International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(10): 194-197
www.biochemjournal.com
Received: 03-08-2024
Accepted: 06-09-2024

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Studies on comparative bioefficacy and phytotoxicity of plant growth regulators on chilli (*Capsicum annuum* L.)

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DOI: https://doi.org/10.33545/26174693.2024.v8.i10c.2440

Abstract
The present investigation entitled "Studies on comparative bioefficacy and phytotoxicity of plant growth regulators on chilli (*Capsicum annuum* L.)" was conducted in summer season of 2023 at All India Co-ordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, with an objective to study effects of different plant growth regulators on growth, flowering, fruiting, yield characters and phytotoxicity symptoms in chilli. The experiment was conducted with ten treatments *viz*., T_1- NAA @ 10 ppm, T_2- NAA @ 15 ppm T_3- NAA @ 20 ppm, T_4- Triacontanol @ 1 ppm, T_5- Triacontanol @ 2.5 ppm, T_6- Triacontanol @ 5 ppm, T_7- GA @ 10 ppm, T_8- GA @ 15 ppm, T_9- GA @ 20 ppm, T_{10}- Control (water spray) laid out in Randomized Block Design with three replications. The plant growth regulators were sprayed twice i.e. first spray at initiation of flowering and second at days to 50 % flowering. Among all the treatments of plant growth regulators the foliar spray of GA @ 10 ppm recorded better results in flowering, fruiting and yield characters followed by Triacontanol @ 1 ppm and NAA @ 20 ppm in chilli. The phytotoxicity symptoms were not observed during the experimental duration as influenced by plant growth regulators.

Keywords: Chilli, summer, plant growth regulators, growth, yield, phytotoxicity

Introduction
Chilli, botanically known as *Capsicum annuum* L. is a vibrant, fiery spice and fascinating species belonging to the nightshade family Solanaceae that has made its mark on global cuisines. The green chillies contain 'rutin' which have medicinal value and is of immense pharmaceutical need (purse glove). It contains capsaicin ($C_{18}H_{37}NO_3$) and several related chemicals, collectively called capsaicinoides, which is responsible for pungency. (Arivazhagan *et al*., 2021) [3]. India is the largest producer of chilli i.e, 1.98 million tonnes and contributes 43 per cent of world chilli production, followed by China, Ethiopia, Thailand, Pakistan. (Anonymous, 2021) [1]. In India, the major chilli growing states are Maharashtra, Andhra Pradesh, Karnataka, Orissa, Tamil Nadu, Madhya Pradesh, Rajasthan, West Bengal. This statistical data shows that there is a good scope for raising chilli production in Maharashtra (Anonymous, 2023b) [2].

Plant growth regulator has an immense potential in vegetable crop production in order to increase the yield and quality of vegetables, synchronization in flowering, earliness, cold and high temperature fruit setting of vegetables. (Bagale *et al*., 2022) [4]. Poor fruit set is one of the major bottleneck in the production of chillies. The plant growth regulators have been found effective in reducing the flower and fruit drops thereby enhancing production of chilli per unit area and per unit time. (Sreenivas *et al*., 2017) [17]. NAA is having beneficial effect like, increased photosynthetic activity, accelerated transport and efficiency of utilizing photosynthetic products resulting in rapid cell elongation and cell division in the meristem which are ultimately responsible for growth, development and higher yield of vegetable crops. A natural plant growth regulator called triacontanol (TRIA) is utilized to increase agricultural productivity, focusing on the morphological characteristics as well as the fruit dropping by using these hormones. (Nalluri *et al*., 2022) [11]. Gibberellins play essential functions during flowering, senescence of the fruit, improving the yield and establishment of

the fruit, abscission, regulation of some metabolic processes, and have been related to tolerance to temperature or stress conditions. The quality of green pepper during harvest and post-harvest were maintained by applying gibberellic acid (GA_3) (Dos *et al*., 2022) [7].

