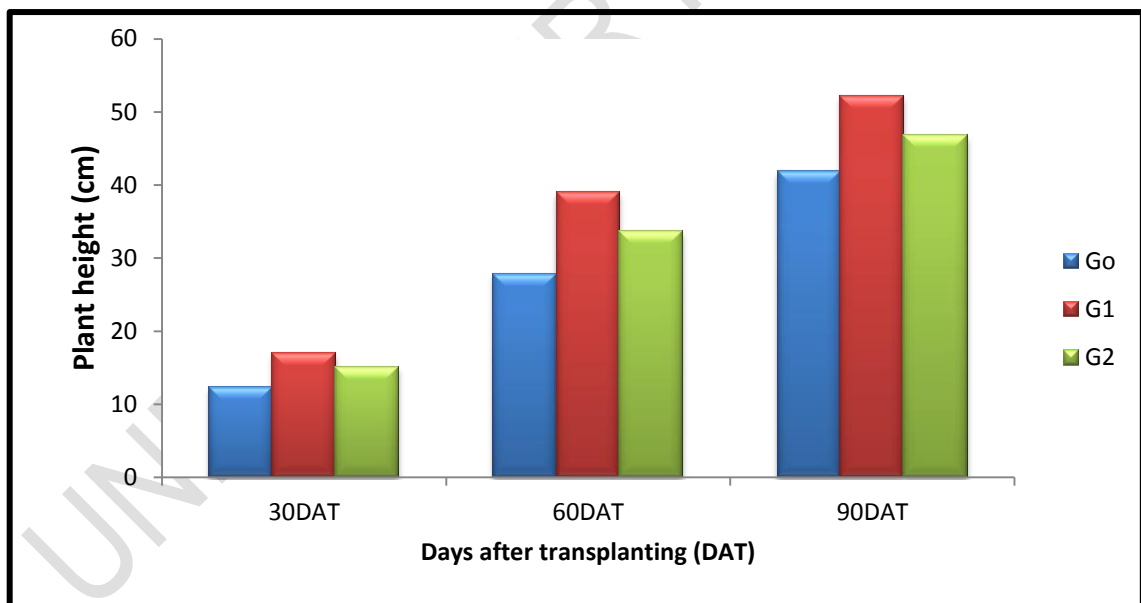
82 3. RESULTS AND DISCUSSION

83 3.1. Plant height (cm)

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

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93 The combined effect showed that the tallest plant (54.50 cm) was observed from G₁M₂
94 treatment combination and the shortest plant (40.00 cm) was recorded from G₀M₃
95 treatment combination (Table 4). Increasing plant height was observed with the
96 application of different concentration of auxin as foliar sprays (NAA 50 ppm) in capsicum



97 under

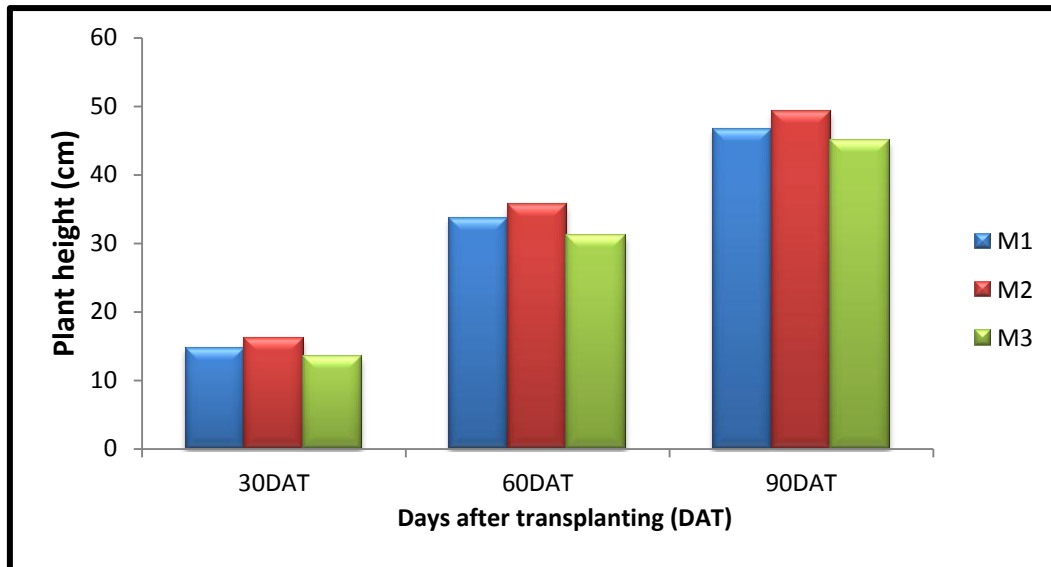
98 Where, G₀= Control, G₁ = NAA (40 ppm) G₂ = Cytokinin (10 ppm)

