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R.N.I. No. 5368/2001

PRINT ISSN 0972-6152
ONLINE ISSN 0976-4615

Progressive Agriculture

An International Journal

Vol. 24, No. 1
February 2024



SOCIETY FOR RECENT DEVELOPMENT IN AGRICULTURE

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R.N.I. No. 5368/2001

PRINT ISSN 0972-6152
ONLINE ISSN 0976-4615

Progressive Agriculture

(An International, Peer reviewed or Refereed Journal)

VOLUME 24, NUMBER (1), FEBRUARY 2024



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PROGRESSIVE AGRICULTURE

Volume 24 (1)

February 2024

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EFFECT OF PRE-HARVEST APPLICATION OF PLANT BIO-REGULATORS AND MICRO-NUTRIENT ON FRUIT RETENTION, YIELD AND QUALITY OF BER

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Abstract

In order to assess the effect of pre-harvest application of plant bio-regulators and micro-nutrients on fruit retention, yield and quality of ber cv. Banarasi Karaka was carried out in the Garden, Department of Fruit Science, C.S. Azad University of Agriculture and Technology, Kanpur (U.P.) between October 2022 to March 2023. The experiment was carried out using eight treatments viz., GA₃ @ 15ppm and 25ppm, NAA @ 40ppm and 50ppm and ZnSO₄ @ 0.2% and 0.4% including a control (water control), which were replicated thrice in randomized block design. It is reported that the application of GA₃ @ 15ppm + NAA @ 40ppm + ZnSO₄ @ 0.2% significantly increased fruit set (162), fruit weight (16.69g), maximum pulp weight (14.31g), fruit width (2.93 cm), ascorbic acid (94.77 mg per 100 g pulp), volume (14.09 cc), specific gravity (1.098 g/cm³), total sugar (13.25 %) and fruit yield (114.70 kg per tree). The plants treated with NAA @ 50ppm resulted in minimum fruit drop (83.4 %) and highest fruit retention (16.66 %), fruit volume (14.40 cc) and fruit length (4.97 cm) in ber fruits under the North Indian plain.

Key Words: Ber, GA₃, NAA, Fruit Drop, Fruit Retention, Yield, Physio-Chemical Characters

Introduction

The ber botanically known as (*Zizyphus mauriatiana* Lamk.), is a tropical fruit tree that belongs to the Rhamnaceae family and it is also referred to as Chinese date, Chinese apple, Jujube, Indian plum, Indian jujube, and Masau. Ber which is long associated with Indian culture is a prominent indigenous fruit of China and India. Ber is used in the Puranas, the Vedas, and other literary works including the Kautilya Arthashastra, Charak Samitha, and others. Ved Vyas, the sage, and author of Purana and Mahabharat, really made one of the Ber tree's primary fruits his residence, earning him the epithet Badrayan (A person living in a forest of ber trees).

Being hardy in nature and heavy bearing, it is being cultivated widely in diversified soil and climatic conditions. It is known as the "King of Arid Fruits". Its fruit contains 14-16 % sugars, 150

mg of vitamin C per 100 g of pulp, besides other minerals. Different parts of ber plants like roots, bark, leaves, flowers, and seeds are also used in Ayurvedic medicine for the treatment of diarrhea, ulcers, biliousness, indigestion, cough, headache, bleeding gums, and asthma. It is also used as a blood purifier and appetizer. Ripe fruits are eaten fresh and utilized in the preparation of jam, jelly, preserves, and candy and they are dried to prepare a product like "Chuhhara." Ber juice is prepared from fresh fruit and used for making squash.

Gibberellins are mostly used for regulating physiological processes, but they also be commercially used to improve the fruit quality of crops. Mainly three physiological processes i.e., lengthening of rachis cells, thinning of flowers growth of fruits were performed by application of GA₃ in plants. The influence of GA₃ also has the ability to postpone fruit senescence, and in a more recent study, it is suggested that GA₃ may even

encourage flowering. GA₃ has been reported to promote fruit set and minimize fruit drop in ber (Gill and Bal 2013).

Naphthalene acetic acid (Auxin) increased fruit set; decreased fruit drop, and brought a beneficial change in the quality of many fruits. Raising auxin concentration in plants prevents abscission. Auxin inhibits abscission by preventing the physiological breakdown of calcium pectate of the middle lamella. Application of NAA (Auxin) also inhibits fruit drop by strengthening the pedicle.

Zinc is considered necessary for the growth and development of fruits. It is an essential element for the formation of chlorophyll and hence very useful for photosynthetic activities. Zinc is a constituent of some enzymes and took part in the synthesis of IAA, therefore, keeping in view, the importance of these plant bio-regulators and micronutrient the present experiment was planned to get concrete information on the effect of these with respect to fruit retention, yield and quality of ber.

Material and Methods

The present investigation was carried out in the Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur from October 2022 to March 2023. Geographically, Kanpur district is located under a subtropical zone between 25.26° and 26.58° North latitude and 79.31° and 80.34° East longitude with an elevation of 135 meters above mean sea level.

The ber cultivar Banarasi Karaka trees that are uniform, healthy, and well-established were chosen for the experimental goal. The trees, which were forty-nine years old, were maintained in good condition by adhering to the recommended fertilizer doses and other horticultural practices. Throughout the research, the entire orchard was kept orderly and consistently maintained. Three unique trees were selected and utilized as a single unit (for one treatment). Consequently, eight treatments were given on 24 trees and the experiment was preceded as planned each of which included foliar sprays of GA₃, NAA, ZnSO₄ and control. The treatments are as follows- T₀-Control (water spray), T₁ (GA₃ @ 15 ppm), T₂ (GA₃ @ 25 ppm), T₃ (NAA @ 40 ppm), T₄ (NAA @ 50 ppm), T₅

(ZnSO₄ @ 0.2%), T₆ (ZnSO₄ @ 0.4%), T₇ (GA₃ @ 15 ppm + NAA @ 40ppm + ZnSO₄@0.2%). In the early morning, foot sprayers with various concentrations of the solutions were used to thoroughly soak the branches of selected trees and water spray was authorized as a form of control. A homogenous spray of plant growth regulators and zinc was applied on the leaves of each treatment on 26th November 2022, when the fruit-setting stage was in progress. The observations were recorded on fruit set per cent fruit drop, fruit retention and physical characters of fruits i.e., fruit size (length and width of fruits), weight, volume (cc), stone and pulp weight, pulp: stone ratio, specific gravity and fruit yield using standard and recorded processes. Chemical characteristics i.e., total soluble solids (TSS), ascorbic acid (vitamin C) and total sugars content after the harvest of fruit were studied using methods as suggested in AOAC (1980).

Result and Discussion

Fruit set, drop and retention:

The physical characteristics of fruits are an expression of fruiting activity which was significantly influenced by GA₃, NAA, ZnSO₄ and their coupled treatments over control (Table 1). It is clear from the data that the fruit set of all treatments was found to be significant over control barring T₅, T₆ and T₇. The maximum fruit set (162) was registered under the combined treatment of GA₃@ 15 ppm + NAA @ 40ppm + ZnSO₄@0.2% (T₇) followed by NAA @ 50 ppm (159). The lowest fruit set (154) was observed in plants kept under control (T₀) application of without anything. The range of the initial fruit set was varied from 154 to 162. Treatments T₄ and T₇ caused enhancement of fruit retention by (16.66%) and (13.89%) respectively proved to be most effective in increasing the set of ber fruits. It is clear that enhancing concentration of GA₃ and NAA individually enhanced fruit set in ascending order of magnitude and it was also observed with their similar trends with coupled treatments and maximized fruit set in enhancing manner with their increasing concentration. The findings are in line with the respect of **Tripathi and Kumar (2022)** in mango, **Badal and Tripathi (2021a)** in guava.

The data pertaining to the effect of foliar treatment of GA₃, NAA, and ZnSO₄ as well as their

combined treatments consistently and positively influenced fruit drop and retention in ber fruits (Table 1). The application of NAA @ 50 ppm significantly reduced fruit drop to minimum (83.40%) and enhanced fruit retention to a maximum (16.66%). In this regard, maximum fruit drop (92.50%) and minimum fruit retention (7.50%) were recorded under control (T_0). Reduction in fruit drop and increased fruit retention during the present investigation may be due to the application of growth regulators attributed to correcting the deficiency of indigenous auxin which prevents the formation of an abscission layer possibly through the inhibition of enzymatic activities such as pectinase. Spraying of NAA on premature flowering in plants develops sufficiently in young fruits and strengthening was also improved with the basal portion of the flower with attached apex portion of branch. Similar results have been reported by Badal and Tripathi (2021a) in guava, Lal *et al.* (2015) in Kinnow, Tiwari *et al.* (2017), Tripathi and Viveka Nand (2022) in anola and Kumar *et al.* (2023a) in ber.

