INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 23, No. 6, p. 102-109, 2023
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Efficacy of bioregulators on tomato plant performance in the summer climate of Bangladesh

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Article published on December 12, 2023

Key words: Tomato, Bioregulators, PGRs, Summer season, Temperature

Abstract

High temperature is a severe environmental stressor that reduces crop yield. Tomato is one of the vegetable crops whose growth, physiology, and yields are highly affected by high temperature during the summer season in Bangladesh. Bioregulators are vital in controlling plant growth and development. In this study, the external application of 4-Chlorophenoxyacetic acid (4-CPA), Naphthalene Acetic Acid (NAA) and Gibberellic Acid (GA_3) were identified as a positive tool in decreasing the stress of the high temperature effect. A pot experiment was arranged under a Completely Randomized Design (CRD) containing three replications. The bioregulator concentrations consisted of control, 20 ppm 4-CPA, 40 ppm 4-CPA, 60 ppm 4-CPA, 10 ppm NAA, 20 ppm NAA, 30 ppm NAA, 20 ppm GA_3, 30 ppm GA_3 and 40 ppm GA_3. The different concentrations of bioregulators had more potentiality to enhance plant height (36.02%), number of branches plant^{-1} (50%), number of leaves plant^{-1} (50%), chlorophyll a content (46.95%), chlorophyll b content (27.97%), total chlorophyll content (38.49%), number of flower cluster plant^{-1} (67.02%), number of flower plant^{-1} (50%), number of fruits plant^{-1} (48.72%) and fruit weight plant^{-1} (64.18%) compared to control. Among the bioregulators, 20 ppm NAA demonstrated the best functional to solved flower and fruit dropping problems of summer tomato. The findings of the study imply that bioregulators can be utilized as a protective agent to increase water use efficiency, osmotic management, and pigment content to reduce the negative effects of high temperature on tomato growth and physiology, resulting in optimum yield.

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Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most highly praised vegetables consumed widely and it is a major source of vitamins and minerals and ranked as second number vegetable of the world after potato (Athinodorou *et al.,* 2021). It is widely employed in a cannery and made into soups, conserves, pickles, ketchup, sauces, juices etc. Tomato is very rich in nutrients, especially potassium, folic acid, vitamin C and contains a mixture of different carotenoids, including vitamin A, effective β-carotene as well as lycopene (Salim *et al.,* 2020).

In summer availability of vegetables is less due to agro-ecological constraints. Tomato plants can grow under a wide range of climatic conditions but they are extremely sensitive to hot and wet growing conditions (Ayenan *et al.,* 2022). High temperature (both day and night), humidity, rainfall and light intensity are the limiting factors of tomato production (Pramanik *et al.,* 2018). These conditions result in abnormal, or reduced, pollen production, abnormal development of female reproductive tissue, hormonal imbalance, low levels of carbohydrates, lack of pollination, and limits fruit set (Ali *et al.,* 2020). High day and night temperature was reported as limiting factor to fruit-set due to an impaired complex of physiological process in the pistil, which results in floral or fruit abscission (Hossain *et al.,* 2018). Lack of suitable cultivars and poor fruit setting of existing varieties especially during the hot/dry season where the demand for tomato is very high is one of the challenges of farmers are facing in tomato production even though there is potential land for cultivation.

Bioregulators (plant growth regulators) are hormone-like chemicals that can increase yields with one application, alter growth patterns, nutritional components, and resistance to different kinds of stress (cold, heat, drought, insects, disease) when applied at extremely low levels. Bioregulators plays an important role in flowering, fruit set, ripening and physiochemical changes during the growing periods of tomato (Kumar *et al.,* 2018). 4-Chlorophenoxy acetic acid (4-CPA) is a synthetic auxin whose application has been reported to increase fruit set and size of tomato in temperature stress conditions (Chishti *et al.,* 2020). 4-CPA is a growth regulator used in reducing pre-harvest fruit drop and resulting in an increased number of fruits and yield in tomato crops (Hossain *et al.,* 2019). Gibberellic acid (GA_3) is important for tomato production to boost yield and improve fruit quality under unfavorable climatic conditions of high temperature (Gelmesa *et al.,* 2010). GA_3 applications help in improvement in a number of the flower cluster, fruit cluster, fruit set, fruit weight, yield, TSS, β-Carotene, vitamin-c and marketable fruit number plant^{-1} and extended maturity time and harvest (Rahman *et al.,* 2019). 1-Naphthalene acetic acid (NAA) affects the physiological process, hastens maturity and produces better quality fruits (Kumar *et al.,* 2018). NAA improved cell growth, cell division, fruit setting and rooting (Nisar *et al.,* 2021).

