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Sarita Sahu
Scientist (Horticulture), College of Agriculture and Research Station, Indira Gandhi Krishi Vishwavidyalaya, Raigarh, Chhattisgarh, India

Vijay Kumar
Professor (Vegetable Science), College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

HG Sharma
Professor and Head (Fruit Science), College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Corresponding Author:
Sarita Sahu
Scientist (Horticulture), College of Agriculture and Research Station, Indira Gandhi Krishi Vishwavidyalaya, Raigarh, Chhattisgarh, India

Effect of plant growth regulators on growth and yield of chilli: A review

Sarita Sahu, Vijay Kumar and HG Sharma

Abstract
The Plant growth regulators play important role in increasing production of vegetables. The great potential of plant growth regulators for reduces the flower and fruit drops and maximizing yield and quality of chilli. This paper reviews the research work done on the use of various plant growth regulators on growth and yield of chilli.

Keywords: Chilli, plant growth regulator, NAA, GA_3 and 2, 4-D

Introduction
Chilli (*Capsicum annum* L.) is an important vegetable and spice crop belongs to the family solanaceae. Chilli fruits are good source of vitamin A and C. Fresh and ripe chillies are used to make all kinds of pickles different sauces and paste. Dried fruits are used to make universal curry power and paste. India is the largest producer of chilli in the world (Athaneria *et al.*, 2011) [7]. But the major problem in chilli production is immature flower and fruit drop, which is caused by physiological and hormonal imbalance in the plants particularly under unfavourable environments such as extremes of temperature i.e. too low or high temperature (Erickson and Makhart, 2001; Joshi and Singh, 2003) [3, 6]. This can be done either by breeding lines which retain large proportion of flowers or through physiological manipulations by spraying of plant growth regulators which reduces the flower drop (Tamilselvi and Vijayraghvan, 2014) [21].
Therefore, information regarding the effect of plant growth regulators on growth and yield of chilli has been reviewed as under.

Vegetative growth
Joshi *et al.*, 1999 [7], reported that application of NAA @ 40 ppm at flower bud initiation and 20 days later produced maximum plant height (74.80 cm) in chilli.
Natesh *et al.*, 2005 [13], reported that among the plant growth regulators which sprayed at flowering stage, GA_3 @ 100 ppm recorded significantly higher plant height (85.7 cm) and number of branches per plant (30.3) followed by GA_3 @ 50 ppm and NAA @ 20 ppm in chilli cv. Byadgi Kaddi.
Sultana *et al.*, 2006 [20] reported that the plant height of chilli was maximum in 10 ppm NAA (44.0 cm) followed by 100 ppm Ethephon (39.0 cm). Number of branches per plant was found maximum with NAA @ 10 ppm and Ethephon @ 100 ppm (12.0).
Singh *et al.*, 2012 [19] revealed that the maximum plant height was found in NAA at 50 ppm sprayed at flower initiation and 20 days later from the first spray in both the cultivars of capsicum *i.e*. California Wonder and Solan Bharpur (114.38 and 111.66 cm, respectively). Similarly the maximum number of secondary branches was found in NAA at 50 ppm in both the cultivars of capsicum *i.e*. California Wonder and Solan Bharpur (13.33 and 11.33, respectively).
Arora *et al.*, 2014 [1], studied on the effect of concentrations and methods of application of 2,4-D and NAA on plant growth, flowering, yield and quality in summer season chilli (*Capsicum annum* L.) cv. Pant C-1 and revealed that among different concentration of NAA 45 ppm of NAA gave significantly maximum plant height (68.6 cm), primary branches (7.80) and number of leaves per plant (2193.20).
Kiranmayi *et al.*, 2014 [14], obtained maximum plant height (83.33 cm), plant spread (137.33cm) and number of primary branches (17.0) in chilli variety Lam-353 when plant sprayed with 20 ppm NAA + 0.05 % boran.
Tamilselvi and Vijayaraghavan 2014 [21], reported that various growth regulators influenced the growth of chilli cv. K 1 when sprayed at flowering and 15 days thereafter.

They observed that enhancement of plant height (70.8 cm in summer and 72.9 cm in winter at 65 Days after planting) and number of primary branches per plant (8.01 in summer and 9.09 in winter) was facilitated effectively by sprayed of NAA @ 40 ppm. The second best treatment was GA_3 @ 20 ppm produced 69.3 cm & 72.4 cm plant height in summer and winter and 8.0 & 9.0 number of branches per plant in summer and winter, respectively.

Kar *et al.*, 2016 [8] reported that spraying of GA_3 @ 50 ppm at 60 DAT resulted in maximum plant height (62.35 cm) followed by NAA @ 40 ppm (58.86 cm). They reported that application of 2, 4-D resulted in growth retardation in comparison to control. The maximum number of branches (8.33) was obtained with the application of 2, 4-D @ 5 ppm followed by control (7.68) in chilli.

Kumari *et al.*, 2016 [18], studied on effect of NAA on growth and yield attributes of chilli and result revealed that the NAA 50 ppm produced highest plant height (68.72 cm) and number of primary branches (12.21) when NAA spayed first at 35 days after transplanting and second at the time of flowering.

Shil and Nath, 2016 [17], studied the application of different concentration of NAA on growth and yield of chilli and revealed that the NAA has positively effect on the plant height. The highest plant height was 39.45 cm and number of branches per plant was 18.0 when the plants were sprayed with NAA 20ppm at 75 days after transplanting whereas lowest was found in the control plot.

Shankhwar *et al.*, 2017 [16] reported that application of plant growth regulators significantly influenced the plant height, number of branches per plant and number of leaves per plant. The highest plant height (56.39 cm) was observed at 90 DAT with spray of NAA @ 40 ppm. Similarly maximum number of branches (26.97) and number of leaves per plant (90.35) was observed in NAA @ 40 ppm at 90 DAT.

Singh *et al.*, 2017, revealed that the maximum plant height (120.59 cm), plant spread (92.57 cm) and number of branches per plant (16.05) was found in NAA @ 60 ppm treated plot of chilli cv. Indra under shed net conditions.