Fruit width and fruit weight:

The data pertaining to fruit width and weight, both were significantly influenced by zinc sulphate. Fruits with a maximum width (2.93cm) and weight (16.69g) were produced from the plants treated with GA_3 @ 15 ppm + NAA @ 40 ppm + $ZnSO_4$ @ 0.2% closely followed by NAA @ 50 ppm, which produced fruit having a width of 2.92 cm and weight of 16.23 g. The fruit with minimum width (2.23cm) and weight (11.79gm) were produced from the plants kept under control (Table 2). This increase in fruit width and fruit weight during the present investigation period may be due to the maximum mobilization of food materials from the site of their production to the storage organs under the influence of applied plant bio-regulator and zinc, which results in an increase in cell division and cell enlargement which ultimately increased the fruit size and weight with the application of gibberellic acid and NAA with zinc. The findings are in consonance with report by Bhadauria *et al.* (2018) in aonla, Lal *et al.* (2016) in Kinnow, Kumar *et al.* (2023a), Sharma *et al.* (2011) and Gami *et al.* (2019) in ber, Maurya *et al.* (2020), Tripathi and Kumar (2022) in Mango.

The volume of fruit was also affected by the application of growth regulators *viz.*, GA_3 , NAA and zinc over control (Table 2). The plants which were treated with NAA @ 50 ppm expressed significantly maximum fruit volume (16.80 cc) closely followed by the treatment of GA_3 @ 25 ppm + zinc @ 0.2 % (14.40 cc). The untreated plants *i.e.*, control (T_0) exhibited significantly the minimum fruit volume of 10.89cc, as compared with the remaining other treatments. The range of fruit volume varies with the tune of 10.89 cc to 14.40 cc in the remaining other treatments. This increase in fruit volume may be due to the better supply of nutrients to the fruits with the application of plant growth regulators and zinc, which enhanced rapid synthesis of metabolites and photosynthates and their translocation to the fruits which ultimately promoted fruit volume. Similar results have been reported by Kumar *et al.*, (2023a) in ber, Gami *et al.* (2019), Devi *et al.* (2019) in ber and Singh and Singh (2015) in aonla.

Pulp weight and specific gravity

The fresh weight of pulp was determined by deducting the weight of stone and peel from fruit weight. Fruits produced from the plants treated with the treatment of GA_3 @ 15 ppm + NAA @ 40 ppm + zinc @ 0.2%, significantly maximized pulp weight (14.31g) and proved more effective when compared with the rest of the treatments as well as control, followed by T_4 (NAA@ 50ppm) which showed 14.13g of pulp weight. The fruits having minimum pulp weight (9.79g) were produced from plants kept under control (Table 2). The range of pulp weight obtained with various concentrations of plant growth regulators and zinc sulphate from 9.79 to 14.31g, which influenced greatly and consistently on pulp weight of fruit. This increase in pulp weight might be due to the better supply of nutrients and photosynthates in plants treated with foliar application of GA_3 , NAA and Zn which might have made rapid synthesis of metabolites particularly carbohydrate and their translocation to the fruits causing relatively greater pulp content. Similar result was also observed by Badal and Tripathi (2021b) in guava, Verma *et al.* (2021) in strawberry and Viveka Nand *et al.* (2023a) in litchi, Kumar *et al.* (2023a) in ber.

The maximum specific gravity of fruits (1.098cc) was recorded with the combined

treatment of GA₃ @ 15 ppm + NAA @ 40 ppm + ZnSO₄ @ 0.2% followed by application of NAA @ 50 ppm (1.083cc), whereas, the minimum specific gravity (1.022cc) was observed in control treatment (Table 2). Application of growth regulators and zinc sulphate results in an optimum supply of plant nutrients and growth hormone in the right amount during the growth period of fruits resulting in an increase in pulp weight and a reduction in stone weight in ber fruits, which might enhance fruit weight, pulp weight and specific gravity of fruits. Similar results have been reported by **Painkra et al. (2012)** in mango **Devi et al. (2019)** and **Gami et al. (2019)** in ber.

Yield

The yield was significantly influenced by the application of NAA, GA₃, and ZnSO₄. The highest yield (114.70 kg) per plant was recorded with the spray of GA₃ @ 15 ppm + NAA @ 40 ppm + zinc @ 0.2%, which were significantly superior over the control (Fig. 1). The lowest yield parameters recorded under control treatment which may be due to the lack of supply of nutrients. This improvement in yield due to the application of plant bio-regulators and micronutrient application may be ascribed to the better photosynthesis, minimum fruit drop with maximum retention and production of bigger size of fruits. Results regarding fruit yield are in agreement with that of **Dashora et al. (2005)**, **Meena et al. (2014)** in aonla, **Maurya et al. (2020)**, **Tripathi and Kumar (2022)** in Mango.

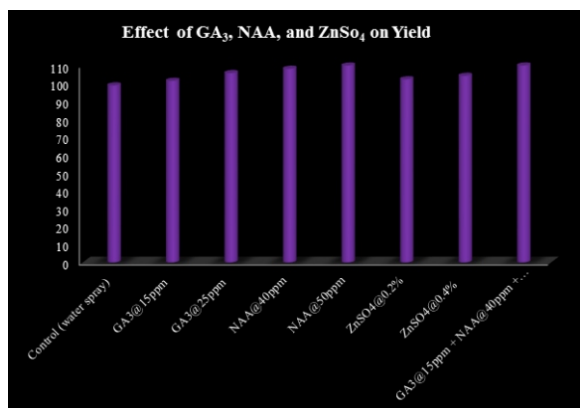


Fig. 1: Effect pre-harvest application of GA₃, NAA, and ZnSO₄ on Yield

Chemical quality attributory traits

The Foliar application of GA₃, NAA and zinc sulphate significantly improved the chemical quality attributory traits of fruits *i.e.*, total soluble solids, ascorbic acid and total sugars. Application of GA₃, NAA and zinc sulphate significantly influenced the biochemical constituents of fruits over the control. The maximum total soluble solids (14.98° Brix) were significantly exhibited in the fruits produced from the plants that were kept under the foliar spray of treatment NAA @ 50 ppm followed by 14.85° Brix total soluble solids in the fruits produced from the treatment of GA₃ @ 15 ppm + NAA @ 40 ppm + zinc @ 0.2 % (Fig. 2). The minimum total soluble solids (13.11°Brix) were obtained in the fruits which were produced from the plants kept as the untreated (control). The range of TSS obtained was from 13.11 to 14.98°Brix in other treatments. This enhancement in total soluble solids content in treated fruit may be due to an increase in the mobilization of carbohydrates from the source to sink in fruit by plant hormone. Besides this, these growth regulators also promoted enzymatic activities and metabolized the carbohydrates into simple sugar and causing strengthening phenomena in the fruit juice which helps in the improvement of total soluble solids content in the fruits of ber. These findings are in line with the reports of **Kumar and Tripathi (2009)** in strawberry, **Kumar et al. (2023b)** in ber, **Gami et al. (2019)** in ber, **Singh and Singh (2015)** in aonla, **Kumar et al. (2022)** in mango and **Viveka Nand et al. (2023b)** in litchi.

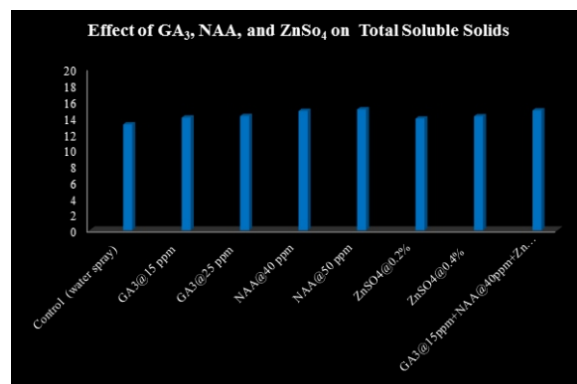


Fig. 2: Effect of pre-harvest application of GA₃, NAA, and ZnSO₄ on total soluble solids

The present findings consistently elaborated that significantly differences were recorded with the application of gibberellic acid, NAA and zinc sulphate with respect to the ascorbic acid content of ber fruits. The significantly maximum ascorbic acid content (94.77 mg/100 g) was assessed with the treatment of GA₃ @ 15 ppm + NAA 40 ppm + zinc @ 0.2% followed by 92.89 mg/100 g ascorbic acid content with the treatment of NAA @ 50 ppm (Table 3). The poorest ascorbic acid content (77.59 mg/100g) was elaborated in the fruits produced from the plants kept as untreated ones (control). The ascorbic acid content was expressed with a tune of 77.59 to 94.77 mg/100g in other treatments. The enhancement in ascorbic acid content has been shown owing to the improvement of ascorbic acid in ber fruits due to the involvement of certain enzymes and metabolic ions in various metabolic activities under the influence of plant growth regulators and zinc sulphate. This increase in ascorbic acid content may be due to the actual synthesis of glucose 6-phosphate throughout the growth and development phase of fruits which is a precursor of ascorbic acid (Vitamin-C). It possibly and considerably happened with the application of plant growth regulators *i.e.*, GA₃, NAA and Zinc sulphate in the present investigation. These findings are in conformity with the reports of Kumar and Tripathi (2009) in strawberry, **Gami *et al.* (2019)** in ber and **Singh *et al.* (2010)** in guava and **Singh and Singh (2015)** in aonla.

The plant growth regulators and zinc concentrations profoundly and significantly influenced the total sugars content in ber fruit (Fig. 3). The treatment of GA₃ @ 15 ppm + NAA @ 40 ppm + zinc @ 0.2% maximized total sugar content (13.25%) followed by 12.90 % total sugars with the treatment of NAA @ 50 ppm. The untreated plants revealed significantly minimum total sugar content (9.12%). The total sugar content increase in fruits might be due to the photosynthetic activities and formation of more carbohydrate content and its translocation to the fruits might be. Sugars are also critically converted into their derivatives by reactions involving several glycolytic pathways. In this experimentation, GA₃, NAA and Zinc also greatly improved in strengthening of these phenomena which enhanced total sugars content in fruits. These findings are in line with the reports of **Gami *et al.* (2019)** and **Singh and Singh (2015)**

in aonla.