Due to the excellent nutritional and health benefits of tomatoes, the demand for tomatoes remains higher throughout the year, but production is far below demand, especially in the summer season. So, the prices of tomatoes in the summer season become out of range for ordinary people. Therefore, to meet up the growing demand and prices of tomatoes priority should be given to summer tomato production. However, bioregulators especially those that promote flower or fruit set and yield, might assist farmers in maximizing production under such conditions. There is little or no information available regarding the use of bioregulators, i.e., 4-CPA, NAA, and GA_3, in tomato production under conditions where production is negatively affected by high temperatures. Considering the above-mentioned facts, a pot experiment has been selected to study the summer tomato production by the application of bioregulators in SAU campus.

Material and methods

Experimental area

This experiment was conducted at the net house, Central Research Farm of Sher-e-Bangla Agricultural University, Dhaka-1207 (90°33' E longitude and 23°77' N latitude) under AEZ 28 (Madhapur Tract) in *kharif* season at March 2022 to November 2022.

Climate and soil

The climate of the experimental site is sub-tropical, wet and humid. The soil of experimental area was silty clay in texture. Soil pH was 6.7 and has organic carbon 0.45%.

Experimental treatments and layout

A summer tomato *viz*. BARI Hybrid Tomato-10 was used in the experiment. The experiment consisted of single factor. The bioregulator concentrations consisted of control, 20 ppm 4-CPA, 40 ppm 4-CPA, 60 ppm 4-CPA, 10 ppm NAA, 20 ppm NAA, 30 ppm NAA, 20 ppm GA_3, 30 ppm GA_3 and 40 ppm GA_3. The experiment was laid out in a Completely Randomized Design (CRD) with three replications. The total numbers of unit pots were 30. The space was kept 1 m between replications. Pot to pot distance in a row was 50 cm.

Crop husbandry

The experimental pots were prepared and weeds, stubbles and crop residues were removed from the soil. The potting soil was fertilized with cowdung 80 g pot^{-1}, urea 2 g pot^{-1}, triple super phosphate (TSP) 2.8 g pot^{-1}, murate of potash (MoP) 2 g pot^{-1}, zypsum 0.88 g pot^{-1} and zinc sulphate 0.04 g pot^{-1} corresponding to 10 ton cowdung ha^{-1}, 250 kg urea ha^{-1}, 350 kg TSP ha^{-1}, 250 kg MP ha^{-1}, 110 kg zypsum ha^{-1} and 5 kg zinc sulphate ha^{-1} as a source of NPKSZn. The half amount of cowdung was applied before the final preparation of pots and rest ½ amount of cowdung, TSP, MoP, zypsum, zinc sulphate and 1/3rd of urea was applied within two installments after 25 and 50 days after transplanting. Healthy seeds were selected by specific gravity method and then immersed in a water bucket for 12 hours and then seeds were sown in a seedbed @0.23 g m^{-2} with 10×2 cm spacing from each other on 1st March 2022. The seeds started sprouting after 3-4 days and bear 3-4 leaf structure after 7-10 days. The 30 days old seedlings were transplanted in the main pot. Gap filling, weeding, application of irrigation water and plant protection measures were taken properly when needed.

Application of bioregulators

In this experiment, the bioregulators (4-CPA, NAA and GA_3) solutions were applied in two installments. Solution of different bioregulators were prepared according to the treatment at early in the morning to avoid dehydration lose. The solution was sprayed directly on the plants using hand sprayer at early flowering (30 DAT) and fruit setting stage (60 DAT).