Mahindre *et al.*, 2018 [12], observed that the spraying of NAA @ 50 ppm at 30, 60 and 90 days after transplanting (DAT) produced maximum plant height (64.10 cm), plant spread (53.13 cm) which was statistically at par with application of GA_3 @ 25 ppm (63.27 cm plant height and 52.80 cm plant spread). They also reported that CCC @ 500 ppm produced maximum number of branches per plant (24.40) followed by CCC @ 750 ppm (23.37) in chilli. The possible reason for increase in number of branches in chilli plant may be due to the increased osmotic uptake of water and nutrient under the influence of which cycocel would have maintained a constant swelling force against softening of cell wall.

Tapdiya *et al.*, 2018 [22], investigated that foliar spray of NAA @ 40 ppm at flower bud initiation stage of chilli and recoded maximum plant height (54.67 cm) followed by GA_3 @ 40 ppm (54.33 cm). The maximum number of branches per plant was observed in NAA @ 40 ppm (3.17) followed by NAA @ 30 ppm (3.10).

The promoting effect of plant height by the application of NAA is might be due to its action as a group of auxins, the cell wall probably reacted favorably and high deposition of cell wall material took place due to high catalyzing activities of carbohydrates and pectiolase. NAA treatment might be attributed to the activation of cell division and cell elongation in the axillary buds, which had a promoting effect on increased number of branches (Kumari *et al.*, 2016) [18].

The beneficial effect of growth promoters like NAA on physiological processes of plants leads to accumulation of carbohydrates and minerals in different parts of the plants and thus resulted in the production of more number of branches and leaves (Tamilselvi and Vijayaraghavan, 2014) [21].

The subsequent increase in plant spread might be due to the fact that, increased photosynthetic metabolic activities and dry matter content in plant was increased due to application of NAA as compared to other plant growth regulators (Mahindre *et al.*, 2018) [12].

Table 1: Effect of plant growth regulators on plant height, number of branches per plant, canopy spread and number of leaves per plant in chilli.

Treatments	Plant height (cm)	Number of branches per plant	Source
NAA 10 ppm	74.0	20.4	Natesh *et al.*, 2005 [13]
NAA 20 ppm	75.9	21.2	
Ethrel 100 ppm	74.2	18.3	
Ethrel 200 ppm	75.0	19.1	
Quantum 50 ppm	74.5	22.2	
Quantum 100 ppm	76.6	24.9	
IAA 50 ppm	75.5	21.6	
IAA 100 ppm	75.0	22.9	
TIBA 25 ppm	74.2	22.6	
TIBA 50 ppm	75.5	23.6	
GA_3 50 ppm	83.0	29.1	
GA_3 100 ppm	85.7	30.3	
Water Spray	69.3	19.2	
SEm	2.21	0.81	
CD (p=0.05)	6.46	2.36	

Treatments	Plant height (cm)	Number of branches per plant	
Control	33.0	10	Sultana *et al.*, 2006 [20]
NAA 10 ppm	44.0	12	
NAA 50 ppm	35.5	10	
Ethephon 100 ppm	39.0	12	
Ethephon 500 ppm	36.3	11	
KNap 1000 ppm	36.0	11	
KNap 5000 ppm	30.0	10	
LSD (0.05)	5.66	1.147	

Treatments	Plant height (cm)		Number of secondary branches per plant		
	California Wonder	Solan Bharpur	California wonder	Solan Bharpur	
IAA at 100 ppm	98.33	102.22	10.66	9.66	Singh *et al.*, 2012 [19]
IAA at 200 ppm	96.88	100.55	10.33	8.33	
NAA at 50 ppm	114.38	111.66	13.33	11.33	
IAA at 100 ppm	103.05	110.27	12.33	10.66	
2,4 -D at 5 ppm	88.05	88.94	10.00	7.33	
2,4 -D at 10 ppm	76.11	72.77	9.00	7.66	
GA_3 at 25 ppm	86.38	97.22	6.66	6.33	
GA_3 at 50 ppm	101.44	100.55	8.66	6.33	
GA_3 at 25 ppm + NAA at 50 ppm	98.33	99.16	7.66	7.66	
GA_3 at 50 ppm + NAA at 100 ppm	97.22	95.83	8.33	5.66	
Control	86.94	85.33	6.00	5.00	
CD (P=0.05)	19.17	16.68	2.37	1.65	

Treatments	Plant height (cm)	Number of primary branches per plant	Number of leaves per plant	Source
NAA 15 ppm	67.20	7.41	1927.80	Arora *et al.*, 2014 [1]
NAA 30 ppm	67.00	7.60	2184.40	
NAA 45 ppm	68.60	7.80	2193.20	
NAA 60 ppm	64.70	7.69	2134.20	
2,4-D 1 ppm	61.60	7.31	2152.20	
2,4-D 2 ppm	64.30	7.70	2154.40	
2,4-D 4 ppm	64.40	7.97	2190.60	
2,4-D 8 ppm	56.30	8.05	1673.60	
control	62.00	7.46	1775.60	
CD at 5 %	3.86	0.46	51.14	

Treatments	Summer (65 DAP)		Winter (65 DAP)		
	Plant height (cm)	Number of primary branches per plant	Plant height (cm)	Number of primary branches per plant	
FANTAC (0.025%)	61.3	6.75	63.5	7.79	Tamilselvi and Vijayaraghavan, 2014 [21]
FANTAC (0.05%)	63.5	7.20	65.5	8.24	
FANTAC (0.075%)	64.7	7.18	64.2	8.22	
FANTAC (0.1%)	67.4	7.84	70.6	8.48	
Cytozyme 2ml/lit	65.8	7.44	67.1	8.88	
GA_3 20 ppm	69.3	8.00	72.4	9.00	
GA_3 50 ppm	66.7	7.70	69.6	8.74	
NAA 40 ppm	70.8	8.01	72.9	9.09	
Brassinolide 0.1ppm	62.3	7.31	66.2	8.35	
Control	59.0	6.99	61.0	8.03	
S.Ed	0.091	0.011	0.099	0.011	
CD (P=0.05)	0.192	0.023	0.208	0.022	