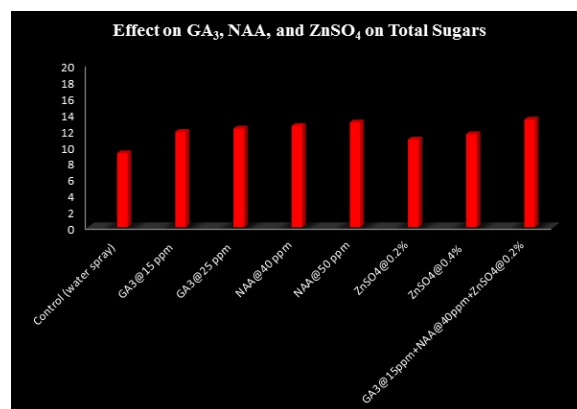


Fig. 3: Effect of pre-harvest application of GA₃, NAA and ZnSO₄ on total sugars

Conclusion

The administration of plant growth regulators, especially GA₃, NAA and Zinc as well as their combination treatments, changed a number of parameters in this study. The combined treatments of GA₃ @ 15 ppm + NAA @ 40 ppm + zinc @ 0.2 % increased total soluble solids content, ascorbic acid, and total sugars. The second effective medication in the current investigation was identified as treatment NAA @ 50 ppm. The combined use of GA₃ @ 15 ppm + NAA @ 40 ppm + zinc @ 0.2% was shown to be more effective in the current investigation period, according to the present finding's scenario. Therefore, in order to boost production and increase farmer's income, it is advised to spray a combination of GA₃ @ 15 ppm + NAA @ 40 ppm + zinc @ 0.2% under the North Indian plain.

Table 1: Effect of Foliar Application of GA₃, NAA, and ZnSO₄ on fruit set, drop and retention percentage

Treatments	Fruit set (%)	Fruit drop (%)	Fruit retention (%)
Control (water spray)	154.00	92.50	7.50
GA ₃ @15 ppm	157.66	88.84	11.16
GA ₃ @25 ppm	156.00	87.30	12.70
NAA @40 ppm	157.33	88.49	11.51
NAA @50 ppm	159.00	83.34	16.66
ZnSO ₄ @ 0.2%	155.00	89.94	10.06
ZnSO ₄ @0.4%	158.66	88.16	11.84
GA ₃ @15 ppm + NAA @40ppm + ZnSO ₄ @ 0.2%	162.00	86.09	13.91
SE(m)±	1.06	1.12	0.15
SE(d)±	1.50	1.58	0.22
C.D. at 5%	3.26	3.43	0.48

Table 2: Effect of Foliar Application of GA₃, NAA, and ZnSO₄ on physico-chemical character of fruits

Treatments	Fruit width (cm)	Fruit weight (g)	Fruit volume (cc)	Fruit pulp weight (g)	Specific gravity (g/cm ³)	Ascorbic acid (mg/100g)
Control (water spray)	2.23	11.79	10.89	9.79	1.022	77.59
GA ₃ @15 ppm	2.53	12.94	12.49	10.74	1.031	84.97
GA ₃ @25 ppm	2.61	14.34	13.69	11.96	1.069	88.14
NAA @40 ppm	2.88	15.63	14.22	12.35	1.083	90.85
NAA @50 ppm	2.92	16.23	14.40	14.13	1.089	92.89
ZnSO ₄ @ 0.2%	2.73	15.13	12.69	13.09	1.048	86.85
ZnSO ₄ @0.4%	2.71	14.01	13.26	13.84	1.057	87.44
GA ₃ @15 ppm + NAA @40ppm + ZnSO ₄ @ 0.2%	2.93	16.69	14.09	14.31	1.09	94.77
SE(m)±	0.03	0.17	0.15	0.23	0.004	1.29
SE(d)±	0.04	0.24	0.22	0.33	0.006	1.82
C.D. at 5%	0.09	0.53	0.48	0.71	0.014	3.96

References

1. A.O.A.C. (1980). Official Methods of Analysis. Association of Official Analytical Chemists, Washington DC.
2. Badal, D. S. and Tripathi, V. K. (2021a). Influence of foliar feeding of NAA and Boron on growth, flowering, fruiting, and yield of winter season guava (*Psidium guajava* L.) cv. L-49. *Biological Forum-An International Journal*, **13**(3): 387-391.
3. Badal, D. S. and Tripathi, V. K. (2021b). Effect of foliar application of NAA and Boron on physico-chemical parameters of winter season guava (*Psidium guajava* L.) cv. Lucknow-49. *The Pharma Innovation Journal*, **10**(9): 928-932.
4. Bhadauria, A. S., Tripathi, V. K., Singh, A. and Gupta, S. (2018). Effect of foliar application of plant bio-regulators and micronutrients on fruit retention, yield, and quality attributes of aonla. *Progressive Research International Journal*, **3**(3): 216-219.
5. Dashora, L. K. Lakhavant, S.S. and Aravind, Akshan, Kavita (2005). Effect of foliar spray on Zinc and Boron on yield and quality of aonla National Seminar on Commercialization of Horticulture in Non-traditional Areas. organized by Central Institute for Arid Horticulture, Bikaner (Rajasthan) from Feb. 4-5, pp-85.
6. Devi, P., Gautam, R. K. S., Singh, J. P., Maurya, S. K. and Chaudhary, A., (2019). Effect of Foliar Application of NAA, GA₃ and Zinc Sulphate on Fruit Drop, Growth and Yield of Ber (*Zizyphus mauritiana* Lamk.) cv. Banarasi Karaka. *International Journal of Current Microbiology and Applied Sciences*, **8**(1): 1679-1683.
7. Gami, J. P., Sonkar, A., Halder and Patidar, D. K. (2019). Effect of Pre-harvest Spray of ZnSO₄, KNO₃ and NAA on Growth, Yield and Quality of Ber (*Zizyphus mauritiana* Lamk.) cv. Seb under Malwa Plateau Conditions. *International Journal Current Microbiology and Applied Sciences*, **8**(03): 1977-1984.
8. Gill, K. S. and Bal, J. S. (2013). Impact of application of growth regulators on Indian jujube. *Acta Horticulturae*, **993**:119-124.
9. Kumar, M., Dwivedi, A. K., Tripathi, V. K. and Shukla, A. (2023a). Influence of different Levels of NAA and 2, 4, 5-T on fruit drop, fruiting, fruit retention, growth and yield of Indian ber (*Zizyphus mauritiana* Lamk.). *International Journal of Plant & Soil Science*, **35** (9):16-29.
10. Kumar, M., Dwivedi, A. K., Tripathi, V. K. and Shukla, A. (2023b). Influence of different levels of NAA and 2, 4, 5-T on fruit quality of Indian ber (*Zizyphus mauritiana* Lamk.). *Biological Forum-An International Journal*, **15**(3): 352-357.
11. Kumar, Raghu and Tripathi, V. K. (2009). Influence of NAA, GA₃ and Boric Acid on growth, yield and quality of strawberry cv. Chandler. *Progressive Horticulture*, **41** (1): 113-115.
12. Kumar, S., Tripathi, V. K. and Dwivedi, A. K., (2022). Influence of GA₃ and ZnSO₄ alone and in combination on fruit drop, yield, and quality attributes of Mango (*Mangifera indica* L.) *Biological Forum-An International Journal*, **14** (3): 1501-1505.
13. Lal, Deepa, Tripathi, V. K., Kumar, Sanjeev and Nayyar, Md. Abu. (2015). Effect of Pre-harvest Application of Gibberellic Acid, NAA, and Calcium Nitrate on fruit drop, maturity and storage quality of Kinnow Mandarin. *Res. Environ Life Sci.*, **8**(4) 561-564.
14. Lal, Deepa, Tripathi, V. K., Nayyar, Md. Abu., Kumar, Sanjeev, Ahmed, M. and Siddiqui, M. W. (2016). Pre-harvest spray of Gibberellic Acid, NAA, and Calcium Nitrate on fruit retention, yield and quality of Kinnow Mandarin. *Environment & Ecology*, **34**(4C): 2288-2292.
15. Maurya, P. K., Tripathi, V. K. and Gupta, S. (2020). Effect of pre-harvest application of GA₃, Naphthalene acetic acid and borax on fruit drop, yield and quality of Mango cv. Amrapali. *Journal of Pharmacognosy and Phytochemistry*, **9**(6): 2123-2127.