Balancing the bioefficacy and avoiding phytotoxicity requires precise knowledge of the specific PGR being used, the plant species, growth stage, and environmental conditions. Proper application techniques, timing and dosage are essential to harness the benefits of plant growth regulators while minimizing any adverse effects on plant health. In view of above background, the present research work was carried out with different concentrations of plant growth regulators to study the effect of plant growth regulators on growth, flowering, fruiting, yield characters and phytotoxicity symptoms in chilli.

Material and Methods

The experiment was conducted during summer season at All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra). During the experimental period of summer 2023, the weekly minimum and maximum temperature for chilli ranged between 17.26° to 27.10°C and 27.37 to 40.07°C, respectively. Over the crop growth period, the average total rainfall was 2.27 mm per day in 22 rainy days. The soil of experimental plot was medium black, calcareous and well drained. The experiment consists of ten treatments *viz*., T_1- NAA @ 10 ppm, T_2- NAA @ 15 ppm T_3- NAA @ 20 ppm, T_4- Triacontanol @ 1 ppm, T_5- Triacontanol @ 2.5 ppm, T_6- Triacontanol @ 5 ppm, T_7- GA @ 10 ppm, T_8- GA @ 15 ppm, T_9- GA @ 20 ppm, T_{10}- Control (water spray) laid out in Randomized Block Design with three replications. The plant growth regulators were sprayed twice i.e. first spray at initiation of flowering and second at days to 50 % flowering.

All the agronomic field practices were adopted as per the recommendations. Regular observations such as growth characters, flowering and fruiting characters, yield characters and phytotoxicity symptoms were recorded at specific time intervals by selecting randomly five plants in each treatment. The data recorded were statistically analysed by using technique of analysis of variance and significance was determined as given by Panse and Sukhatme (1985) [12] for Randomized Block Design.

Results and Discussion

The results obtained from the present investigation have been presented in the following sub-heads:

Effect on growth characters

The maximum plant height was recorded in T_4 i.e., Triacontanol @ 1 ppm (90.40 cm) which was at par with treatments T_7 i.e., GA @ 10 ppm (90.13cm), T_8 i.e., GA @ 15 ppm (88.60 cm) and T_3 i.e., NAA @ 20 ppm (87.27 cm) and minimum in T_{10} i.e., Control (82.07cm). However, the maximum plant spread was found in T_3 i.e., NAA @ 20 ppm (64.80 cm) which was at par with GA @ 10 ppm (61.23 cm), T_4 i.e., Triacontanol @ 1 ppm (60.83 cm), T_2 i.e., NAA @ 15 ppm (60.33 cm) and T_9 i.e., GA @ 20 ppm (59.64 cm) except T_{10} i.e., Control (54.97 cm). These results were might be due to the plant growth regulators regulate plant height, plant spread by influencing cell division and elongation in the growing portions of the plant, promoting internode elongation, and altering hormonal balance. These results are in conformity with the results reported by Gare *et al*. (2017) [8], Mahindre *et al*. (2018) [9] in chilli.

Number of primary branches observed highest with the treatment T_7 i.e., GA @ 10 ppm (3.20) which was at par with T_3 i.e., NAA @ 20 ppm (2.74), T_1 i.e., NAA @ 10 ppm (2.73), T_4 i.e., Triacontanol @ 1 ppm (2.72) and T_9 i.e., GA @ 20 ppm (2.72) while, lowest in treatment T_{10} i.e., Control (2.07). The increase in number of branches might be due to the influences of axillary bud development and branching patterns contributing to the proliferation of primary branches. Their simultaneous transfer to the axillary buds would have provided a more efficient sink for photo-assimilates mobilization. These results are in line with Pundir *et al*. (2020) [13], Das and Sheikh (2023) [6] in chilli.