Treatments	Plant height (cm) at 60 DAT	Number of branches per plant	
Control	53.02	7.68	Kar *et al.*, 2016 [8]
NAA (40 ppm)	58.86	6.71	
GA_3 (50 ppm)	62.35	7.22	
Planofix (400 ppm)	56.80	6.64	
2,4-D (5 ppm)	48.86	8.33	
SEm	0.640	0.152	
CD at 5 %	1.868	0.445	

Treatments	Plant height (cm)	Number of branches per plant	
NAA 5 ppm	35.20	15	Shil and Nath, 2016 [17]
NAA 10 ppm	37.78	17	
NAA 20 ppm	39.45	18	
Control	35.05	15	
SE (m)±	4.12	NS	
CD at 5 %	1.39	1.25	

Treatments	Plant height (cm)	Number of branches per plant	Number of leaves per plant	
NAA (20 ppm)	47.77	17.66	75.61	Shankhwar *et al.*, 2017 [16]
NAA (40 ppm)	56.39	26.97	90.35	
NAA (60 ppm)	52.73	23.20	87.59	
GA3 (25 ppm)	48.78	15.80	78.15	
GA3 (50 ppm)	51.94	19.72	84.01	
GA3 (75 ppm)	49.12	16.74	80.29	
Ascorbic acid (100 ppm)	41.47	13.06	74.06	

Ascorbic acid (200 ppm)	44.50	14.97	76.69	
Ascorbic acid (400 ppm)	46.77	16.05	79.30	
Control.	39.64	11.97	73.81	
SEm	0.95	0.69	1.71	
CD at 5%	2.86	2.08	5.12	

Treatments	Plant height (cm)	Number of branches per plant	Plant spread (cm)	
Control	85.28	9.85	78.02	
GA_3 30 ppm	103.49	11.99	85.64	
GA_3 60 ppm	99.85	11.14	83.41	
GA_3 80 ppm	88.07	11.72	76.36	
GA_3 100 ppm	85.62	10.08	74.85	Singh *et al.*, 2017
NAA 30 ppm	109.38	13.56	87.10	
NAA 40 ppm	94.04	10.99	81.34	
NAA 60 ppm	120.59	16.05	92.57	
NAA 100 ppm	90.83	10.70	72.60	
CD at 5%	1.13	0.26	3.25	

Treatments	Plant height (cm)	Number of branches per plant	Canopy spread (cm)	
NAA 50 ppm	64.10	19.00	53.13	
NAA 100 ppm	60.17	17.38	48.00	
NAA 150 ppm	62.03	19.57	51.40	
GA_3 10 ppm	56.13	16.07	48.90	
GA_3 25 ppm	63.27	18.20	52.80	
GA_3 50 ppm	58.17	20.07	50.13	Mahindre *et al.*, 2018 [12]
CCC 250 ppm	54.23	21.23	44.50	
CCC 500 ppm	52.67	24.40	46.30	
CCC 750 ppm	50.27	23.37	47.10	
Control	55.10	15.13	42.30	
SE (m)±	0.28	0.17	0.22	
CD at 5 %	0.85	0.51	0.67	

Treatments	Plant height (cm)	Number of branches per plant	
NAA 50 ppm	53.32	2.57	
NAA 100 ppm	53.03	2.47	
NAA150 ppm	52.65	2.43	
GA3 50 ppm	53.03	2.93	
GA3 100 ppm	52.67	2.80	
GA3 150 ppm	52.32	2.70	
NAA 20 ppm	52.33	2.97	
NAA 30 ppm	53.00	3.10	Tapdiya *et al.*, 2018 [22],
NAA 40 ppm	54.67	3.17	
GA3 20 ppm	53.33	2.93	
GA3 30 ppm	54.00	2.83	
GA3 40 ppm	54.33	2.63	
control (untreated)	52.00	2.40	
SE(m)	0.30	0.067	
CD at 5 %	0.86	0.197	

Flowering

Singh *et al.*, 2012 [19], studied the effect of bio-regulators on growth and yield parameters of capsicum cultivars under controlled condition and revealed that the minimum number of days taken for first flowering was observed in NAA @ 50 ppm which sprayed two times, first at flower initiation and second at 20 days later from first spray on flower cluster of plant in both the cultivars of capsicum viz., California wonder and Solan Bharpur (41.10 days and 41.66 days, respectively). This treatment was found maximum number of flowers per plant (35.44 and 32.77) and minimum number of days taken for 50% plant to flowering (51.0 days and 51.33 days) in both the cultivar of capsicum viz., California wonder and Solan Bharpur, respectively.

Raj *et al.*, 2016 [15], studied the effect of growth regulators on growth and yield of chilli. The growth regulators were applied as foliar spray at 30 an 60 days after transplanting. The earlier flowering was recorded in NAA @ 75 ppm (38.26days) followed by GA_3 @ 60 ppm (38.72days).

Shil and Nath, 2016 [17], evaluated the effect of NAA on chilli, the crop were sprayed with different concentration of NAA at 35 and 45 days after transplanting and observed that increase of all concentration of NAA has positive effect on early flower initiation. It is recorded that when NAA has been applied @ 20 ppm, the initiation of flowering was earlier by almost one week (68 days) as compared to control treatment (75 days).

Singh *et al.*, 2017, studied the impact of naphthalene acetic acid and gibberallic acid on growth and yield of capsicum cv. Indra under shade net conditions and growth regulators were sprayed at two stages *i.e.* at pre bloom and fruit development stage. They indicated that the minimum number of days to first flowering (32.51 days) and maximum number of flower per plant (11.83) was found in NAA @ 60 ppm.

Table 2: Effect of plant growth regulators on flowering in chilli.

