**Application of Plant Growth Regulators Improves Fruit Quality in Chilli (*Capsicum annuum* L.)**

**ABSTRACT**

Application of plant growth regulators (PGRs) has shown promising results in improving fruit quality in various horticultural crops. The present study aimed to evaluate the qualitative traits of chilli cv. Pant Chilli-1 as influenced by application of plant growth regulators. The trial was conducted during 2022-23 at the Vegetable Research Centre of the Govind Ballabh Pant University of Agriculture & Technology, Pantnagar, Uttarakhand. The experiment was laid out in randomised block design (RBD) comprising seven treatments, viz. Triacontanol @250 mL ha-1, NAA @10 ppm ha-1 and four concentrations of Paclobutrazol, i.e., 50, 60, 70 and 87.5 mL ha-1, and a control, replicated three times. The results revealed that the maximum ascorbic acid content (117.43 mg 100 g-1) and TSS (7.80 °Brix) in fruits were observed in plants treated with Paclobutrazol @87.5 mL ha-1. This treatment recorded 27.23% higher ascorbic acid content and 53.85% higher TSS compared to the control treatment.

***Keywords:*** *Chilli; paclobutrazol; triacontanol; NAA; ascorbic acid; total soluble solids.*

**1. INTRODUCTION**

Chilli (*Capsicum annuum* L.) is an important solanaceous vegetable-cum-spice crop cultivated commercially across the tropical and subtropical regions of the world for its pungent fruits, which are consumed both in raw and dried forms. The global demand of chilli has steadily increased owing to its diverse uses in food processing, nutraceuticals and pharmaceuticals, attributed to its rich content of capsaicinoids, vitamins (especially ascorbic acid) and antioxidants (Bal et al.*,* 2022). Fruit quality traits, including size, shape, colour, total soluble solids and nutrient composition, are a key concern alongside yield which significantly influence market acceptability, consumer preference and shelf life (Kyriacou and Rouphael, 2018; Mathiazhagan et al., 2021).

Improving fruit quality through conventional agronomic practices often faces limitations due to genetic constraints and environmental variability. In this context, application of plant growth regulators (PGRs) has emerged as a promising strategy to regulate plant physiological processes and enhance both yield and qualitative traits in horticultural crops. PGRs influence important physiological processes such as cell division and elongation, apical dominance and biosynthesis of secondary metabolites, thereby improving fruit quality under variable environmental conditions (Farman et al., 2019). Among the PGRs, α-Naphthyl Acetic Acid (NAA) is a synthetic auxin which regulates fruit set by preventing premature flower and fruit drop, and enhances mobilization of assimilates to the developing fruits, which can lead to better biochemical characteristics (Anbarasi and Venkatraman, 2022; Surendar et al., 2020). Likewise, triacontanol (TRIA) is known to enhance photosynthesis, enzyme activity and protein synthesis, leading to improved fruit quality traits (El-Beltagi et al., 2025). Paclobutrazol (PBZ), a triazole compound, functions as a gibberellin inhibitor, reducing excessive vegetative growth and promoting partitioning of assimilates towards the developing fruits, thereby improving their quality (Kumar et al., 2023; Orozco-Meléndez et al., 2022).

Several studies have demonstrated the effectiveness of these PGRs in improving fruit quality attributes in chilli, however, comparative and integrative studies evaluating their differential effects on the fruit quality attributes of chilli under field conditions remain limited. Therefore, the present study was undertaken to investigate the effects of application of plant growth regulators on fruit quality traits of chilli with an aim to determine how their use in commercial chilli production can enhance quality and market competitiveness.

**2. MATERIALS AND METHODS**

**2.1 Experimental details**

The present investigation was carried out during the winter-summer season of 2022-23 at the Vegetable Research Centre of the G. B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, using the chilli cv. Pant Chilli-1. The experimental site is located at 29°N latitude and 79.30°E longitude, at an elevation of 243.84 m above mean sea level, in the *tarai* region of the Himalayas. The physico-chemical properties of the soil were determined by adopting standard analytical methods as described in Table 1.