16. Meena, H. Tiwari, R. and Singh, O. P. (2014). Effect of nutrient spray on growth, fruit yield and quality of aonla. *Annals of plants and Salt Research*, **16**(3): 242-245.
17. Painkra, R. K., Panigrahi, H. K., and Prabhakar, S. (2012). Effect of plant growth regulators on fruit drop and physico-chemical composition of mango (*Mangifera indica* L.) cv. Langra. *Flora and Fauna*, **18**(2): 213-216.
18. Sharma, J., Sharma, S. K., Panwar, R. D. and Gupta, R. B., (2011). Fruit retention, yield, and leaf nutrient content of ber as influenced by foliar application of nutrients and growth regulators. *Environment and Ecology*, **29**(2):627-631.
19. Singh, A. and Singh, H. K. (2015). Application of plant growth regulators to improve fruit yield and quality in Indian Gooseberry. *Journal of Agri. Search*, **2**(1): 20-23.
20. Singh, S. K., Jaiswal, U. S. and Niraj, K. (2010). Influence of foliar spray of triacontanol and zinc on the yield and quality of guava (*Psidium guajava* L.) cv. Allahabad Safeda. *Indian Agriculturist*, **54**(3/4): 185-187.
21. Tiwari, P., Tripathi, V. K. and Singh A. (2017). Effect of foliar application of plant bio-regulators and micronutrients on fruit retention, yield and quality attributes of aonla. *Progressive Research-An International Journal*, **12**(Special-IV): 2565-2568.
22. Tripathi, V. K. and Kumar, Y. (2022). Effect of pre-harvest application of GA₃ and ZnSO₄ alone and in combination on fruit drop, yield and quality attributes of mango. *Progressive Horticulture*, **54**(1): 62-67.
23. Tripathi, V. K. and Viveka Nand (2022). Effect of foliar application of Boron, Zinc and NAA on fruit retention, yield and quality attributes of aonla. *Progressive Horticulture*, **54**(1): 76-81.
24. Verma, Somendra, Dwivedi, A. K. and Tripathi, V. K. (2021). Effect of gibberellic acid and boron on growth, yield and yield attributory traits in strawberry (*Fragaria x ananassa* Duch.) under North Gangetic Plains. *Biological Forum-An International Journal*, **13**(3): 262-267.
25. Viveka Nand, Dwivedi, A.K. and Tripathi, V. K. (2023a). Effect of plant growth regulator and micronutrient on growth, flowering, and physical quality parameters of litchi (*Litchi chinensis* Sonn.) cv. Dehradun. *International Journal of Plant & Soil Science*, **35**(9): 111-122.
26. Viveka Nand, Dwivedi, A.K. and Tripathi, V. K. (2023b). Influence of GA₃ and ZnSO₄ on fruiting, yield and quality parameter of litchi (*Litchi chinensis* Sonn.) cv. Dehradun. *Journal of Experimental Agriculture International*, **45**(6): 20-30.

Received : September 2023; Revised : October 2023; Accepted : January 2024



IMPACT OF INTEGRATED NUTRIENT MANAGEMENT ON YIELD PARAMETERS OF TURNIP (*BRASSICA RAPA L.*) CV. PURPLE TOP WHITE GLOBE UNDER WESTERN UTTAR PRADESH CONDITIONS

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Abstract

A field experiment was conducted under the title of Impact of integrated nutrient management on yield parameters of turnip (*Brassica rapa L.*) cv. Purple Top White Globe under Western Uttar Pradesh conditions at Horticulture Research Farm, Department of Horticulture, Ch. Charan Singh University Campus, Meerut (U.P.) India, during the year 2018 – 2019. The treatments involved in the study were eight in numbers viz. T₁ Control (No fertilizers), T₂ (RDF 120 : 60 : 60:: N:P:K Kg/ha), T₃ (Farm yard manure @ 24 tonnes/ha), T₄ (Vermicompost @ 6 tonnes/ha), T₅ (75%RDF + Farm yard manure @ 6 tonnes/ha), T₆ (75%RDF + Vermicompost @ 1.5 tonnes/ha), T₇ (50%RDF + Farm yard manure @ 12 tonnes/ha), T₈ (50%RDF + Vermicompost @ 3 tonnes/ha). The experimental field was laid out in Randomized Block Design (RBD). The soil of the experimental field was well drained, sandy loam having good moisture and heat absorbing capacity. Results revealed that maximum root length (18.06 cm.), root diameter (6.42), root weight (191.30 g) and root yield (277.84) were recorded under the 50%RDF + Vermicompost @ 3 tonnes/ha as compared to all other treatments

Keywords: Turnip, INM, NPK, FYM and Vermicompost

Introduction

Turnip is widely cultivated as root vegetable, leaf vegetable, and oilseed. Globally the turnip crop is cultivated over 1.17 million hectares with production of 4.21 million tonnes (FAO 2017). In India turnips are grown in an area of 0.04 million hectares with production of 0.54 million tonnes (FAO 2017). Turnip is a cross pollinated vegetable crop. The edible part of turnip is a modified root (napiform). The roots develop best flavour, texture and size at a temperature of 10°–15°C. The short day length and cool weather favour proper development of roots, but warm temperature adversely affect root quality and root become woody. Purple Top White Globe is a high yielding variety of turnip. This variety is suitable for growing during *Rabi* season. Purple Top White

Globe was introduced from Europe. This variety was introduced and recommended by Indian Agricultural Research Center, Regional station Katrain. The roots of this variety are round, bright purple on top, and lower half creamy white. The flesh is white, firm, crisp and mildly sweet.

Integrated nutrient management (INM) depends on the use of judicious combinations of organic, inorganic and biofertilizers. Integrated nutrient management helps to maintain soil health and increase the crop productivity and preserve soil productivity for future generation. One of the most important ways to increase production of turnip and quality is nutrient management of the particular crop. Although several agronomic factors affect turnip production but the optimum level of organic manures and

inorganic fertilizers are the most necessity factors affecting the production and productivity of root yield of turnip. Integrated use of organic manures with optimum level of NPK fertilizers not only improves the nutrient situation and soil health but also solidify the crop yield at higher level (Yadav and Vijayakumari, 2003).

Nitrogen fertilizers are widely adopted to increase crop yield. The role of nitrogen agreeable because it is a needful component of protein nucleic acids, chlorophyll and some vital enzymes (Parvez *et al.*, 2004). Similarly, phosphorus and potassium are also play a vital role in the plant metabolism for optimizing the growth and development. These nutrients are easily available by the use of chemical fertilizers but the continuous application of chemical fertilizers may lead to ample defacement of soil health which is reflected in completely reduction in physical, chemical and biological characters of soil. On the other hand organic manures viz. farm yard manure and vermicompost are basic sources of essential plant nutrients and applied in large quantities. They also contain other growth promoting agents like enzymes and hormones. In the process of decomposition of organic manures, they give humus, which helps to improve the physical, chemical and biological properties of the soil. Some scientist reported that organic manures release organic acids during decomposition which suppress some fungal pathogens and nematode infestation. The organic materials like farm yard manure, crop residues, green manure and vermicompost commonly used to improve soil condition and soil fertility status reported by several scientists (Das *et al.*, 1991). The benefits of farm yard manure and compost can be used for the decreasing of environmental pollution. Proper nutrient supply through the organic and inorganic fertilizers plants may inspire the yield in turnip.

Methods and Materials

The present investigation was conducted at Horticulture Research Farm, Department of Horticulture Ch. Charan Singh University, Campus, Meerut (U.P.) during *Rabi* season 2018-19. The topography of the experimental field was plain with good irrigation facilities. The soil of experimental field was sandy loam, well drained,

neutral in reaction, low in organic carbon and average in nitrogen, phosphorus and potassium. The treatments involved in the study were eight in numbers i.e. T₁ Control (No fertilizers), T₂ (RDF (120 : 60 : 60) NPK Kg/ha), T₃ (Farm yard manure @ 24 tonnes/ha), T₄ (Vermicompost @ 6 tonnes/ha), T₅ (75%RDF + Farm yard manure @ 6 tonnes/ha), T₆ (75%RDF + Vermicompost @ 1.5 tonnes/ha), T₇ (50%RDF + Farm yard manure @ 12 tonnes/ha), T₈ (50%RDF + Vermicompost @ 3 tonnes/ha). The experiment was laid out in a randomized block design with three replications. All the organic manures and chemical fertilizers were applied as per treatment. Farm yard manure and vermicompost were applied treatment wise before one week of sowing. Half of the recommended nitrogenous fertilizers were applied as basal dose as per treatment and remaining half dose of nitrogen was applied in two split dose after 30 days of sowing. Phosphate and potassium fertilizers were applied as basal dose during the final preparation of field before the seed sowing. The seeds of turnip were sown by hand dibbling method on 30 cm high ridge by the maintaining row to row distance of 45 cm and plant to plant 15 cm. the data related to yield parameters namely: root length (cm), root diameter (cm), root weight (g) and yield (q/ha) were recorded for the analysis. Five plants were randomly selected from each replication to record the data of above mentioned parameters. Appropriate standard and uniform cultural practices viz. irrigation, weeding, thinning, earthing up etc. and plant protection measures were adopted for raising healthy crop. The data recorded during the course of investigation were statistically analyzed by using analysis of variance (ANOVA) technique (Fisher, 1958) for drawing conclusion.