Treatments	Days taken for first flower		Days taken for 50 % plants to flower		Number of flowers per plant		Source
	California Wonder	Solan Bharpur	California wonder	Solan Bharpur	California wonder	Solan Bharpur	
IAA at 100 ppm	41.66	41.77	51.33	52.44	49.33	48.21	Singh *et al.*, 2012 [19]
IAA at 200 ppm	41.87	41.98	52.00	52.66	51.77	50.66	
NAA at 50 ppm	41.10	41.66	51.00	51.33	63.11	57.21	
IAA at 100 ppm	41.67	41.88	51.66	52.33	56.99	55.66	
2,4 -D at 5 ppm	42.66	42.11	52.66	52.33	46.66	44.66	
2,4 -D at 10 ppm	42.55	42.33	54.66	55.66	45.44	42.88	
GA_3 at 25 ppm	53.44	53.99	63.66	64.66	45.99	47.33	
GA_3 at 50 ppm	53.66	54.11	64.33	62.33	47.1	48.11	
GA_3 at 25 ppm + NAA at 50 ppm	46.11	44.33	56.66	55.33	46.88	47.99	
GA_3 at 50 ppm + NAA at 100 ppm	45.55	44.32	55.0	54.00	46.22	49.99	
Control	43.66	43.33	62.33	62.38	42.66	43.11	
CD (P=0.05)	2.79	1.32	7.84	4.99	2.79	6.52	

Treatments	Days to Flowering	Source
NAA at 25 ppm	46.25	Raj *et al.*, 2016 [15]
NAA at50 ppm	39.82	
NAA at 75 ppm	38.26	
GA_3 at 20 ppm	42.53	
GA_3 at 40 ppm	39.28	
GA_3 at 60 ppm	47.56	
2,4 -D at 5 ppm	43.14	
2,4 -D at 7.5 ppm	41.38	
2,4 -D at 10 ppm	38.72	
Ethrel at 300 ppm	40.13	
Ethrel at 400 ppm	41.28	
Ethrel at 500 ppm	46.75	
Control	43.76	
SE (m)±	1.057	
CD (P=0.05)	3.292	

Treatments	Days taken for first flower	Source
NAA 5 ppm	70	Shil and Nath, 2016 [17]
NAA 10 ppm	70	
NAA 20 ppm	68	
Control	75	
SE (m)±	NS	
CD at 5 %	1.89	

Treatments	Days to first flower	Number of flowers per plant	Source
Control	38.43	7.09	Singh *et al.*, 2017
GA_3 30 ppm	33.14	8.87	
GA_3 60 ppm	37.11	7.93	
GA_3 80 ppm	37.72	7.73	
GA_3 100 ppm	39.54	6.71	
NAA 30 ppm	34.88	10.10	
NAA 40 ppm	35.81	8.16	
NAA 60 ppm	32.51	11.83	
NAA 100 ppm	40.10	6.36	
CD at 5%	0.46	0.27	

Treatments	Days to 50 % flowering	Source
NAA 50 ppm	42.33	Tapdiya *et al.*, 2018 [22]
NAA 100 ppm	43.00	
NAA150 ppm	44.33	
GA3 50 ppm	42.33	
GA3 100 ppm	43.33	
GA3 150 ppm	44.33	
NAA 20 ppm	39.00	
NAA 30 ppm	39.67	
NAA 40 ppm	40.67	
GA3 20 ppm	40.00	
GA3 30 ppm	40.67	
GA3 40 ppm	41.00	

control (untreated)	45.67	
SE(m)	0.51	
CD at 5 %	1.51	

Tapdiya *et al.*, 2018 [22], evaluated the effect of growth regulators on quantitative characters of chilli var Jayanti. The growth regulators *i.e.* NAA and GA_3 with concentration of 50, 100 and 150 ppm each were used for seed treatment before sowing and same growth regulators *i.e.* NAA and GA_3 with concentration of 20, 30 and 40 ppm each were applied as foliar application at flower bud initiation in chilli. The result of days to 50 % flowering varied among the growth regulators foliar application and seed treatment method. The minimum number of days to 50 % flowering (39 days) was recorded in NAA @ 20 ppm whereas its maximum was in control (45.67 days).

Early flowering in chilli may be due to the increased synthesis of cytokinin and auxin in the root tissue by their enhanced activity due to the application of NAA. Their simultaneous transport to the axillary buds would have resulted in a better sink for the mobilization of photo-assimilates at a faster rate. This has helped in the early transformation from the vegetative phase to reproductive phase (Tapdiya *et al.*, 2018) [22].

Fruit set

Gollagi, 1999 [5], reported that maximum fruit set in chilli was found with the application of NAA @ 10 ppm (77.2%) at 45 and 65 days after transplanting as compared to unsprayed plot (57.7 %).

Joshi *et al.*, 1999 [7], reported that maximum fruit set per cent (59.63 %) was observed with application of NAA 40 ppm at flower bud initiation and 20 days later in chilli.

Singh *et al.*, 2012 [19], reported that the maximum fruit set per cent was found in treatment NAA @50ppm in both the cultivars of capsicum viz., California Wonder and Solan Bharpur (57.69 % and 57.70 %, respectively).

Arora *et al.*, 2014 [1], revealed that NAA 45 ppm gave maximum fruit set percent (66.58%) and lowest was observed in control treatment (42.70 %).

Gare *et al.*, 2017 [4], studied the effect of plant growth regulators on growth, yield and yield attributing characters of rainfed chilli at Kolhapur district of Maharashtra. The NAA was foliar sprayed at 6, 8 and 10 weeks after transplanting and resulted that foliar spray of NAA @ 60 ppm recorded significantly highest fruit set per cent (84.2%) followed by NAA @ 50 ppm (80.8 %).

Tapdiya *et al.*, 2018 [22] showed that among the different growth regulators and its concentration NAA 40 ppm was found highest fruit set per cent (44.11 %) followed by NAA 30 ppm (43.47 %). in chill.

Table 3: Effect of plant growth regulators on fruit set in chilli.