Data collection

Data on the following parameters were recorded during the period of the experiment such as:- Plant height (cm), Number of branches plant^{-1}, Number of leaves plant^{-1}, Chlorophyll a (mg g^{-1}), Chlorophyll b (mg g^{-1}), Total chlorophyll (mg g^{-1}), Number of flower cluster plant^{-1}, Number of flower plant^{-1}, Number of fruits plants^{-1} and Fruit weight plant^{-1} (kg).

Photosynthetic pigments, i.e., chlorophyll a, b and total chlorophyll were determined in the green leaf oh the plants at 95 days after transplanting, colorimetrically as described by (Inskeep and Bloom, 1985).

Statistical analysis

The data obtained for different parameters were statistically analyzed following IBM SPSS Statistics 26.0 and mean separation were done by DMRT at 5% level of significance (Gomez and Gomez, 1984).

Results and discussion

Plant height

The plant height of tomato differed remarkedly by the application of different bioregulators (Table 1). Among the treatment variations, 20 ppm NAA (102.83 cm) showed the tallest plant height whereas, the control (75.60 cm) showed the shortest plant height. Plant height mostly determined by varietal genetic variation but may be bioregulators application give a favorable environment by releasing nutrient which stimulates the plant growth characters like plant height. This might be due to the influence of plant growth regulators on the vegetative parts of the plant. Sing *et al.* (2018) found that external application of NAA increased the height of tomato plant. Taiz and Zeiger (2009) reported that by promoting cell growth and division, the gibberellin stimulates elongation of internodes. Gibberellin and auxin both played a role in stem elongation, with auxin stimulating growth through cell division and expansion and gibberellin acting on both cell expansion and cell number (Majda and Robert, 2018; Kou *et al.*, 2021).

Number of branches plant^{-1}

The different hormones had significant influenced on the number of branches plant^{-1} (Table 1). The maximum number of branches was produced by 20 ppm NAA (6.00) treatment. On the other hand, 60 ppm 4-CPA, 10 ppm NAA, 30 ppm GA_3 and control treatment (4.00) produced the minimum number of branches. This finding positively correlate with Sing *et al.* (2018) that was the number of branches may positively respond to the foliar application of NAA. Sarkar *et al.* (2014) reported that, application of bioregulators increased the number of branches of tomato plant.

Table 1. Effect of bioregulators on the growth parameters of tomato plant

Treatment	Plant height (cm)	Branch plant^{-1} (No.)	Leaves plant^{-1} (No.)
Control	75.60 d	4.00 d	28.00 c
20 ppm 4-CPA	80.37 cd	5.50 ab	30.00 c
40 ppm 4-CPA	91.30 abc	4.43 cd	33.67 bc
60 ppm 4-CPA	98.40 ab	4.10 d	34.00 bc
10 ppm NAA	79.37 cd	4.10 d	35.00 bc
20 ppm NAA	102.83 a	6.00 a	42.00 a
30 ppm NAA	82.87 cd	5.03 bc	38.00 ab
20 ppm GA_3	97.57 ab	4.50 cd	28.00 c
30 ppm GA_3	95.50 ab	4.07 d	32.00 bc
40 ppm GA_3	87.37 bcd	5.00 bc	38.00 ab
SE (±)	1.93	0.13	0.98

Values followed by the same letter(s) did not differ significantly at 5% level of probability