Effect on flowering and fruiting characters

The treatment T_7 i.e., GA @ 10 ppm required least days for 50 % flowering about 46.67 days which was at par with treatment T_3 i.e., NAA @ 20 ppm (48.67 days) while maximum in T_{10} i.e., Control (53.16 days). These results are in accordance with the study of Sahu *et al*. (2017) [15] and Baghel and Singh (2024) [5] in chilli. The treatment T_7 i.e., GA @ 10 ppm required least days (54.67) for fruiting in chilli which was at par with treatment T_4 i.e., Triacontanol @ 1 ppm (56.00 days), T_3 i.e., NAA @ 20 ppm (56.67 days), T_8 i.e., GA @ 15 ppm (57.33 days) and T_2 i.e., NAA @ 15 ppm (58 days) maximum days in T_{10} i.e., control (62.34 days). The results are in line with findings of Sahu *et al*. (2017) [15] and Rahman and Yadav (2022) [14] in chilli. Among all the treatments the maximum fruit set per cent (78.67%) was recorded in the treatment T_7 i.e., GA @ 10 ppm which was at par with treatment T_4 i.e., Triacontanol @ 1 ppm (76.67 %), T_3 i.e., NAA @ 20 ppm (76.00%) and T_8 i.e., GA @ 15 ppm (74.67 %) minimum in T_{10} i.e., control (63.67 %). Similar findings were proposed by Gare *et al*. (2017) [8], Sahu *et al*. (2017) [15], and Tapdiya *et al*. (2018) [18] in chilli. Minimum flower drop (%) was recorded in T_7 i.e., GA @ 10 ppm (21.33 %). It was at par T_3 i.e., NAA @ 20 ppm (23.33 %), T_4 i.e., Triacontanol @ 1 ppm (24.00 %) and T_8 i.e., GA @ 15 ppm (26.00 %). Conversely, the highest flower drop (%) was observed in T_{10} i.e., Control (38.71 %). The results are in conformity with Gare *et al*. (2017) [8] in chilli.

Effect on yield characters and yield of chilli

The yield characters like average fruit weight were recorded highest in T_7 i.e., GA @ 10 ppm (2.35 g). Fruit length and diameter were recorded in ranged between 7.00 to 7.54 cm and 0.90 to 0.99 cm, respectively. Number of fruits per plant was recorded maximum in T_7 i.e., GA @ 10 ppm (552.07). It was at par with treatment T_4 i.e., Triacontanol @ 1 ppm (540.15), T_3 i.e., NAA @ 20 ppm (533.80) and T_8 i.e., GA @ 15 ppm (496.00), while minimum in T_{10} i.e., Control (354.05 fruits per plant). Among the treatments, the maximum green fruit yield per plant of chilli was recorded in T_7 i.e., GA @ 10 ppm (1.23 kg) which was at par with treatment T_4 i.e., Triacontanol @ 1 ppm (1.14 kg), T_8 i.e., GA @ 15 ppm (1.10 kg) and T_3 i.e., NAA @ 20 ppm (1.04 kg). However, the minimum in T_{10} i.e., Control (0.74 kg). Maximum yield per plot was recorded in T_7 i.e., GA @ 10 ppm (19.97 kg) which is at par with the treatment T_4 i.e., Triacontanol @ 1 ppm (19.62 kg) and T_3 i.e., NAA @ 20

ppm (17.35 kg). Whereas, the minimum in T_{10} i.e., Control (10.46 kg). Yield per hectare was recorded highest in T_7 i.e., GA @ 10 ppm (363.05 q ha^{-1}) which is at par with the treatment T_4 i.e., Triacontanol @ 1 ppm (356.68 q ha^{-1}), T_3 i.e., NAA @ 20 ppm (315.41 q ha^{-1}) and T_8 i.e., GA @ 15 ppm (287.54 q/ha). Whereas, the minimum in T_{10} i.e., Control (190.24 q ha^{-1}).