Treatments	Fruit set per cent		Source
	California Wonder	Solan Bharpur	
IAA at 100 ppm	49.48	49.75	Singh *et al.*, 2012 [19]
IAA at 200 ppm	49.35	49.30	
NAA at 50 ppm	57.69	57.70	
IAA at 100 ppm	56.20	54.65	
2,4 -D at 5 ppm	48.78	45.00	
2,4 -D at 10 ppm	48.77	46.77	
GA_3 at 25 ppm	49.77	47.46	
GA_3 at 50 ppm	49.95	50.31	
GA_3 at 25 ppm + NAA at 50 ppm	50.00	49.64	
GA_3 at 50 ppm + NAA at 100 ppm	51.87	49.55	
Control	47.99	44.59	
CD (P=0.05)	3.16	5.50	

Treatments	Percentage of Fruit set (%)	Source
NAA 15 ppm	52.62	Arora *et al.*, 2014 [1]
NAA 30 ppm	60.60	
NAA 45 ppm	66.58	
NAA 60 ppm	58.46	
2,4-D 1 ppm	60.40	
2,4-D 2 ppm	63.55	
2,4-D 4 ppm	64.85	
2,4-D 8 ppm	56.99	
control	42.70	
CD (P = 0.05)	2.73	

Treatments	Percent Fruit set	Source
NAA 40 ppm	73.5	Gare *et al.*, 2017 [4]
NAA 50 ppm	80.8	
NAA 60 ppm	84.2	
Ethrel 150 ppm	66.8	
Ethrel 200 ppm	67.1	
Ethrel 250 ppm	69.9	
Tricontanal 1 ppm	69.6	
Tricontanal 2 ppm	70.6	

Tricontanal 3 ppm	79.6	
Control	61.3	
SEm	1.17	
CD at 5 %	3.53	

Treatments	Fruit setting (%)	Source
NAA 50 ppm	40.54 (39.5)*	Tapdiya *et al.*, 2018 [22]
NAA 100 ppm	40.33 (39.4)	
NAA150 ppm	40.26 (39.4)	
GA3 50 ppm	42.72 (40.8)	
GA3 100 ppm	42.49 (40.7)	
GA3 150 ppm	42.29 (40.6)	
NAA 20 ppm	43.36 (41.2)	
NAA 30 ppm	43.47 (41.5)	
NAA 40 ppm	44.11 (41.6)	
GA3 20 ppm	42.16 (40.5)	
GA3 30 ppm	42.26 (40.5)	
GA3 40 ppm	43.31 (41.2)	
control (untreated)	39.97 (39.2)	
SE(m)	0.08	
CD at 5 %	0.25	
(*) Figures in parentheses are $\sqrt{x}$ values.		

The promoting effect of NAA on fruit set percentage might be ascribed to more efficient utilization of food for reproductive growth, higher photosynthetic efficiency and enhance source to sink relationship of the plant, increase uptake of nutrients and water, reduced transpiration and respiration enhanced translocation and accumulation of sugar and other metabolites (Arora *et al*., 2014) [1].

The growth regulators like NAA, GA_3 are known to involve in inhibition of cellulose and pectinase activities and abscission production which might have reduced the premature flower drop apart from involved in ovary development during seed filling process in chilli (Tapdiya *et al.*, 2018) [22].

Yield and yield components

Natesh *et al.*, 2005 [13], indicated that maximum number of fruits per plant (24.0), fruit length (16.3 cm), fruit diameter (3.7 cm) was recorded in GA_3 @ 100 ppm while NAA @ 10 ppm recorded highest dry fruit yield (1414.9 kg ha^{-1}) followed by GA_3 @ 100 ppm (1406.1 kg ha^{-1}).

Sultana *et al.*, 2006 [20], conducted the experiment to study the effect of different concentration of three growth regulators NAA, Ethephon and KNoP on yield and seed quality of chilli. The growth regulators were sprayed two weeks after transplanting using separate spray machines and result obtained that significantly highest number of fruits per plant was obtained in NAA @ 10 ppm (136.3) followed by ethephon @ 500 ppm (112.3). The maximum length (6.0 cm) and width (1.0 cm) of fruit was observed in ethephon @ 100 ppm. The highest yield of green chilli was recorded in NAA @ 10 ppm *i.e.* 277.8 g plant^{-1}.

Singh *et al.*, 2012 [19], revealed that NAA @ 50 ppm which sprayed two times, first at flower initiation and second at 20 days later from first spray on flower cluster of plant in both the cultivars of capsicum viz., California wonder and Solan Bharpur recorded maximum number of fruits per plant (35.44 and 32.77, respectively), yield per plant (1.85 kg and 1.26 kg, respectively), fruit length (6.96 cm and 6.91 cm, respectively) and fruit breadth (6.3 cm and 6.83 cm, respectively),.

Veishnav, *et al.*, 2012 [23], reported that highest green fruit yield per plant was observed with the application of NAA @ 40 ppm and variety NUN 2070 (179.59 g) followed by NAA @ 20 ppm and variety NUN 2070 (174.69 g). The highest dry fruit yield per plant was observed with NAA @ 40 ppm and variety Nun 2070 (38.68 g) followed by NAA @ 20 ppm and variety NUN 2070 (37.65 g). The highest green fruit yield (133.03 q ha^{-1}) and dry fruit yield per hectare (28.65 q ha^{-1} were observed with NAA @ 40 ppm and variety Nun 2070.

Singh *et al.*, 2015 [18], studied the effect of Naphthalene Acetic Acid (NAA) on yield of chilli. Application of NAA first at appearance of first flowering and a total of twelve numbers of spraying were applied. Result revealed that the maximum yield of chilli was obtained the plant treated with NAA @ 50 ppm (14.17 q ha^{-1}) followed by NAA @ 20 ppm (12.32 q ha^{-1}) and distilled water sprayed (9.87 q ha^{-1}).

Kar *et al.*, 2016 [8], study the response of different levels of potassium along with foliar application of plant growth regulators in chilli. The growth regulators were sprayed at 30 and 45 days after transplanting and revealed that highest number of fruits per plant was obtained with spraying of GA_3 @ 50 ppm (120.22) followed by NAA @ 40 ppm (112.48). The highest dry fruit yield (2888.70 kg ha^{-1}) was obtained with application of NAA @ 40 ppm followed by GA_3 @ 50 ppm (2655.38 kg ha^{-1}).

Kumari *et al.*, 2016 [18], evidented that application of NAA @ 50 ppm gave highest number of fruits (71.33), fruit length (8.55 cm), fruit diameter (1.41 cm), fruit weight (2.81 g), fruit yield per plant (202.53 g) and fresh fruit yield (108.30 q ha^{-1}).

Raj, *et al.*, 2016 [15], recorded that number of fruits per plant (94.83), fruit length (6.80 cm), yield per plot (2.72 kg per 3.2 m^2) and projected yield per hectare (6.37 t ha^{-1}) were observed in plant raised from NAA 75 ppm treated plants.