Results and Discussion

The perusal of data clearly reveal that the different integrated nutrient treatments significantly affected yield parameters viz. root length, root diameter, root weight, and yield (table- 1). The maximum root length (18.06 cm) and diameter of root (6.42 cm), were recorded under integrated combination of organic and inorganic fertilizer i.e., T₈ (50%RDF + Vermicompost @ 3 tonnes/ha) followed by 75%

RDF + Vermicompost @ 1.5 tonnes/ha (17.21 cm) and (6.28 cm) respectively, while the minimum root length (14.83 cm) and diameter of root (5.20 cm.) were recorded under T₁ Control (no fertilizers). In the comparative study of soil application of organic manures (vermicompost and farmyard manure), it was found that vermicompost had more pronounced effect to increase root length and root diameter as compared to the farmyard manure. These findings are in line with Vijaykumari *et al.*, 2012 who also recorded maximum root length (24.51cm) and root weight of single radish (211.67g) under application of vermicompost. Soil application of vermicompost @ 2.5 t/ha + Azotobacter @ 2.5 kg/ha significantly increase the root length and root diameter as compared to application of farmyard manure in case of radish reported by Kumar *et al.*, 2018. The integrated application of organic and inorganic fertilizers might helped in increasing availability of major nutrients to plant due to enhanced early root growth and cell multiplication to more absorption of soil ultimately resulting in increased root length and root diameter of turnip. The soil application of vermicompost and farm yard manure increase the available of nitrogen to the plants beside the major nutrients, vermicompost is a rich source of trace elements viz., calcium, magnesium, zinc, copper, iron, and manganese (Prabha *et al.*, 2005). It is well known that nitrogen play vital role in food manufacturing and phosphorus and potassium essential for better root and leaf stomata activity for producing maximum biomass.

The maximum root weight (191.30 g) and root yield (277.84 q/ha), were recorded under integrated combination of organic and inorganic fertilizer *i.e.*, T₈ (50%RDF + Vermicompost @ 3 tonnes/ha) followed by (187.01 g) and (271.34 q/ha) respectively under T₆ (75% RDF + Vermicompost @ 1.5 tonnes/ha) while the minimum root weight (131.19 g.) and root yield (190.23 q/ha) were recorded under T₁ Control (no fertilizers). The findings are closely conferment with the findings of Kumar *et al.*, 2014 in case of carrot. The beneficial effect of integrated nutrient management on yield and yield attributing characters might be due to enhanced supply of macro and micro nutrients during entire growing season. Significant increase in yield under the influence of vermicompost was largely a function of improved growth and the consequent increase in different yield attributes. Vermicompost might have increased the efficiency of added chemical fertilizers in the soil, activities of nitrogen fixing bacteria and increased rate of humification which enhances the availability of both native and added nutrients in soil resulting in increasing yield and yield attributing characters. (Sreeniwas *et al.*, 2000). Application of vermicompost helps in increase the organic matter content of the soil and maintaining soil natural productivity (Gupta *et al.*, 2011). Gibberellins ultimately increase the activity of amylase enzyme, which is responsible for converting starch into sugar. These results are in accordance with the finding of Tomar *et al.*, 1998. The combined application of NPK to the turnip root yield increased availability of have

Table-1 Effect of different integrated nutrient management treatments on yield parameters of turnip (*Brasica rapa* L.) cv. Purple Top White Globe

Treatments	Notation	Root length (cm.)	Root diameter (cm.)	Root weight (g)	Root yield (q/ha)
Control (no fertilizers)	T ₁	14.83	5.20	131.19	190.23
RDF (120 : 60 : 60) NPK Kg/ha	T ₂	16.19	5.76	171.77	249.06
Farm yard manure @ 24 tonnes/ha	T ₃	16.61	5.85	175.89	255.37
Vermicompost @ 6 tonnes/ha	T ₄	17.01	6.09	181.24	262.15
75%RDF + Farm yard manure @ 6 tonnes/ha	T ₅	17.09	6.14	183.02	264.37
75%RDF + Vermicompost @ 1.5 tonnes/ha	T ₆	17.21	6.28	187.01	271.34
50%RDF + Farm yard manure @ 12 tonnes/ha	T ₇	17.15	6.18	184.00	267.46
50%RDF + Vermicompost @ 3 tonnes/ha	T ₈	18.06	6.42	191.30	277.84
CD at 5%		0.84	0.11	1.83	1.86
SE(±m)		0.27	0.03	0.59	0.61

major nutrients to plants as it might have enhanced early root growth and cell multiplication leading to more absorption of other nutrients from deeper layers of soil ultimately resulting in increased plant growth in terms of plant height, dry matter accumulation and leaf area index.

Bibliography

1. Das, M., Singh, B.P., Ram, M., Dwivedi, B.B. and Prasad, R.N. (1991). Influence of organic manures on Native plant nutrient. *Journal Indian Society of Soil Science*; 39: 286-291.
2. Fisher R.A. and Yates, F 1949. Statistical tables for biological, Agricultural and medical research, no. Ed. 3.pp. vii+112 pp.
3. Gupta, A.K., Ray, B., Singh, M.P., Upadhyaya, V. and Singh, C.K. (2011). Effect of fertilizers and vermicompost on growth, yield and biochemical changes in *Abelmoschus esculentus*. *Plant Archives*; 11(1):285-287.
4. Kumar, A., Rana, M.K. and Baswana, K.S. (2007). Effect of crop residues and farm yard manure on yield and quality of carrot (*Daucus carota* L.) roots. *Haryana Journal of Horticultural Sciences*. 36 (3/4): 367-369.
5. Kumar, P., Meghwal, P.R. and Painuli, D.K. (2014). Effect of organic and inorganic nutrient sources on soil health and quality of carrot. *Indian Journal of Horticulture*; 71(2): 222-226.
6. Kumar, S., Dev, P., Kumar, J., and Kumar H. (2018) Impact of organic manures and biofertilizers on the performance of radish (*Raphanus sativus* L.) *HortFlora Research Spectrum*; 7 (2):137-140.
7. Pervez, M. A., C. M. Ayub, B. A.Saleem, N.A. Virk and N.Mahmood, (2004). Effect of nitrogen levels and spacing on growth and yield of radish (*Raphanus sativus* L.). *International Journal of Agriculture and Biology*; 6(3): 504-506.
8. Prabha, L., Indira, M., Jeyaraaj, A. and Jeyarraj, R. (2005). Macro and micronutrient changes in vermicomposting of vegetable waste using *Eudrilus eugeniae*. *South Asian Journal of Socio Political Studies*, pp.129.
9. Sreenivas, C., Muralidhar S. and Rao M.S. (2000). Vermicompost, a viable component of IPNSS in nitrogen nutrition of ridge gourd. *Annals of Agricultural Research*; 21(1):108–113.
10. Thamburaj, S. and Singh, N. (2001). Textbook of vegetables tuber crops and Spices. Indian Council of Agricultural Research, New Delhi.
11. Tomar, V.K., Bhatnagar, R.K. and Palta, R.K. (1998). Effect of vermicompost on production of brinjal and carrot. *Bhartiya Krishi Anusandhan Patrika*: 13(3-4):153-156.
12. Vijayakumari, B., Sasikala, V., and Poornima, C.P. (2012). Effect of organic and inorganic manures on biometric and yield parameters of radish (*Raphanus sativus* L.) cv. Pusa Chetki. *International Journal of Plant Science*; 7(1): 130-134.
13. Yadav, H. and Vijayakumari, B. (2003). Influence of vermicompost with organic and inorganic manures on biometric and yield parameters of chilli (*Capsicum annum* L.) var. Pallavi. *Crop Research*; 25:236-243.

Received : October 2023; Revised : November 2023; Accepted : January 2024



NUTRIENT METABOLISM AND GROWTH PERFORMANCE OF ENDOTOXIN INDUCED SUB-CLINICAL STRESS RATS SUPPLEMENTED WITH PHYTOGENIC FEED ADDITIVE

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Abstract

The present experiment was carried out to assess the impact of the phytogenic feed additives (PFA) of either powder meal or crude extract form supplementation on nutrient digestibility and growth performance of endotoxin-induced sub-clinical stress rats. Adult wistar rat (n=40), distributed into 4 groups, were administered endotoxin alone or with supplementation of PFA in powder meal and crude extract form at the rate of 1.5% and 0.15%, respectively, of total DMI along with an appropriate non-endotoxin control during an eight weeks study period. The weekly body weight and digestion trial at the end of experimental period was conducted to assess the ameliorating effect of PFA on growth performance and nutrient digestibility in rats. The results indicated that endotoxin administration at low dose level of 0.2 µg/kg BW causes no influence on intake of nutrients but lowers the digestibility of OM. However, a decrease ($P<0.05$) in BW gain was observed at first to third weeks of study which gets tapered and finally diminished in later week of study. It suggests that endotoxin administration at low dose level of 0.2 µg/kg BW in rats induces no significant changes in digestibility of major nutrient but lower voluntary feed intake and the body weight growth during the early week of study, and the phytogenic feed additives (PFA) formulation of either powder meal or crude extract form at selected dose level was effective in arresting these adverse changes to a great extent throughout the study period.

Keywords: Phytogenic feed additives, Wistar rats, low dose endotoxin, nutrient metabolism, growth performance

Introduction

The animals kept under unhygienic conditions frequently exposed to different bacterial and viral contagions which may result to lost their lives but majority of time these animals recover and don't show symptoms; rather they suffer internally from the disease at subclinical level resulting loss in health and productivity. Among the infectious diseases majority are caused by Gram-negative bacteria which produces an endotoxin (Rietschel et al., 1990), the main pathogenic factors involved in infection, inflammation and a potent stress inducer. The phenomenon of sub-clinically

elevated levels of endotoxin in the blood flow has recently been described as “metabolic endotoxemia” under which multiple important illness pathologies, nutrient metabolism and their effect on growth performance are area of interest and now being investigated. Much more research must be commenced to determine the harmful effect of very low dose (metabolic) endotoxemia and its neutralization by use of different exogenous sources intervention, expected to play protective roles and include supplementation with mainly synthetic products like vitamins C and E, selenium, etc in diet of animals. However, current

public interest about the usage of synthetic compounds, coupled with modifications in regulations on the utilization of simulated medicaments, has accelerated interest and research on the application and efficacy of using natural products in the diets.