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

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

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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

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

111 3.2. Number of branches per plant

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

125 3.3. Days from transplanting to 1st flowering

126 The minimum days from transplanting to 1st flowering (50.83 days) was found from G1
127 treatment, while the maximum (63.00 days) from G0 treatment (Table 2). It is recorded
128 that when NAA has been applied @ 20 ppm the initiation of flowering was earlier by
129 almost one week. A similar finding was recorded by **Desai, [11]**. The minimum days from
130 transplanting to 1st flowering (55.41 days) was recorded from M2 treatment, while the
131 maximum (59.33 days) was attained from M3 treatment (Table 3). The present result
132 indicated that different application method affects in 1st flowering. The minimum days
133 from transplanting to 1st flowering (48.50 days) was found from G1M2 treatment
134 combination, while the maximum (64.00 days) was observed from G0M3 treatment
135 combination (Table 4). From presented data, it can be observed that NAA has a positive
136 effect on early flower initiation.

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138 **3.4. Days from transplanting to 50% flowering**

139 The minimum days from transplanting to 50% flowering (90.17 days) was found from G1
 140 treatment, while the maximum days (103.67 days) was attained from G0 (Table 5)
 141 treatment. Data recorded on days from transplant to 50% flowering was in agreed with
 142 the findings of [12]. The minimum days from transplanting to 50% flowering (94.50 days)
 143 was observed from M3 treatment, while the maximum days (98.83 days) was recorded
 144 from M1 treatment, which was statistically identical to M2 (Table 6). The minimum days
 145 from transplanting to 50% flowering (87.50 days) was showed in G1M3 treatment
 146 combination, while the maximum days (105.50 days) was found from G0M1 treatment
 147 combination which was statistically identical to G0M2 (Table 7).

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

Treatment s	Plant height (cm)			No. of branches per plant			Days from transplantin g to 1 st flowering
	30 DAT	60 DAT	90DA T	30 DAT	60 DAT	90DA T	
G0	12.3c	27.8c	41.83 c	3.56c	8.78c	14.11 b	63.0 a
G1	16.9a	38.9a	52.18 a	6.11a	12.56 a	17.33 a	50.8 c
G2	15.0b	33.5b	46.76 b	5.00b	11.00 b	15.44 b	58.1 b
CV %	6.42	8.67	8.25	12.68	11.58	8.45	12.8 4
LSD (0.05)	0.55	2.98	0.99	0.69	1.03	1.76	0.41

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

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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 transplantin g to 1 st flowerin g
	30 DAT	60 DAT	90DAT	30DAT	60 DAT	90DAT	
M1	14.76b	33.68a b	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

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

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

Treatment s	Plant height (cm)			No of branches per plant			Days from transplantin g to 1 st
	30 DAT	60DAT	90DAT	30 DAT	60 DAT	90DAT	

	flowering						
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

161 In a column means having the similar letter(s) are statistically similar and those having the dissimilar letter(s)
 162 differ significantly at 0.05 level of probability
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164 3.5. Number of flowers per plant

165 The maximum number of flowers per plant (434.12) was recorded from G1 treatment,
 166 whereas the minimum number (136.62) was obtained from G0 treatment (Table 5). It
 167 was noticed that the application of NAA enhanced flower production, reduced flower
 168 abscission that contributed the maximum number of flowers per plant compared to plants
 169 that treated with others hormone and control. Plant growth regulators play an essential
 170 role in flower development [13]. The maximum number of flowers per plant (322.75) was
 171 attained from M3 treatment, while the minimum number (234.44) was found from M1
 172 treatment (Table 6). The highest number of flowers per plant (500.29) was recorded from
 173 G1M3 treatment combination, while the lowest number (106.69) was found from G0M1
 174 treatment combination (Table 7). It can be said that plant growth regulators modify plant
 175 physiological process using in small amount and plays an essential role in plant growth,
 176 elongation and flower development.