Gare *et al.*, 2017 [4], assessed the effect of plant growth regulator on growth, yield and yield attributing character of rainfed chilli variety 'Phule Sai' and observed that foliar application of 60 ppm NAA at 6, 8 and 10 weeks after transplanting gave significantly highest dry red chilli yield (1910 kg ha^{-1}) and was at par 50 ppm NAA (1885 kg ha^{-1}). This treatment (NAA @ 50 ppm) recorded maximum number of fruits per plant (53.4) and dry red chilli yield (61.41 g plant^{-1}). They also recorded that maximum fruit length (9.10 cm) was found in NAA 40 ppm which was statistically at par with other treatment.

Singh, *et al.*, 2017, revealed that NAA @ 60 ppm increased fruit weight (169.66 g), number of fruits per plant (9.87), fruit yield per plant (1.67 kg) and fruit yield per hectare (69.76 t ha^{-1}).

Shil and Nath, 2016 [17], reported that NAA @ 20 ppm recorded maximum number of fruits per plant (250), yield per plant (250.7 g) and yield per hectare (11.2 t ha^{-1}).

Mahindre *et al.*, 2018 [12], indicated that maximum number of fruits per plant (144.17) in chilli was produced in NAA @ 50 ppm which was statistically at par with GA_3 @ 50 ppm (143.97). The data regarding to yield per plant revealed that the maximum green chilli yield per plant (440.0 g) was obtained from NAA @ 50 ppm followed by GA_3 @ 50 ppm (428.73 g).

Tapdiya *et al.*, 2018 [22], reported that the significantly more fruit length was found in NAA @ 40 ppm (7.27 cm) which was at par with NAA @ 30 ppm (7.21 cm). Similarly foliar application of NAA @ 40 ppm recorded more fruit girth (0.83 cm), average fruit weight (3.44 g), number of fruits per plant (150.93) and fruit yield per plant (430.60 g). The minimum fruit yield per plant was recorded in control (290.10 g).

The higher yield in chilli after the spray of NAA and inferred that the higher yield was due to appropriate growth of plants, control of abscission layer in full bloom stage and acceleration in full development by the positive hormonal actions (Khurana *et al*., 2004) [9].

Increase in yield of chilli due to application of NAA may be attributed to enhanced photosynthetic activity and increased production and accumulation of carbohydrates and favourable effect on vegetative growth and retention of flowers and fruits which increased number of fruits per plant besides increase in size (Singh *et al.*, 2015) [18].

The increase in yield of chilli and its components may be due to influence of growth regulators on better growth of plant, higher fruit set and lower flower and fruit drop. The plant sprayed with growth regulators remained physiologically more active to build up sufficient food reserve (source) for developing flowers and fruits (sink) (Raj, *et al.*, 2016) [15].

NAA might be responsible for increase in photosynthetic activities within the plant which might be resulted in more production of carbohydrates and related products responsible for increase in growth. Fruit size, fruit weight of chilli, ultimately responsible for increased yield of chilli (Mahindre *et al.*, 2018) [12].

The growth regulators are reported to bring a rapid change in the phenotypes of plant and also influence the plant growth, right form seed germination to senescence either by enhancing or by suppressing the growth promoters and growth retardants, respectively. Growth promoters help in fruit ripening and ultimately may enhance yield and productivity ((Tamilselvi and Vijayraghvan, 2014) [21].

Table 4: Effect of plant growth regulators on yield and yield component in chilli.

Treatments	Number of fruits $plant^{-1}$	Fruit length (cm)	Fruit diameter (cm)	Dry fruit yield (kg ha^{-1})	Source
NAA 10 ppm	16.0	13.2	3.4	1414.9	Natesh *et al.*, 2005 [13]
NAA 20 ppm	18.9	14.6	3.5	1180.3	
Ethrel 100 ppm	14.5	12.5	3.1	1277.7	
Ethrel 200 ppm	17.2	14.0	3.0	1320.6	
Quantum 50 ppm	18.3	12.6	3.5	1303.0	
Quantum 100 ppm	18.3	13.1	3.0	1312.0	
IAA 50 ppm	15.7	10.5	2.8	1316.9	
IAA 100 ppm	16.3	11.8	2.7	1320.0	
TIBA 25 ppm	15.5	11.7	3.1	1229.2	
TIBA 50 ppm	15.9	14.4	3.0	1285.6	
GA_3 50 ppm	20.9	15.1	3.2	1400.9	
GA_3 100 ppm	24.0	16.3	3.7	1406.1	
Water Spray	6.6	7.7	2.4	1135.5	
SEm	0.52	0.24	0.09	67.7	
CD (p=0.05)	1.47	0.67	0.27	203.1	

Treatments	Number of fruits $plant^{-1}$	Fruit length (cm)	Fruit width (cm)	Fruit yield $plant^{-1}$ (g)	Source
Control	71.0	5.5	0.81	146.6	Sultana *et al.*, 2006 [20]
NAA 10 ppm	136.3	5.3	0.93	277.8	
NAA 50 ppm	91.3	4.6	0.86	176.4	
Ethephon 100 ppm	107.7	6.0	1.00	221.1	
Ethephon 500 ppm	112.3	5.9	0.80	206.0	
KNap 1000 ppm	104.3	5.4	0.86	202.0	
KNap 5000 ppm	103.7	5.5	0.90	189.4	
LSD (0.05)	10.19	0.38	0.17	29.65	

Treatments	Green fruit yield $plant^{-1}$ (g)	Dry fruit yield $plant^{-1}$ (g)	Green Fruit yield (q ha^{-1})	Dry Fruit yield (q ha^{-1})	Source
V1N0	125.80	25.27	90.03	17.24	Veishnav, *et al.*, 2012 [23]
V1N1	136.18	31.97	100.87	23.68	
V1N2	150.30	35.70	111.33	26.45	
V1N3	155.59	37.38	115.25	27.69	
V1N4	144.53	34.99	107.06	25.92	
V1N5	138.48	33.28	105.20	27.65	
V2N0	155.09	27.85	120.14	20.22	
V2N1	164.41	34.08	129.19	25.24	
V2N2	174.69	37.65	130.02	27.89	
V2N3	179.59	38.68	133.03	28.65	
V2N4	174.17	35.92	129.40	26.61	
V2N5	169.27	35.12	125.38	26.02	
V3N0	130.50	20.61	95.23	10.82	