Phytogenic feed additives (PFA) are good candidates among natural products which are relatively new and the knowledge is still rather limited. Moreover, it represents a novel management tool that is green, clean and ethical (Martin, 2006). Plants generally characterized by high concentrations of beneficial phytochemical compounds which on consumption by animals produces beneficial effect but to the limited extent because of few varieties of phytochemical presence. This beneficial effect can be increased manifold by use of network of PFA with distinctive chemical properties which works in an integrated manner to obtain the health benefit of animals. With all preceding points into consideration, the present study was proposed to investigate the amelioration potential of a unique mixture of the different herbal combinations as a feed additive in a green, clean, ethical, easy and economical way for use in diet of endotoxin induced sub-clinical stress rats.

Materials and Methods

Phytogenic feed additive and its extract

The novel phytogenic feed additive (PFA) formulation comprised of a mixture of fourteen different herbals mainly *Woodfordia fruticosa*, *Trigonella foenum-graecum*, *Terminalia chebula*, *Andrographis paniculate* and *Solanum nigrum* with functional attributes of antioxidant, gastro-intestinal (GI), hepatic and immune function were powdered and blended in the form of a homogenous mixture and packed for further use in experiment.

Phytogenic feed additives extract was prepared using absolute ethanol. About 50g of phytogenic feed additive powder was shaken in 500ml of absolute ethanol for 24 hours at room temperature (27-30°C), followed by filtration through four layers of gauze. This filtrate was then centrifuged for 15 minutes at 8000 rpm and the supernatant was collected and then the ethanol

was evaporated in an oven at 45°C or below. The powder was stored at 4°C in air tight container. This powder was then constituted with purified water as per requirement and was added to the treatment group diet just before feeding to the rats. The entire requirement of the feeding trial was prepared once in a single lot to last for the whole experimental period and packed in an airtight non-reactive plastic bag till further use.

Endotoxin preparation and its administration

Bacterial endotoxin (*Escherichia coli* O55:B5, L2880; Sigma-Aldrich, St. Louis, MO) dissolved in sterile pyrogen-free normal saline was freshly prepared as stock solution with concentration of 10 µg/ml just prior to the start of the experiment. At the start of the experiment, body weight of all the animals were recorded before feeding and watering in the morning to ensure that the total dose of endotoxin is administered according to their body weight. Animals in treatment groups were administered with endotoxin@ 0.2 µg/kg BWi.p.at weekly intervals.

Animals, housing and experimental diets

Adult wistar rats (n=40) of about 90-130g and 4-6 weeks old were divided randomly into four equal groups (control, CONT; endotoxin-challenged@ 0.2 µg/kg BW, ENDO; endotoxin-challenged but supplemented with phytogenic additive in form of powder, pENDO and endotoxin-challenged but supplemented with phytogenic additive in form of extract, eENDO) of ten each (having 5 replicates of 2 each) maintained in solid bottom polypropylene cages with wire top under controlled condition. The leads obtained from the previous experiments and related literature, the endotoxin dose level (0.2 µg/kg BW) was selected at which clear changes in all the physiological, biochemical and oxidative stress indices were observed. At this selected dose of endotoxin administration, the rats showed elevated temperature, heart rate and respiration rate with no sign of severe pathological changes or pre-shock state. The rats were fed on basal diet prepared by taking different feed ingredient of Bengal gram dal, soya bean meal, rice, crushed sorghum, whole milk, soya oil and mineral vitamin premix in proper proportion to meet the nutrient

requirement. The control (CONT) and positive control (ENDO) groups were fed on basal diet with no supplementation whereas treatment groups pENDO and eENDO offered feed with supplementation of phytogenic additive in powdered and extract form at dose level of 15% and 0.15% of DMI, respectively. The diet of all ingredient with proper proportion was cooked in pressure cooker at 15psi for 10 min and then added mineral-vitamin premix with proper mixing. The phytogenic additives in powder and extract form were added at respective dose to the cooked diet just before feeding to the rats. Experimental diet quantity offered was calculated so as to meet the protein and energy requirements of rats in compliance with NRC recommendations lasted for a period of 8 weeks. The rats were allowed free access to experimental diet and water throughout the trial period. Proper ethical care and management procedures were adopted during the entire period of the study. An experimental duration of 8 weeks will involve periodic blood collection and analysis, a digestion trial and immune response studies.

Body weight changes and dry matter intake

Body weight of individual rat was recorded at weekly intervals before feeding and watering in the morning using electronic weighing scale to calculate average daily gain in body weight. The dry matter intake of all replicates under different dietary groups was recorded daily. The rats were offered weighed amount of respective basal diet food once a day and left over food after 24 hours of offering was removed and taken as refusal. The offered and residue samples were subjected to dry matter analysis in order to find out the dry matter intake of rats.

Digestion trial

Digestion trial of 4 days duration was conducted at the end of feeding trial involving quantification of food intake and faeces excreted for assessing the digestibility of nutrients. Rats were shifted to wire netting cages for proper adaption before starting the digestion trial and regular routine was followed as that of feeding trial. The leftover food after 24 hours of offering was removed from the enclosure. The samples for

offered food and residue left were collected and pooled animal replicate wise over the period of four days during the collection period of digestion trial. At the end of digestion trial, the collected sample were finally brought to departmental laboratory for further processing and nutrient analysis. The feeding schedule during digestion trial was same as it was during feeding trial. Weighed amount of feeds were offered and residues, if any, was collected daily in the morning. The representative samples of feeds offered and residue collected were sampled, and analyzed daily for their DM content. The pooled and dried feed and residue samples were stored in airtight containers for further chemical analysis. All faeces excreted by individual replicate during the preceding 24h period was removed from the tray, collected in properly labelled plastic bags, individually weighted and finally brought to laboratory for further processing and analysis. The collected fresh faecal sample were taken out from plastic bags, mixed thoroughly and suitable aliquot was transferred to glass bottle containing 20% sulphuric acid for nitrogen estimation. Additional aliquot of faeces were taken for dry matter estimation. The representative samples of collected faeces and offered food were dried at 60-70 °C for 24 hours in a hot air oven. Later, it was grounded in a wiley mill through 2 mm screen and transferred to airtight polythene bags for storage till further analysis.

The samples of offered food, left over residue and faeces excreted were analyzed as per the standard methods suggested by AOAC (Association of Official Analytical Chemist), 2000 for proximate principles.

Statistical analysis

All the data obtained in the above experiment were statistically analyzed as per the standard statistical procedure of Snedecor and Cochran 1994 using IBM SPSS, version 20. Significant differences ($P < 0.05$) among treatment means and separation of homogenous subset will be determined as per Duncan's multiple range test. The analysed data were considered to be significant at $P < 0.05$ and declared as trend at $0.05 < P = 0.10$.

Results and Discussion

The compounded phytogenic feed additive (PFA) comprised of fourteen selected medicinal herbs was subjected to extensive assessment for its supplementation effects on nutrient metabolism and growth performance in rats with endotoxin induced sub-clinical stress. The low dose of endotoxin 0.2 µg/kg BW at weekly interval was administered to the animals of treatment groups for sub-clinical stress induction with and without supplementation of phytogenic feed additive. Similar dose level was also taken by Kumar et. al., 2014 in his study for inducing stress in goats. This low dose level of 0.2 µg/kg BW produces the observable changes in physiological, biochemical and oxidative stress indices with little or no harm to the animals whereas the endotoxin administration frequency of weekly interval keeps the animals in sub-clinical stress for longer duration which was needed in the present experiment.

Chemical composition of basal diet

The composition of ingredients used in preparation of basal diet together with their nutrient composition are presented in the Table 01. The locally available common ingredient such as rice, sorghum, soyabean meal, bengal gram, skimmed milk powder, soyabean oil and mineral mixture supplement were used for preparation of basal diets resulting to contains 93.08% OM, 20.27% CP, 4.93% EE, 67.87% total carbohydrates, 6.92% total ash, 1.69% crude fibre and 66.18% Nitrogen free extract on DM basis. The composition of all the nutrients matches the nutrient requirement profile for laboratory rats (NRC, 1995), ensuring adequate availability of all essential nutrients along with minerals and vitamins. On the whole, there was no appreciable variation in the nutritional profile among the four diets, which is due to the fact that the basal diet remained the same with only variation being addition of PFA in powder meal form @1.5% DMI in pENDO and crude extract form @0.15% DMI in eENDO PFA supplemented groups.