177 3.6. Number of fruits per plant

178 The highest number of fruits per plant (410.60) was attained from G1 treatment, while
 179 the lowest number (83.05) was recorded from G0 treatment (Table 5). A maximum
 180 number of fruit was found in plant growth regulators (NAA) treated plants compared to
 181 control. Deb et al., [14] found a significant response of NAA concerning number of fruits
 182 per plant. The maximum number of fruits per plant (283.31) was obtained from M3
 183 treatment, while the minimum number (193.06) was obtained from M1 treatment (Table
 184 6). The highest number of fruits per plant (480.32) was recorded from G1M3 treatment
 185 combination, while the minimum number (49.35) was found from G0M1 treatment
 186 combination (Table 7).

187 3.7. Individual fruit weight (g)

188 The maximum weight (6.03 g) of individual fruit was recorded from G1 treatment, while
 189 the minimum weight (4.63 g) was observed from G0 treatment (Table 5). The maximum
 190 weight (5.67 g) was found from M3 treatment while the minimum (4.93 g) was recorded
 191 from M1 treatment which was statistically identical with M2 treatment (Table 6). The
 192 maximum weight (6.86 g) of individual fruit was attained from G1M3 treatment
 193 combination, while the minimum weight (4.40 g) was found from G0M1 treatment
 194 combination (Table 7) and it was statistically similar to G0M2 and G0M3 treatment
 195 combination. From the results of the present study indicated that combined effect of NAA
 196 40 ppm with foliar spray at flower bud initiation stage might have induced better growth

197 condition and ultimately led to increase individual fruit weight per plant. Similar results
 198 were noticed by [Revanappa, \[15\]](#).

199 **Table 5. Effect of plant growth regulators on growth and yield contributing**
 200 **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

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

203 **Table 6. Effect of application method on growth and yield contributing parameters**
 204 **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

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

209 **Table 7. Combined effect of plant growth regulators and application method on**
 210 **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
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212 **3.8. Length and diameter of fruit (cm)**

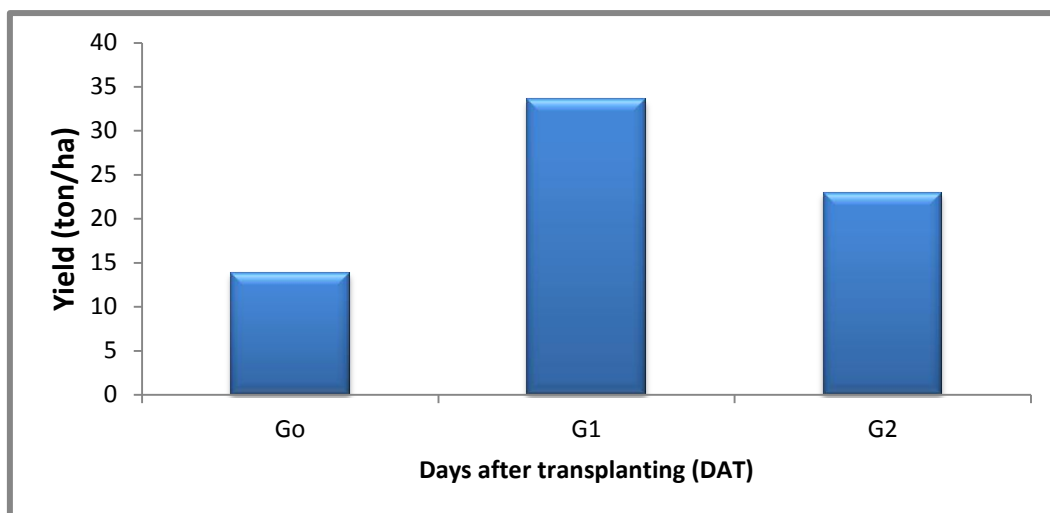
213 Application of different plant growth regulators varied significantly on length and diameter
 214 of fruit. Maximum fruit length (8.74 cm) and diameter (0.78 cm) of chilli were found in G1
 215 treatment, whereas minimum fruit length (7.86 cm) and diameter (0.61 cm) were
 216 recorded from G0 treatment (Table 8). Plant growth regulators have the possibility to
 217 increase length of fruit. The finding was also supported by Hasanuzzaman et al., [16].
 218 However, maximum (8.44 cm) fruit length was found in M3 treatment which was
 219 statistically identical to M2 treatment and maximum diameter (0.72 cm) was found in M3
 220 treatment, whereas minimum fruit length (8.06 cm) and diameter (0.66 cm) were
 221 recorded in M1 treatment (Table 9). Maximum fruit length (8.98 cm) was recorded in
 222 G1M3 treatment combination which was statistically identical to G1M2 (8.85) and
 223 maximum diameter (0.81 cm) also found in G1M3 treatment combination, whereas
 224 minimum fruit length (7.70 cm) was recorded in G0M1 treatment combination which was
 225 statistically similar to G0M2 (7.86 cm) and G0M3 (8.02 cm) and G0M1 gave the
 226 minimum diameter (0.60 cm) of fruit which was statistically identical to the treatment
 227 combination of G0M2 (0.61) (Table10).