**Table 1. Physico-chemical properties of the experimental soil**

|  |  |  |
| --- | --- | --- |
| **Particular** | **Value** | **Analytical method employed** |
| Texture | Silty | Feel method |
| pH | 7.12 | 1:2.5 soil water suspension method (Jackson, 1973) |
| Available N (kg ha-1) | 160.22 | Alkaline KMnO4 method (Subbiah and Asija, 1956) |
| Available P2O5 (kg ha-1) | 46.87 | Olsen’s method (Olsen et al., 1954) |
| Available K2O (kg ha-1) | 323.90 | Neutral 1 N ammonium acetate (NH4OAc) extraction and flame photometry method (Jackson, 1973) |
| Organic carbon (%) | 0.85 | Wet digestion method (Walkley and Black, 1934) |

The experiment was laid out in a randomised block design comprising seven different treatments, replicated thrice. There were a total of 21 experimental plots, each with a net area of 17.28 m2. Well-decomposed FYM @20 t ha-1 was incorporated into the field at the time of final field preparation, and the recommended dose of fertilisers (RDF), i.e., 100:50:50 kg ha-1 N:P2O5:K2O was applied before transplanting the seedlings. The basal application comprised full doses of P and K, and half dose of N. The remaining N was provided as top dressing in two split doses, i.e., at 30-35 days and 60-65 days after transplanting (DAT). A total of 24 plants were planted in each plot at a spacing of 60 cm × 45 cm. Intercultural operations (e.g., weeding) and plant protection measures were carried out as per the crop recommendations, as and when required. Different doses of three plant growth regulators (PGRs), i.e., Paclobutrazol, Triacontanol and NAA, were applied as foliar sprays as mentioned in Table 2. All the PGRs were purchased from Sumitomo Chemical India Ltd., Danpur, Uttarakhand, India.

**Table 2. Treatment details**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **Dose (ha-1)** | **Method and time of application** |
| T1 : Paclobutrazol 40% SC | 50 mL | One foliar spray at 40-50 days after transplanting (DAT) |
| T2 : Paclobutrazol 40% SC | 60 mL |
| T3 : Paclobutrazol 40% SC | 70 mL |
| T4 : Paclobutrazol 40% SC | 87.5 mL |
| T5 : Triacontanol 0.05% EC | 250 mL | Three sprays at 25, 45 and 60 DAT |
| T6 : α-Naphthyl Acetic Acid (NAA) | 10 ppm | First spray at flowering stage and second spray, 20-30 days later |
| T7 : Control | - | No spray of PGRs |

SC: Suspension concentrate, EC: Emulsifiable concentrate

**2.2 Fruit quality attributes**

The data related to ascorbic acid content and total soluble solids (TSS) in green chilli fruits were recorded by adopting standard protocols as described below:

**2.2.1 Ascorbic acid content (mg 100 g-1)**

Ten fruit samples were randomly selected from each treatment and the procedure described below was followed to determine the ascorbic acid content in chilli fruits:

**(a) Preparation of 3% metaphosphoric acid (HPO3):** HPO3 sticks (30 g) were dissolved in 1 L distilled water to obtain 3% metaphosphoric acid.

**(b)** **Preparation of standard ascorbic acid solution:** 100 mg of L-ascorbic acid was measured the volume was made up to 100 mL with 3% metaphosphoric acid. Then, 10 mL aliquot was taken and the volume was made up to 100 mL with 3% metaphosphoric acid (1 mL = 0.1 mg ascorbic acid).

**(c) Preparation of dye:** 50 mg of sodium salt of 2, 6-dichlorophenol indophenol and 42 mg of sodium bicarbonate (NaHCO3) were dissolved in 150 mL of hot distilled water. The solution was cooled and the final volume was made up to 200 mL by adding distilled water.

**(d) Standardisation of dye:** 5 mL of standard ascorbic acid solution and 5 mL of 3% HPO3 solution were mixed in a conical flask and titrated with the dye solution till appearance of pink colour.

*Dye factor =* $\frac{0.5}{Titre value}$

**(e) Preparation of sample:** Ten green chilli fruit samples were crushed to extract 10 mL of juice. The final volume was made up to 50 mL with addition of 3% metaphosphoric acid.