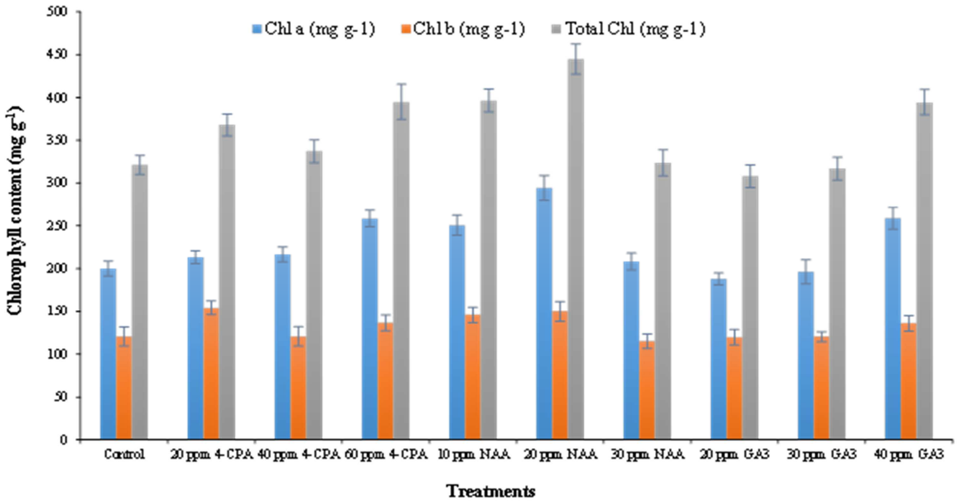

Fig. 1. Effect of bioregulators on the chlorophyll pigments of tomato plant

Number of leaves plant^{-1}

The number of leaves plant^{-1} varied considerably by the application of different bioregulators (Table 1). Among the treatments, 20 ppm NAA (42.00) exhibit the maximum number of leaves plant^{-1}. On the other side, control treatment (28.00) exhibits the minimum number of leaves plant^{-1}. Bioregulators stimulate the growth parameter which ultimately increased the leaf number. The mechanism of increasing the number of leaves and branch due to application of bioregulators that lead to slowing down of cell division and reduction in cell expansion as well as reduce plant height but partially increases the number of branches ultimately increases the leaf number (Sarkar *et al.,* 2014). These results show a strong correlation with Rezazadeh *et al.* (2015) that application of plant growth regulators significantly decreased plant height and increased the number of leaves in Purple Firespike.

Chlorophyll content

The application of bioregulators positively responded to the different photosynthetic pigments like chlorophyll a, chlorophyll b and total chlorophyll (Fig. 1). In respect of chlorophyll a, the highest content display from 20 ppm NAA treatment (294.48 mg g^{-1}), whereas the lowest content from 20 ppm GA_3 treatment (188.18 mg g^{-1}). In regarding to chlorophyll b, the highest content indicates from 20 ppm 4-CPA treatment (154.62 mg g^{-1}) and the lowest content from 30 ppm NAA treatment (115.30 mg g^{-1}). In concerning total chlorophyll, the maximal content observed from 20 ppm NAA treatment (294.48 mg g^{-1}). On the other hand, the minimal content observed from 20 ppm GA_3 treatment (308.14 mg g^{-1}). This might be due to the bioregulators stimulated cell division and cell elongation, therefore the foliar spray of these growth substances in the present study significantly increased the leaf length and width which might have facilitated higher chlorophyll content in leaves. Our results are consistent with Ray *et al.* (2002) claim that applying NAA yielded the highest chlorophyll content. Sarker *et al.* (2021) have demonstrated that various levels of bioregulators were significant on chlorophyll content of mungbean.

Number of flower cluster plant^{-1}

There was a significant difference on number of flower cluster plant^{-1} in response to bioregulators (Table 2). The maximum number of flower cluster plant^{-1} was produced from 60 ppm 4-CPA (9.47). On the contrary, the control (5.67) produced the minimum number of flower cluster plant^{-1}. GA_3 applications help in improvement in a number of the flower cluster of tomato plant (Rahman *et al.,* 2019). Uddain *et al.* (2009) reported that the increasing level of GA_3 had promotive effect on the number of flower cluster plant^{-1} in case of tomato. Application of GA_3 and NAA increases the production of flower in tomato due to enhanced plant growth and faster rate of plant development by the action of GA_3 and NAA in cell elongation and there by increased cell enlargement, cell division and differentiation which in turn result into increase in number of flowers buds (Ritesh *et al.,* 2022).

Table 2. Effect of bioregulators on the yield contributing attributes of tomato plant.