Table 01. Nutrient composition of basal diet fed to Wistar rats (%DM basis) in different dietary groups of endotoxin induced sub-clinical stress

Ingredients	Level	Nutrients	Percentage
Composition% fresh basis		Nutrient composition (%DM basis)	
Rice	30	Organic matter	93.08
Sorghum	19	Crude protein	20.27
Soyabean meal	18	Ether extract	4.93
Bengal gram	25	Total carbohydrates	67.87
Skimmed milk powder*	4	Total ash	6.92
Soyabean oil	4	Crude fibre	1.69
		Nitrogen free extract	66.18
*Appropriate mineral and vitamin supplements; Composition: Ca 11.3%, P 9.5%, Mg 378 mg, Na 2079mg, K 4.2mg, Cl 2740.5mg, Fe 83.2 mg, Cu 10.4mg, Zn 94.5mg, Mn 5.3mg, Se 330.8µg, I 831.6µg, vit A(RE) 1431.7, Cholecalciferol 13.0µg, Vit E (α-tocopherol) 28.4mg, vit K (menadione) 1.5mg, Thiamine 1.3mg, Riboflavin 5.0mg, Pyridoxine 1.4 mg, Niacin 16.1 mg, Pantothenic acid 14.2mg, Cobalamin 33.1µg, Folic acid 255.2µg, Choline 1606.5mg; Amount/kg DM (=3780 kcal)			

Voluntary Feed Intake

The voluntary mean intake of feed recorded on a weekly basis during the whole period of study is presented in Table 02. There were significant changes ($P>0.05$) observed in weekly intake (g/d) of feed among the rats belonging to different groups on fifth and eighth weeks of experimental feeding with the lowest feed intake for the ENDO group followed by CONT and supplemented (pENDO and eENDO) groups, respectively. The observed changes were similar among the groups for both fifth and eighth week of voluntary feed intake. A similar trend ($P=0.072$ and $P=0.063$ for first and second week, respectively) also observed for the first two weeks among the groups for feed intake during experimental feeding. The intake pattern showed a gradual increase with advancing period of experimentation from about 12.39 ± 0.47 , 12.40 ± 0.35 , 14.22 ± 0.72 and 12.86 ± 0.44 g/day during the first week to the respective levels of 16.62 ± 0.94 , 15.31 ± 1.18 , 18.94 ± 0.59 and 19.68 ± 1.37 g/day at the eighth week for CONT, ENDO, pENDO and eENDO groups respectively. As a result, the overall average mean daily feed

intake also showed a similar trend ($P=0.078$) among the four groups with lowest in ENDO (14.12 ± 0.77) groups, followed by CONT (15.28 ± 0.55) and supplemented pENDO (16.34 ± 0.26) and eENDO (16.23 ± 0.78 g/day) groups reflecting some influence of both endotoxin in reducing intake at low subclinical dose level and dietary PFA as compensatory increase on feed consumption. However, there was no significant ($P>0.05$) different on intake was observed among the groups when DMI data were compared as intake percent BW or percent MBW.

The mean DMI per 100g BW of rats was 8.16 ± 0.51 , 8.82 ± 0.21 , 8.60 ± 0.69 , 8.40 ± 0.46 g/d ($P=0.327$) for CONT, ENDO, pENDO, eENDO groups, respectively. These value not withstanding, a trend of reduced DMI (g/d) with endotoxin administration and on compensatory increase with PFA supplementation. Voluntary feed intake is a multi-factorial phenomenon and is controlled by many factors including age, species, climate, type of feed, its availability, palatability and feedback mechanisms (Decruyenaere *et al.*, 2009). Thus, while reviewing the present data, it was observed that a mixed kind of response has been reported while defining the relationship between herbal feed additive use and feed intake; the variability could be because of factors related to the type and dose of herbal feed additive supplementation (Hosoda *et al.*, 2006; Jain *et al.*, 2011; Ibrahim *et al.*, 2011) besides the animal factors. The available reports ranged from adverse effects (Mohammed *et al.*, 2004; Cardozo *et al.*, 2006) to no effect (Benchaa *et al.*, 2007); but there are other reports describing stimulating influence of PFA on feed consumption (Po *et al.*, 2012). The variable effect of PFAs on feed intake was also perceived in our earlier experiment while studying the potential use of three different formulations (Choubey, 2013).

The FCR which is feed intake per g body weight gain is highest for ENDO (8.45 ± 0.88) groups with reducing value of eENDO (6.70 ± 0.83) followed by pENDO (6.08 ± 0.46) and CONT (6.03 ± 0.60) groups indicates negative effect of endotoxin on feed intake and growth. However, this negative effect was not very much evident in both supplemented groups whose value were very much comparable to control groups with pENDO performance better

than eENDO groups. This trends ($P=0.095$) indicate the more effectiveness of PFA supplementation in powder meal form than crude extract form which may be attributed to presence of few more phytochemical, an active PFA ingredient missing from the crude extract derived from extraction by ethanol. However, this difference is very less and both the supplemented groups shows almost similar result for FCR value.

Table 02. Weekly voluntary feed intake (g/d of DM) of Wistar rats in different dietary groups of endotoxin induced sub-clinical stress

Attributes	Dietary groups*				SEM	P-Value
	CONT	ENDO	pENDO	eENDO		
Total DM intake (g)						
1st Week	12.39± 0.47	12.40± 0.35	14.22± 0.72	12.85± 0.44	0.29	0.072
2nd Week	12.61± 0.51	11.36± 0.56	13.44± 0.42	13.16± 0.63	0.31	0.063
3rd Week	15.25± 0.63	14.05± 0.84	15.26± 0.11	15.36± 0.85	0.34	0.493
4th Week	15.25± 0.58	14.14± 0.73	15.78± 0.33	15.63± 0.92	0.34	0.343
5th Week	15.56a b±0.49	14.00a ±0.93	16.49b ±0.31	16.54b ±0.71	0.38	0.047
6th Week	18.24± 0.96	16.27± 1.06	19.17± 0.50	19.36± 1.11	0.51	0.119
7th Week	16.29± 0.72	15.39± 1.18	17.44± 0.38	17.23± 0.85	0.43	0.314
8th Week	16.62a b±0.94	15.31a ±1.18	18.94b ±0.59	19.68b ±1.37	0.63	0.035
Overall average						
g/d	15.27± 0.55	14.12± 0.77	16.34± 0.26	16.23± 0.78	0.35	0.078
g/100g BW	8.16±0 .23	8.79±0 .08	8.48±0 .32	8.47±0 .22	0.12	0.327
g/100g W0.75	30.01± 0.63	31.15± 0.45	31.40± 0.91	31.33± 0.77	0.35	0.497
FCR	6.03±0 .60	8.45±0 .88	6.08±0 .46	6.70±0 .83	0.40	0.095

*CONT: Control; ENDO: Endotoxin Control; pENDO: Endotoxin with PFA supplemented as powder; ;

eENDO: Endotoxin with PFA supplemented as extract

^{abcd}Means with different superscripts in a row differ significantly ($P<0.05$)

Intake and digestibility of nutrients during digestion trial

The average daily intake and digestibility of nutrients in different treatments groups during digestion trial is presented in Table 03. The mean body weight of wistar rats during the digestion trial conducted at the end of experiments was ranged from 223.23 ± 20.31 g to 267.67 ± 19.60 g with no significant changes among the experimental groups. The mean BW were 262.68 ± 20.42 , 223.23 ± 20.31 , 252.42 ± 21.66 and 267.67 ± 19.60 ,

respectively for CONT, ENDO, pENDO and eENDO groups. There was no significant difference in the intake and digestibility of nutrients among the dietary groups other than the organic matters. The mean dry matter intake (DMI) expressed as percent of BW and MBS during the digestion trial ranges from 7.15 ± 0.16 to 7.54 ± 0.27 and 27.54 ± 0.61 to 29.96 ± 1.18 , respectively with no significant difference observed among the dietary groups. The daily DM intake of rats ranged from 15.91 ± 1.32 to 19.78 ± 1.29 g and are also not significantly varied among the four groups.

The digestibility (%) of DM, OM, CP, EE, TCHO, CF and NFE ranged between 82.56 ± 1.25 to 85.47 ± 0.28 , 85.19 ± 0.87 to 87.62 ± 0.20 , 81.78 ± 1.40 to 84.81 ± 0.70 , 88.79 ± 1.95 to 90.37 ± 0.90 , 77.43 ± 1.63 to 80.96 ± 0.38 and 30.77 ± 2.59 to 42.93 ± 3.87 , 76.81 ± 1.67 to 80.48 ± 0.39 respectively, among the four different dietary groups. A significant ($P < 0.05$) decrease in digestibility of OM was observed in both supplemental (pENDO and eENDO) groups, with an intermediary trend in ENDO group as compared to control. Similar to this, a trend ($P = 0.071$) was observed in the digestibility of dry matter among all the four groups. A similar trend ($P = 0.086$) of decreased digestibility of nitrogen free extract was evident in pENDO, eENDO group with an intermediary trend in ENDO group in comparison to CONT. However, there were no significant ($P < 0.05$) changes of digestibility of other nutrient among the different dietary groups. Overall, it could be said that endotoxin administration causes no significant changes in intake of nutrients but lowers the digestibility of OM which were not very well taken care by PFA supplementation in either powder or extract form at stated levels in the feed.