V3N1	136.50	24.83	101.11	18.39	
V3N2	147.08	27.20	108.94	20.14	
V3N3	160.28	29.45	120.13	21.81	
V1N4	148.31	28.02	109.86	20.75	
V3N5	142.54	26.88	105.58	19.91	
SE ±	0.71	0.84	0.53	0.62	
CD at 5%	2.05	2.41	1.52	1.78	

V_1 : NP-2034, V_2 : NUN-2070, V_3 : NUN-6525 and NAA levels (N_0 : Con-trol, N_1 : 10 ppm, N_2 : 20 ppm, N_3 : 40 ppm, N_4 : 60 ppm and N_5 : 80 ppm)

Treatments	Fruit Yield (q ha^{-1})	Source
Plant sprayed with distilled water	9.87	Singh *et al.*, 2015 [18]
Plant sprayed with NAA 20 ppm	12.32	
Plant sprayed with NAA 50 ppm	14.17	

Treatments	Number of fruits plant^{-1}	Fruit yield (kg ha^{-1})	Source
Control	98.64	2310.96	Kar *et al.*, 2016 [8]
NAA (40 ppm)	112.48	2888.70	
GA_3 (50 ppm)	120.22	2655.38	
Planofix (400 ppm)	101.46	2544.28	
2,4-D (5 ppm)	70.02	1910.98	
SEm	1.00	18.63	
CD at 5 %	2.926	54.38	

Treatments	Number of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit yield plant $^{-1}$ (g)	Fresh fruit yield (q ha^{-1})	Source
NAA 0 ppm	55.66	7.85	1.12	2.11	119.09	66.03	Kumari *et al.*, 2016 [18]
NAA 25 ppm	65	8.15	1.23	2.61	162.57	88.87	
NAA 50 ppm	71.33	8.55	1.41	2.81	202.53	108.39	
NAA 75 ppm	69.44	8.47	1.38	2.79	196.65	104.84	
CD at 5%	0.61	0.08	0.014	0.029	1.80	0.95	

Treatments	Number of fruits plant^{-1}	Fruit length (cm)	Fruit diameter (cm)	Fruit yield plot $^{-1}$ (kg per 3.2 m^2)	Projected yield (t ha^{-1})	Source
NAA at 25 ppm	79.98	6.15	1.02	2.16	5.07	Raj *et al.*, 2016 [15]
NAA at50 ppm	88.83	6.70	1.09	2.58	6.05	
NAA at 75 ppm	94.83	6.80	1.21	2.72	6.37	
GA_3 at 20 ppm	81.70	6.68	1.14	1.96	4.60	
GA_3 at 40 ppm	85.56	6.48	1.14	2.26	5.29	
GA_3 at 60 ppm	87.86	6.09	1.24	2.33	5.46	
2,4 -D at 5 ppm	75.83	6.46	1.12	2.09	4.89	
2,4 -D at 7.5 ppm	79.13	6.29	1.19	1.67	3.91	
2,4 -D at 10 ppm	63.37	5.90	1.21	1.33	3.11	
Ethrel at 300 ppm	73.93	6.62	1.07	1.98	4.64	
Ethrel at 400 ppm	71.53	6.24	1.08	1.54	3.85	
Ethrel at 500 ppm	59.83	6.18	1.06	1.25	2.91	
Control	70.97	6.08	1.05	1.85	4.34	
SE (m)±	1.799	0.145	0.114	0.102	0.249	
CD (P=0.05)	5.603	0.453	0.354	0.317	0.777	

Treatments	Number of fruits plant^{-1}	Fruit yield plant $^{-1}$ (g)	Fruit yield (t ha^{-1})	Source
NAA 5 ppm	188	195.6	9.0	Shil and Nath, 2016 [17]
NAA 10 ppm	237	212.4	10.0	
NAA 20 ppm	250	250.7	11.2	
Control	180	200.8	9.2	
SE (m)±	13.95	5.15	3.4	
CD at 5 %	4.48	1.63	1.19	

Treatments	Dry red chilli yield (kg ha^{-1})	Fruit length (cm)	Number of fruits plant^{-1}	Dry red chilli yield (g plant^{-1})	Source
NAA 40 ppm	1810	9.1	47.6	54.74	Gare *et al.*, 2017 [4]
NAA 50 ppm	1885	8.5	51.0	58.65	
NAA 60 ppm	1910	8.9	53.4	61.41	
Ethrel 150 ppm	1594	8.9	42.9	49.34	
Ethrel 200 ppm	1657	8.5	43.6	50.14	
Ethrel 250 ppm	1701	8.8	45.2	51.98	
Tricontanal 1 ppm	1722	8.9	45.4	52.21	
Tricontanal 2 ppm	1761	8.6	45.9	52.79	

Tricontanal 3 ppm	1812	8.3	49.7	54.16	
Control	1491	8.5	39.2	45.08	
SEm	26.34	0.53	1.04	1.58	
CD at 5 %	79.56	NS	3.13	4.74	

Treatments	Fruit Weight (g)	Number of fruits plant^{-1}	Fruit yield plant $^{-1}$ (g)	Fruit yield (t ha^{-1})	Source
Control	158.63	4.51	0.71	29.79	Singh *et al.*, 2017
GA_3 30 ppm	167.62	7.82	1.31	54.64	
GA_3 60 ppm	163.23	7.10	1.15	48.25	
GA_3 80 ppm	155.69	6.04	0.94	39.21	
GA_3 100 ppm	149.84	5.51	0.82	34.38	
NAA 30 ppm	168.26	8.41	1.41	58.96	
NAA 40 ppm	159.53	6.89	1.09	45.77	
NAA 60 ppm	169.66	9.87	1.67	69.76	
NAA 100 ppm	144.65	5.09	0.73	30.69	
CD at 5%	1.47	0.51	0.07	3.34	