228 **3.9. Yield per plant (g)**

229 Yield is the main achievement for performing the production of a crop. Highest and
 230 quality yield is the main target of producing a crop. Under the present study, the highest
 231 yield per plant (516.66 g) was found from G1 treatment, while the lowest yield per plant
 232 (177.25 g) was observed from G0 treatment (Table 8). The highest yield per plant
 233 (401.05 g) was found from M3 treatment, while the lowest yield per plant (289.33 g) was
 234 recorded from M1 treatment (Table 9). Combined effect showed that the highest yield per
 235 plant (583.21 g) was attained from G1M3 treatment combination, while the lowest yield
 236 per plant (134.34 g) was found from G0M1 (Table 10) treatment combination. This result
 237 also is in agreement with the findings of Bhalekar et al., [17] where he revealed that NAA
 238 spray at flowering stage recorded higher fruit yield compared to control.

239 **3.10. Yield per hectare (ton)**

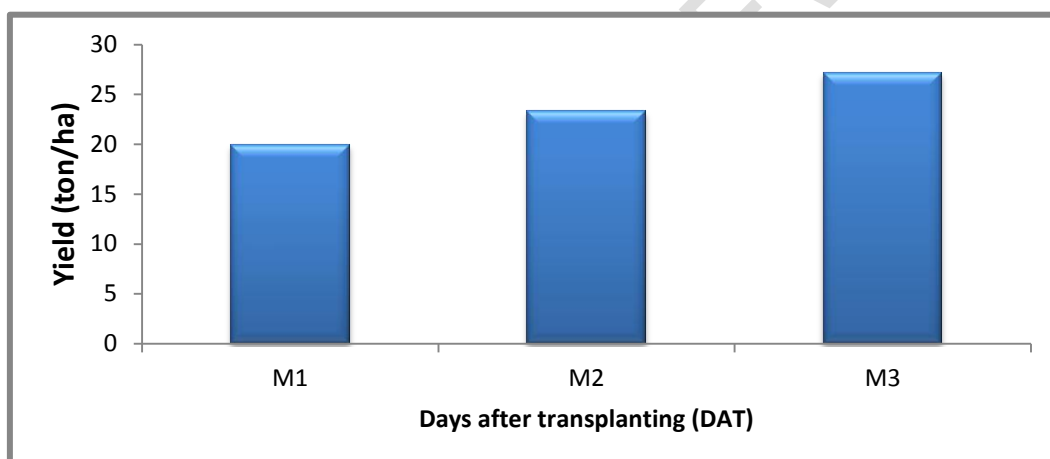
240 Application of different plant growth regulators significantly affects the yield of chilli. The
 241 highest yield per hectare (33.56 ton) was observed from G1 treatment, while the lowest
 242 yield per hectare (13.85 ton) was recorded from G0 treatment (Fig 3 and Table 8). Pargi,
 243 [18] conducted a pot experiment on tomato and found a maximum yield of tomato with
 244 NAA @ 40 ppm followed by NAA @ 30 ppm. These results proved that the maximum
 245 growth, yield and yield attributes were found with plant growth regulators than control. In
 246 case of application method, the highest yield per hectare (27.12 ton) was recorded from
 247 M3 treatment, while the minimum yield per hectare (19.92 ton) was observed from M1
 248 treatment (Fig 4 and Table 9). The maximum yield per hectare (38.10 ton) was recorded
 249 from G1M3 treatment combination, while the minimum yield per hectare (11.21 ton) was
 250 found from G0M1 treatment combination (Table 10).



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

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



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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

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

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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

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

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

Treatment s	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

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

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 274 **Table 10. Combined effect of plant growth regulators and application method on**
 275 **growth and yield contributing parameters at harvest stage of chilli**

Treatment s	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

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 277 significantly at 0.05 level of probability

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 279 **4. CONCLUSION**

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

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COMPETING INTERESTS

The authors have declared that no competing interests exist.

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