**(f) Evaluation of ascorbic acid content:** 10 mL of aliquot was added in a conical flask and titrated with the standard dye until a rose pink end point was attained, that persisted for at least 15 seconds. The ascorbic acid content was then calculated using the following formula:

*Ascorbic acid content (mg 100 g-1 fruit sample) =* $\frac{Burette reading × Dye factor × Volume made }{Volume of aliquot taken for estimation × Weight of sample used for sample preparation}$ *× 100*

**2.2.2 TSS (°Brix)**

Ten green chilli fruits from each treatment were collected and crushed with the help of mortar and pestle for extraction of juice. One drop of juice was put on the prism of a hand refractometer (A 0.32% Brix, Erma Inc.), which was calibrated with distilled water after each reading, and the value recorded was expressed in °Brix.

**2.2.3 Statistical analysis**

The observations on different fruit quality attributes were recorded and the data based on the mean of individual characters were statistically analyzed using the OPSTAT software designed and developed by the Department of Mathematics and Statistics, CCS Haryana Agricultural University, Hisar.

**3. RESULTS AND DISCUSSION**

The data presented in Table 3 show that application of plant growth regulators had a significant effect on ascorbic acid content and total soluble solids (TSS) of chilli fruits. Among the various treatments, T4 (Paclobutrazol @87.5 mL ha-1) registered the maximum ascorbic acid content (117.43 mg 100 g-1) in fruits, which was statistically at par with all other treatments except T5, i.e.,Triacontanol @250 mL ha-1 (94.63 mg 100 g-1) and T7, i.e., Control (92.30 mg 100 g-1). The minimum ascorbic acid content in fruits was observed in the control treatment. Likewise, the plants treated with Paclobutrazol @87.5 mL ha-1 (T4), recorded the highest TSS (7.80 °Brix) in fruits, which was at par with the value (6.93 °Brix) observed in fruits of plants treated with Paclobutrazol @70 mL ha-1 (T3). The lowest TSS (5.07 °Brix) was recorded in fruits of plants subjected to T7 (Control), which was at par with T5, i.e., Triacontanol @250 mL ha-1 (5.80 °Brix).

Ascorbic acid is an important component of the nutritional profile of chilli, while TSS of fruit is one of the quality parameters that significantly affects consumer acceptability. Paclobutrazol (PBZ) is a growth retardant, i.e., it inhibits cell elongation and internode extension (Desta and Amare, 2021). The greater suppression of vegetative growth directs the assimilates in a unidirectional manner to the developing fruits, resulting in high-quality fruits from plants treated with PBZ. Also, PBZ treatment has been proved to increase partitioning of assimilates to economically important plant parts (Kumar et al., 2023) which, in case of chilli, is the fruit. Thus, the relocation of carbohydrates along with assimilate partitioning to the fruits were responsible for the increased ascorbic acid and TSS in the fruits treated with PBZ (Rai et al., 2003). Similar findings were reported by Sarker and Rahim (2018) in mango, in which application of paclobutrazol @7500 ppm resulted in the highest ascorbic acid content and TSS in fruits.

**Table 3. Effect of plant growth regulators on vitamin C content and TSS of chilli fruits**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **Ascorbic acid content (mg 100 g-1)** | **TSS (°Brix)** |
| T1 : Paclobutrazol @50 mL ha-1 | 108.90 | 6.40 |
| T2 : Paclobutrazol @60 mL ha-1 | 110.00 | 6.77 |
| T3 : Paclobutrazol @70 mL ha-1 | 115.37 | 6.93 |
| T4 : Paclobutrazol @87.5 mL ha-1 | 117.43 | 7.80 |
| T5 : Triacontanol @250 mL ha-1 | 94.63 | 5.80 |
| T6 : NAA @10 ppm ha-1 | 106.93 | 6.33 |
| T7 : Control | 92.30 | 5.07 |
| CD (*P*=0.05) | 3.90 | 0.93 |