Treatments	Number of Fruits per plant	Yield per plant	Source
NAA 50 ppm	144.17	440.00	Mahindre *et al.*, 2018 [12]
NAA 100 ppm	131.90	423.00	
NAA 150 ppm	139.40	390.27	
GA_3 10 ppm	129.80	377.23	
GA_3 25 ppm	134.97	410.00	
GA_3 50 ppm	143.97	428.73	
CCC 250 ppm	121.20	350.03	
CCC 500 ppm	125.67	360.07	
CCC 750 ppm	130.97	380.37	
Control	110.40	330.00	
SE (m)±	0.34	1.38	
CD at 5 %	1.02	4.11	

References

1. Arora Indu, Singh JP, Singh RK. Effect of concentrations and methods of application of 2, 4-D and NAA on plant growth, flowering, yield and quality in summer season chilli (*Capsicum annum* L.) cv. Pant C-1. Adv. Res. J Crop Improv. 2014; 5(2):176-180.
2. Athaneria, Moresh Kumar, Senger N, Panday BR. Influence of biofertilizers and NAA on growth and yield of chilli (*Capsicum annum* L.) cv. JM-283. Veg. Sci. 2011; 38(1):101-103.
3. Erickson AN, Makhart AH. Flower production, fruit set and physiology of bell pepper during elevated temperature and vapour pressure deficit. J American Soc. Hort. Sci. 2001; 126(6):697-702.
4. Gare BN, Raundal PU, Burli AV. Effect of plant growth regolators on growth, yield and yield attributing characters of Rainfed Chilli (*Capsicum annuum* L.). Adv. Agril. Res. & Tech. J. 2017; 1(2):195-197.
5. Gollagi SG. Influence of growth regulators and nutrients for increasing productivity potential and quality in chilli (*Capsicum annuum* L.). Thesis, M.Sc. (Agri.), University of Agriculture Science, Dharwad India, 1999, 98p.
6. Joshi NC, Singh DK. Effect of plant bioregulators on growth and yield of chilli (*Capsicum annum* L.). Prog. Hort. 2003; 35(2):212-215.
7. Joshi NC, Singh DK, Jain SK. Response of plant bio-regulators on growth and yield of chilli during summer season. Adv. Hort. For. 1999; 7:95-99.
8. Kar B, Patra C, Padhiary AK, Mohanty SK. Effect of different levels of potassium and plant growth regulators on different yield attributes of Chilli (*Capsicum annuum* L.). International J of Sci., Env. & Tech. 2016; 5(5):3147-3159.
9. Khurana DS, Manchanda D, Singh K. Influence of naphthalene acetic acid on growth and fruit yield of chilli. Haryana J Hort. Sci. 2004; 33(3/4):274-275.
10. Kiranmayi P, Jyothi KU, Kumari KU, Vani VS, Sneetha DRS. Effect of NAA, 4-CPA and boron on growth and yield of green chilli (*Capsicum annum* L.) var. Lam-353 in summer. Agrotechnol. 2014; 2(4):216-222.
11. Kumari Amrita, Singh VK, Shree S, Kumar V, Kumar M. Effect of NAA on growth and yield attributes of chilli (*Capsicum annum* L.) production under integrated use of organic and inorganic fertilizers. The Bioscan. 2016; 11(2):1281-1284.
12. Mahindre PB, Jawarkar AK, Ghawade SM, Tayade VD. Effect of different concentration of plant growth regulators on growth and quality of green chilli. J of Pharmacognosy and Phytochemistry. 2018; SP1:3040-3042.
13. Natesh N, vyakaranhal BS, Gouda MS, Deshpande VK. Influence of growth regulators on growth, seed yield and quality of chilli cv. Byadgi Kaddi. Karnataka Journal of Agricultural Science. 2005; 18(1):36-38.
14. Prateek Singh, Devi Singh, Deepak Kumar, Jaiswal Singh DK, Vaibhav Singh. Impact of Naphthalene Acetic Acid and Gibberellic Acid on Growth and Yield of Capsicum, *Capsicum annum* (L.) cv. Indra under Shade Net Conditions. Int. J Curr. Microbiol. App. Sci. 2017; 6(6):2457-2462.
15. Raj Chandini A, Holebasappa K, Hore JK, Chattopadyay N. Growth and yield of chilli (*Capsicum annum* L.) as influenced by different growth regulators. The Bioscan. 2016; 11(1):385-388.
16. Shankhwar B, Nigam AK, Vasure N, Vishvakarma D. Effect of different plant growth regulators on growth of chilli (*Capsicum annum* L.) cv. Pusa Jwala. Agric. Update, 12(TECHSEAR-5), 2017, 1187-1189.

17. Shil S, Nath D. Effect of NAA on growth and yield attributes of chilli during winter season under climatic condition of Tripura. International J of Agri. Sci. 2016; 51(8):2192-2193.
18. Singh DK, Rudra BC, Das B, Gangopadhyay PK. Effect of Naphthelene acetic acid on yield of chilli (*Capsicum annum* L.). J Agric. Technol. 2015; 2(1-2):84-86.
19. Singh RN, Pal SL, Rana DK, Rawat SS, Gusain MS. Effect of bio-regulators on growth and yield parameters of capsicum cultivars under controlled condition. Hort. Flora Res. Spectrum. 2012; 1(1):50-54.
20. Sultana W, Fattah QA, Islam MS. Yield and seed quality of chilli (*Capsicum annum* L.) as affected by different growth regulators. Bangladesh J Bot. 2006; 35(2):195-197.
21. Tamilselvi, Vijayaraghavan. Impact of plant growth regulators and formulations on growth of chilli (*Capsicum annuum* L.), Plant Gene and Trait. 2014; 5(8):1-3. (Doi: 10.5376/pgt.2014.05.0008).
22. Tapdiya GH, Gawande PP, Ulemale PH, Patil RK, Naware MS. Effect of Growth Regulators on Quantitative Characters of Chilli (*Capsicum annuum* L.). Int. J Curr. Microbiol. App. Sci. 2018; 6:2151-2157.
23. Veishnav N, Singh BK, Singh AK. Effect of NAA on growth and yield of chilli. Environment and Ecology. 2012; 30(4):1261-1263.