Treatment	Flower cluster plant^{-1} (No.)	Flower plant^{-1} (No.)	Fruit plant^{-1} (No.)	Fruit weight plant^{-1} (kg)
Control	5.67 d	28.00 d	25.33 c	0.67 e
20 ppm 4-CPA	6.47 cd	31.67 cd	27.33 bc	0.75 de
40 ppm 4-CPA	8.00 b	37.67 abc	33.67 ab	0.80 d
60 ppm 4-CPA	9.47 a	40.00 ab	36.00 a	1.01 ab
10 ppm NAA	6.07 cd	34.33 bcd	31.33 abc	0.85 cd
20 ppm NAA	8.97 a	42.00 a	37.67 a	1.10 a
30 ppm NAA	7.97 b	36.67 abc	31.00 abc	0.94 bc
20 ppm GA_3	6.47 cd	31.00 cd	28.67 bc	0.77 de
30 ppm GA_3	6.53 cd	31.67 cd	28.33 bc	0.84 cd
40 ppm GA_3	6.90 c	36.67 abc	34.33 ab	1.00 ab
SE (±)	0.24	0.95	0.9	0.02

Values followed by the same letter(s) did not differ significantly at 5% level of probability.

Number of flower plant^{-1}

Number of flowers plant^{-1} varied considerably due to the influence of different bioregulators (Table 2). Among the treatment variations, 20 ppm NAA (42.00) exposed the topmost number of flowers plant^{-1} whereas, the control (28) exposed the lowermost number of flowers plant^{-1}. Plant growth regulators were used, which resulted in more blossoms plant^{-1} (Rahman *et al.,* 2015). GA_3 promotes flower primodia production in tomato plant which was confirmed by Uddain *et al.* (2009). GA_3 use had enhanced the quantity of open flowers and flower buds (Guan *et. al.,* 2019).

Number of fruits plant^{-1}

The fruits number plant^{-1} varied notably among the different bioregulators (Table 2). In between treatment variations, 20 ppm NAA (37.67) revealed the maximum fruit number plant^{-1}. On the other side, the control (25.33) showed the minimum fruit number plant^{-1}. High temperature decreases the levels of auxin and gibberellins-like substance, especially in floral buds and developing fruits of tomato.

Therefore, shortage of auxin and gibberellins could cause the reduction of fruit set under high temperature. Application of auxin and GA_3 presumably reduced the effect of high temperature and thus would have increased fruit set of tomatoes (Rahman *et al.,* 2015). 4-Chlorophenoxy acetic acid (4-CPA) is a synthetic auxin whose application has been reported to increase fruit set and size of tomato in temperature stress conditions (Chishti *et al.,* 2020). GA_3 is known to promote fruit development in pollinated ovaries that undergo dormancy due to high temperature (Singh *et al.,* 2018). NAA improved cell growth, cell division, fruit setting and rooting (Nisar *et al.,* 2021). Chovatia *et al.* (2010) stated that application of NAA at the time of flowering prevents pre-harvest flower abscission by increasing the available plant hormone (auxin) concentration at this critical phase of reproductive development in tomato plants which ultimately increases the number of fruits. The outcomes are consistent with Rai *et al.* (2002) and Choudhury *et al.* (2013) conclusion.

Fruit weight plant^{-1} (kg)

The application of bioregulators remarkedly increased the fruit weight of plants (Table 2). In the different treatment variations, 20 ppm NAA (1.10 kg) exhibits the upper most fruit weight. However, the control (0.67 kg) treatment displays the lower most fruit weight plant^{-1}. This might be due to the application of auxin and GA_3 by which the plant remained physiologically more active to build up sufficient food stocks for developing flowers, fruit and resulted in increased fruit set, which ultimately lead to higher yields. This result is in agreement with the findings of Baliyan *et al.* (2013) where reported that tomato fruit set and yield was increased by the application of 4-CPA as compared to the fruit set where no hormone was applied. Patel *et al.* (2012) revealed that the application of NAA increases the fruit diameter and yield in tomato. Application of 4-CPA helps in reducing pre-harvest fruit drop and resulting in an increased number of fruits and yield in tomato crops (Hossain *et al.,* 2018). In order to increase output and improve fruit quality while growing tomatoes in harsh climate circumstances with high temperatures, gibberellic acid (GA_3) is crucial (Gelmesa *et al.,* 2010; Rahman *et al.,* 2019).