The findings might be the result of application of plant growth regulators like Triacontanol, utilize food for reproductive growth (flowering and fruit set) more efficiently, enhance efficiency of Calvin cycle in photosynthesis and enhanced source to sink relationship of the plant, increased uptake of nutrients and water, reduced transpiration and respiration, enhanced translocation and accumulation of sugar and other metabolites. GA helps synchronize flowering, leading to uniform fruit production and higher yields. It improves enzyme activity and membrane permeability, facilitating better nutrient absorption and assimilate transport. These factors collectively lead to healthier and more robust plant, capable of producing higher yields. NAA supports ng optimal plant growth, controlling the abscission layer during full bloom, and accelerating fruit development through positive hormonal effects. NAA can extend fruiting period, allowing for multiple harvests over a long timeframe, thereby increasing overall yield. These results are in agreement with the findings of Pundir *et al*. (2020) [13], Naga *et al*. (2022) [10] and Singh *et al*. (2022) [16] in chilli.

There were no any phytotoxic symptoms observed due to effects of different plant growth regulators tested in present investigation on chilli plant. These findings are in close vicinity with those reported by Sreenivas *et al*. (2017) [17].

Table 1: Effect of different plant growth regulators on growth, flowering and fruiting characters of chilli.

Tr. No.	Plant height (cm)	Plant spread (cm)	Number of primary branches plant^{-1}	Days to 50% flowering	Days to fruiting	Fruit set (%)	Flower drop (%)
T_1	84.67	57.57	2.73	51.33	58.67	71.00	28.67
T_2	83.42	60.33	2.67	50.67	58.00	72.00	28.00
T_3	87.27	64.80	2.74	48.67	56.67	76.00	23.33
T_4	90.40	60.83	2.72	49.67	56.00	76.67	24.00
T_5	85.70	57.91	2.40	50.33	59.33	71.33	27.33
T_6	86.19	55.33	2.27	50.00	59.00	72.00	28.00
T_7	90.13	61.23	3.20	46.67	54.67	78.67	21.33
T_8	88.60	55.70	2.33	50.33	57.33	74.67	26.00
T_9	86.31	59.64	2.72	51.00	58.67	72.00	28.00
T_{10}	82.07	54.97	2.07	53.16	62.34	63.67	38.71
S.E.m. ±	1.31	1.74	0.16	0.97	1.25	1.91	1.90
CD at 5%	3.91	5.18	0.49	2.90	3.73	5.67	5.65

Table 2: Effect of different plant growth regulators on yield characters and yield of chilli.

Tr. No.	Fruit length (cm)	Fruit diameter (cm)	Weight of fruit (g)	No. of fruits plant^{1}	Yield plant^{1} (kg)	Yield plot^{1} (kg)	Yield (qha^{-1})
T_1	7.29	0.96	1.97	486.06	0.97	13.99	254.40
T_2	7.37	0.93	1.90	482.22	0.99	14.85	269.94
T_3	7.52	0.95	1.93	533.80	1.04	17.35	315.41
T_4	7.40	0.97	2.15	540.15	1.14	19.62	356.68
T_5	7.07	0.94	1.91	479.29	0.94	15.09	274.31
T_6	7.31	0.95	2.23	456.29	0.96	14.14	257.01
T_7	7.54	0.99	2.35	552.07	1.23	19.97	363.05
T_8	7.21	0.95	2.10	496.00	1.10	15.81	287.54
T_9	7.39	0.96	2.32	432.06	0.95	14.78	268.64
T_{10}	7.00	0.90	1.82	354.05	0.74	10.46	190.24
S.E.m. ±	0.21	0.02	0.17	20.52	0.07	1.43	25.99
CD at 5%	NS	NS	NS	60.97	0.20	4.25	77.24

Conclusion

From the foregoing results and discussion, it could be concluded that the Analysis of Variance showed significant differences existed among the different plant growth regulators treatments for most of the characters. In regards to growth, flowering, fruiting and yield characters, GA @ 10 ppm, Triacontanol @ 1 ppm and NAA @ 20 ppm showed the best results. Plant growth regulators like GA, NAA and TRIA enhance growth and its attributes, reduce flower drop and increase fruit set, indirectly contributing in increasing yield of chilli in summer season under Maharashtra condition.

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