**4. CONCLUSION**

The present study concluded that the fruit quality attributes varied significantly with the application of different plant growth regulators. Among the various treatments, the foliar spray of Paclobutrazol @87.5 mL ha-1 was found superior in improving the ascorbic acid content and TSS of chilli fruits. This study widens the use of PGRs for commercial chilli cultivation in the *tarai* region of Uttarakhand for better quality fruits. However, optimal concentrations of the PGRs should be taken into consideration at multiple representative locations to test their efficacy and phytotoxicity prior to their recommendations. Chilli is an important vegetable that is consumed on a daily basis either in raw or dried forms and, therefore, research on improving its quality through application of PGRs is a significant contribution to wholesome food consumption.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT etc.) and text-to-image generators have been used during writing or editing of the manuscript.

**REFERENCES**

Anbarasi, D., & Venkatraman, M. (2022). Effect of plant growth regulators on growth, yield and quality characters of chilli (*Capsicum annuum* L.). *Annals of Plant and Soil Research*, *24*(4), 543-546.

Bal, S., Sharangi, A. B., Upadhyay, T. K., Khan, F., Pandey, P., Siddiqui, S., Saeed, M., Lee, H. J., & Yadav, D. K. (2022). Biomedical and antioxidant potentialities in chilli: Perspectives and way forward. *Molecules*, *27*(19), 6380.

Desta, B., & Amare, G. (2021). Paclobutrazol as a plant growth regulator. *Chemical and Biological Technologies in Agriculture*, *8*, 1-15.

El-Beltagi, H. S., Gad, M., Abdel-Haleem, M., Shalaby, T. A., Rezk, A. A., & Hamdy Khedr, E. (2025). Triacontanol: a Multifunctional Growth Regulator for Enhancing Stress Tolerance. *Journal of Crop Health*, *77*(2), 1-20.

Farman, S., Mushtaq, A., & Azeem, M. W. (2019). Plant growth regulators (PGRs) and their applications: A review. *International Journal of Chemical and Biochemical Sciences*, *15*, 94-103.

Jackson, M. L. (1973). Soil chemical analysis. Pentice Hall of India Pvt. Ltd., New Delhi, India, *498*: 151-154.

Kumar, A., Bhuj, B. D., Dhar, S., Rajkumar, Rizwan, M., Thapa, R. K., Kumar, H., Kumar, V., Singh, A., Kumar, V., Rajput, A., Kumar, K., & Misra, V. K. (2023). *International Research Journal of Plant Science*, *14*(2), 1-20.

Kyriacou, M. C., & Rouphael, Y. (2018). Towards a new definition of quality for fresh fruits and vegetables. *Scientia Horticulturae*, *234*, 463-469.

Mathiazhagan, M., Chidambara, B., Hunashikatti, L. R., & Ravishankar, K. V. (2021). Genomic approaches for improvement of tropical fruits: fruit quality, shelf life and nutrient content. *Genes*, *12*(12), 1881.

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *U.S. Department of Agriculture Circular*, *939*: 19.

Orozco-Meléndez, L. R., Hernández-Rodríguez, O. A., Cruz-Álvarez, O., Robles-Hernández, L., Ávila-Quezada, G. D., Chavez, E. S., Porras-Flores, D. A., & Ojeda-Barrios, D. L. (2022). Paclobutrazol and its use in fruit production: A review. *Phyton*, *91*(1), 1-12.

Rai, N., Nath, A., Yadav, D. S., & Yadav, R. K. (2003). Effect of different concentration of paclobutrazol (PP333) on growth, flowering and quality of bottle gourd. *Agricultural Science Digest*, 23(1), 44-46.

Sarker, B. C., & Rahim, M. A. (2018). Influence of paclobutrazol on growth, yield and quality of mango. *Bangladesh Journal of Agricultural Research*, *43*(1), 1-12.

Subbiah, B. V., & Asija, G. L. (1956). A rapid procedure for the determination of available nitrogen in soil. *Current Science*, *25*:259-260

Surendar, P., Sekar, K., Sha, K., & Kannan, R. (2020). Effect of plant growth regulators on growth of chilli (*Capsicum annuum* l.). *Plant* *Archives*, *20*(1), 1544-1546.

Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, 37(1): 29-38.