Conclusion

In conclusion, long term exposure to high temperature in summer season stop the cells work and resulted in a stagnant plant growth. The foliar application of bioregulators (4-CPA, NAA and GA_3) were generally effective in alleviating the injury caused by high temperature through stimulating the vegetative growth, photosynthetic pigments, and bioconstituents activities which could be reflected on yield and quality of tomato fruit. Foliar spraying of bioregulators being the most effective than control treatment. These observations will provide an overview of bioregulators under summer season in tomato that might guide tomato plants and related species. However, further investigations are required to elucidate the possible role of bioregulators on plant growth regulating activity in different Agro-Ecological Zones (AEZ) of Bangladesh. It is postulated that the foliar spraying with bioregulators at high temperatures during summer season planting may positively regulate the tomato growth and thus improved productivity.

Acknowledgments

The author expresses heartfelt gratitude to the Ministry of Science and Technology, Bangladesh for their invaluable financial support in conducting this research.

References

Ali MR, Quddus MA, Trina TN, Salim MMR, Asaduzzaman M. 2020. Influence of plant growth regulators on growth, yield, and quality of tomato grown under high temperature in the tropics in the summer. International Journal of Vegetable Science **28**(1), 1-17.

Athinodorou F, Foukas P, Tsaniklidis G, Kotsiras A, Chrysargyris A, Delis C, Kyratzis AC, Tzortzakis N, Nikoloudakis N. 2021. Morphological diversity, genetic characterization, and phytochemical assessment of the cypriot tomato germplasm. Plants **10**(8), 1698.

Ayenan MAT, Danquah A, Hanson P, Asante IK, Danquah EY. 2022. Tomato (*Solanum lycopersicum* L.) genotypes respond differently to long-term dry and humid heat stress. Horticulturae **8**(2), 118.

Baliyan SP, Rao KM, Baliyan PS, Mahabile M. 2013. The effects of 4-chlorophenoxy acetic acid plant growth regulator on the fruit set, yield and economic benefit of growing tomatoes in high temperatures. International Journal of Agricultural Science & Research **3**(2), 29-36.

Chishti SAS, Aleem S, Sharif I, Nadeem K, Parveen N, Najeebullah M. 2020. Influence of 4-CPA growth regulator for enhancing yield of tomato during low night temperature stress. Pakistan Journal of Agricultural Research **33**(2), 217-223.

Choudhury S, Islam N, Sarkar MD, Ali MA. 2013. Growth and yield of summer tomato as influenced by plant growth regulators. International Journal of Sustainable Agriculture, **5**(1), 25-28.

Chovatia RS, Ahlawat TR, Kavathia YA, Jivani LL, Kaila DC. 2010. Effect of plant growth regulators on vegetative growth, flowering and yield of bitter gourd cv. Priya. Indian Journal Horticulture **67**(11), 254-258.

Gelmesa D, Abebie B, Desalegn L. 2010. Effects of gibberellic acid and 2, 4-dichlorophenoxyacetic acid spray on fruit yield and quality of tomato (*Lycopersicon esculentum* Mill.). Plant Breeding and Crop Science **2**(10), 316-324.

Gomez KA, Gomez AA. 1984. Statistical procedures for agricultural research. John wlley and Sons. Inc. New York, 67-215.

Guan YR, Xue J, Xue Y, Yang R, Wang S, Zhang X. 2019. Effect of exogenous GA_3 on flowering quality, endogenous hormones, and hormone and flowering-associated gene expression in forcing cultured tree peony (*Paeonia suffruticosa*). Journal of Integrative Agriculture **18**, 1295–1311.

Hossain ME, Amin R, Sani MNH, Ahamed KU, Hosain MT, Nizam R. 2018. Impact of exogenous application of plant growth regulators on growth and yield contributing attributes of summer tomato. International Journal of Plant and Soil Science **24**(5), 1-14.

Hossain SM, Sarker C, Mahmud S. 2019. Effect of plant growth regulator on the growth and high yield of heat tolerant tomato variety (*Lycopersicon esculentum* Mill). American Journal of Pure Applied Science **1**(5), 30-43.

Inskeep WP, Bloom PR. 1985. Extinction coefficients of chlorophyll a & b in NN-dimethylformade and 80% acetone. Plant Physiology **77**(2), 483-485.

Kou E, Huang X, Zhu Y, Su W, Liu H, Sun G, Chen R, Hao Y, Song S. 2021.Crosstalk between auxin and gibberellin during stalk elongation in flowering Chinese cabbage. Scientific Reports **11**, 3976.

Kumar S, Singh R, Singh V, Singh MK, Singh AK. 2018. Effect of plant growth regulators on growth, flowering, yield and quality of tomato (*Solanum lycopersicum* L.). Journal of Pharmacognosy and Phytochemistry **7**(1), 41-44.

Majda M, Robert S. 2018.The Role of Auxin in Cell Wall Expansion. International Journal of Molecular Science **19**(4), 951.

Nisar M, Rahman HU, Khan MS, Khan I, Fatima S, Waseem K, Rahman K. 2021. Assessing impact of naphthalene acetic acid on the growth and yield of okra (*Abelmoschus esculentus* (L.) Moench). Pakistan Journal of Scientific & Industrial Research Series A: Physical Sciences **64**(1), 35-45.

Patel JS, Sitapara HH, Patel KA. 2012. Influence of plant growth regulators on growth, yield and quality of tomato and brinjal. International Journal of Forestry and Crop Improvement **3**(2), 116-118.

Pramanik K, Pradhan J, Sahoo SK. 2018. Role of auxin and gibberellins growth, yield and quality of tomato: A review. Journal of Pharmaceutical Innovation **7**, 301-305.

Rahman M, Nahar MA, Sahariar MS, Karim MR. 2015. Plant growth regulators promote growth and yield of summer tomato (*Lycopersicone sculentum* Mill.). Progressive Agriculture **26**(1), 32-37.

Rahman MS, Saki MJ, Hosain MT, Rashid S. 2019. Cumulative effect of zinc and gibberellic acid on yield and quality of tomato. International Journal of Bioscience **14**(3), 350-360.

Rai GK, Singh J, Singh S, Gupta AK. 2002. Effect of plant growth regulators (IAA and NAA) and micronutrient mixtures (Humaur and Multiplex) on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.) Annals of Biology **18**(1), 13-17.

Rezazadeh A, Harkess R. 2015. Effects of pinching, number of cuttings per pot, and plant growth regulators on height control of purple firespike. Horttechnology, 25.

Ritesh KJ, Rabin T, Arjun KS. 2022. Effect of GA3 and NAA on tomato production under protected cultivation in Kaski, Nepal. Journal of Agriculture and Food Research **10**, 100450.

Salim MMR, Rashid MH, Hossain MM, Zakaria M. 2020. Morphological characterization of tomato (*Solanum lycopersicum* L.) genotypes. Journal of the Saudi Society of Agricultural Sciences **19**(3), 233-240.

Sarkar MD, Kabir K, Jahan MS, Arefin SMA. 2014. Performance of summer tomato in response to maleic hydrazide. International Journal of Scientific and Research Publications **4**, 556-558.

Sarker BC, Talukder M, Roy B. 2021. Chlorophyll synthesis, growth and yield performance of summer mungbean CV. BARI moog-6 in response to BAP and NAA. Bangladesh Journal of Botany **50**, 209-217.

Singh SK, Kumar A, Beer K, Singh VP, Patel SK. 2018. Effect of naphthalene acetic acid (NAA) and gibberellic acid (GA_3) on growth and fruit quality of tomato (*Lycopersicon esculentum* Mill.). International Journal of Current Microbiology and Applied Sciences **7**(3), 306-311.

Taiz L, Zeiger E. 2009. Fisiologia Vegetal. 4th ed. Porto Alegre: Artmed, 819.

Uddain J, Hossain KA, Mostafa MG, Rahman MJ. 2009. Effect of different plant growth regulators on growth and yield of tomato. International Journal of Sustainable Agriculture **1**(3), 58-63.