Table 03. Intake and digestibility of organic nutrients by wistar rats during the digestion trial in different dietary groups of endotoxin induced sub-clinical stress

Attributes	Dietary groups*				SEM	P-Value ^{e†}
	CONT	ENDO	pENDO	eENDO		
Trial BW, g	262.68 ± 20.42	223.23 ± 20.31	252.42 ± 21.66	267.67 ± 19.60	10.20	0.499
DMI, %BW	7.22 ± 0.42	7.15 ± 0.16	7.54 ± 0.27	7.42 ± 0.11	0.13	0.732
DMI, %MBS	28.85 ± 1.12	27.54 ± 0.61	29.96 ± 1.18	29.89 ± 0.45	0.46	0.263

Dry matter (DM)						
DMI, g	18.62 ± 0.41	15.91 ± 1.32	19.00 ± 1.60	19.78 ± 1.29	0.66	0.224
DMD, g	15.91 ± 0.35	13.37 ± 1.11	15.71 ± 1.38	16.43 ± 1.07	0.55	0.264
DMD, %	85.47 ± 0.28	84.06 ± 0.63	82.56 ± 1.25	83.08 ± 0.55	0.43	0.071
Organic matter (OM)						
OMI, g	20.79 ± 3.49	14.70 ± 1.22	17.60 ± 1.48	18.36 ± 1.20	1.07	0.312
OMD, g	18.22 ± 3.05	12.68 ± 1.04	15.02 ± 1.33	15.65 ± 1.04	0.94	0.280
OMD, %	87.62 ^b ± 0.20	86.29 ^{ab} ± 0.46	85.19 ^a ± 0.87	85.26 ^a ± 0.43	0.34	0.019
Crude protein (CP)						
CPI, g	4.53 ± 0.76	3.20 ± 0.27	3.79 ± 0.32	3.91 ± 0.25	0.23	0.305
CPD, g	3.84 ± 0.64	2.65 ± 0.19	3.10 ± 0.27	3.26 ± 0.23	0.20	0.252
CPD, %	84.81 ± 0.70	83.15 ± 2.78	81.78 ± 1.40	83.43 ± 1.22	0.74	0.588
Ether extract (EE)						
EEL, g	1.10 ± 0.19	0.79 ± 0.06	0.91 ± 0.08	0.94 ± 0.06	0.06	0.307
EED, g	0.98 ± 0.16	0.71 ± 0.05	0.80 ± 0.06	0.85 ± 0.05	0.05	0.308
EED, %	88.84 ± 1.18	90.02 ± 1.97	88.79 ± 1.95	90.37 ± 0.90	0.70	0.813
Total carbohydrates (TC)†						
TCI, g	15.16 ± 2.54	10.72 ± 0.89	12.91 ± 1.09	13.51 ± 0.88	0.78	0.312
TCD, g	12.28 ± 2.06	8.48 ± 0.71	10.02 ± 0.91	10.58 ± 0.68	0.64	0.262
TCD, %	80.96 ± 0.38	79.14 ± 0.76	77.43 ± 1.63	78.33 ± 0.69	0.54	0.108
Crude fibre (CF)						
CFI, g	0.38 ± 0.06	0.28 ± 0.02	0.35 ± 0.03	0.37 ± 0.02	0.02	0.395
CFD, g	0.12 ± 0.02	0.11 ± 0.01	0.15 ± 0.02	0.13 ± 0.02	0.01	0.678
CFD, %	30.77 ± 2.59	39.33 ± 4.46	42.93 ± 3.87	33.67 ± 4.89	2.20	0.201
Nitrogen free extract (NFE)						
NFEI, g	14.78 ± 2.48	10.59 ± 0.88	12.56 ± 1.06	13.15 ± 0.86	0.75	0.339
NFED, g	11.90 ± 2.00	8.36 ± 0.70	9.67 ± 0.88	10.21 ± 0.66	0.61	0.288
NFED, %	80.48 ± 0.39	78.90 ± 0.76	76.81 ± 1.67	77.71 ± 0.71	0.56	0.096

Imult1*CONT: Control; ENDO: Endotoxin Control; pENDO: Endotoxin with PFA supplemented as powder; eENDO: Endotoxin with PFA supplemented as extract

^{abcd}Means with different superscripts in a row differ significantly ($P < 0.05$)

†TC = OM-(CP+EE)

Body weight changes

The weekly averages of BW change of the experimental rats are presented in Table 04. With an average initial BW of 109.14 ± 2.19 , 112.28 ± 2.63 , 114.42 ± 3.61 and 112.42 ± 5.59 g, the animals under CONT, ENDO, pENDO and eENDO grew to attain the final BW of 258.42 ± 20.09 , 212.18 ± 17.68 ,

268.20±12.13 and 260.42±23.36 g, respectively, at the end of eight weeks feeding trial. There was significant variation ($P<0.05$) in the body weight of rats recorded at first to third weeks with similar trends at fourth ($P=0.071$) and fifth ($P=0.065$) weeks. It is reported that endotoxin leads to stress and metabolic response that include the release of cytokines, appetite depression, reduced growth and less feed utilization (Plata Salaman, 1998). During immunological stress, amino acids are directed away from lean tissue growth for the synthesis of acute-phase proteins (Reeds and Jahoor, 2001) and there are increased protein catabolism and urinary N excretion (Sahoo, 2020) which may lead to lack of growth or body weight loss of animals. Similarly, the significant decrease ($P<0.05$) in BW gain was observed in ENDO group with comparison to the other three groups because of continuous exposure to endotoxin which corroborate with earlier finding. Obviously, the animals under the later group had very low gain in BW because of the persistence of an infection-like situation; hence do not deserve to be compared to control situations. This endotoxin exposure simulating the subclinical infection leads stressful condition with breakdown of body tissue which reduced the weekly body weight in the first four weeks during the experimental period. However, this reduction was very well overcome by PFA supplementation, as the group attained the BW gain which was parallel to that of the CONT animals. This clearly indicates that the PFA formulation possess enough potential to be used as a feed additive in stressful situations of subclinical infection.

Table 04. Weekly body weight (g) changes of wistar rats in different dietary groups of endotoxin induced oxidative stress

Attribu tes	Dietary groups*				SEM	P-Valu e
	CONT	ENDO	pENDO	eENDO		
<i>Weekly BW (g)</i>						
Initial (0d)	109.14± 2.19	112.28± 2.63	114.42± 3.61	112.42± 5.59	1.77	0.797
1 st Week	134.23 ^b ±3.81	118.08 ^a ±3.26	139.28 ^b ±5.18	140.78 ^b ±5.45	2.93	0.010
2 nd Week	161.82 ^b ±6.33	138.18 ^a ±5.88	164.04 ^b ±7.05	165.80 ^b ±5.84	3.87	0.022
3 rd Week	182.32 ^b ±8.87	154.46 ^a ±7.59	186.62 ^b ±6.26	181.20 ^b ±7.82	4.57	0.036
4 th Week	200.84± 11.92	170.10± 9.36	207.72± 7.71	204.82± 11.71	5.86	0.071
5 th Week	212.96± 12.98	176.62± 10.72	219.58± 8.26	216.22± 13.86	6.66	0.065

6 th Week	232.72±17.96	193.14±13.67	241.02±10.91	233.12±17.40	8.21	0.154
7 th Week	235.84±17.66	194.94±15.68	245.64±11.77	237.56±19.17	8.74	0.162
Final (56d)	258.42±20.09	212.18±17.68	268.20±12.13	260.42±23.36	9.98	0.181
Body weight						
Net gain, g	149.32±19.04	99.92±6.04	153.84±11.22	148.00±26.13	10.03	0.188
0Avg. daily gain, g	2.67±0.34	1.78±0.29	2.75±0.20	2.64±0.47	0.18	0.187

*CONT: Control; ENDO: Endotoxin Control; pENDO: Endotoxin with PFA supplemented as powder; ; eENDO: Endotoxin with PFA supplemented as extract
^{abc}Means with different superscripts in a row differ significantly ($P<0.05$)

Growth acceleration is often seen following the return of favourable conditions after a period of growth depression (Jobling, 2010). At later stage post fifth weeks, this observation differs showing almost similar growth till the end of the experiment in all the dietary groups which clearly indicate the body adaptation behaviour toward the long exposure of endotoxin and this growth depression were very well taken care by the endotoxin groups. Nonetheless, the similar values between CONT and PFA supplemented groups pENDO and eENDO throughout the experimental period could very well support the potential of the PFA in either form of powder meal or crude extract, can be very effectively used as a feed additive to counter the adverse effect on body weight under low dose of endotoxin induced sub-clinical stress.

Conclusion

Endotoxin administration at low dose level of 0.2 µg/kg BW in rats induces no significant changes in digestibility of major nutrients but lower voluntary feed intake and the body weight growth during the early week of study, and the PFA formulation of either powder meal or crude extract form at selected dose level was effective in arresting these adverse changes to a great extent throughout the study period.

References

1. AOAC (2000). Official Methods of Analysis, 17th ed. Association of Official Analytical Chemists, Washington, DC.
2. Benchaar, T.A. McAllister, P.Y. and Choulnard. (2007). Digestion, rumen fermentation, ciliate protozoal

- populations, and milk production from dairy cows fed cinnamaldehyde, quebracho condensed tannin, or *Yucca schidigera* saponin extracts. *Journal of Dairy Science*, 91: 4777–4786
3. Cardozo, P.W., Calsamiglia, S., Ferret, A. and Kamel, C. (2006). Effects of natural plant extracts on protein degradation and fermentation profiles in continuous culture. *Journal of Animal Science*, 84: 2801–2808
 4. Choubey, M. (2013). Effect of phytochemical feed additives on nutrient utilization, health status and splanchnic tissue physiology of ruminants. Thesis, Ph. D. Deemed University, Indian Veterinary Research Institute, Izatnagar, India.
 5. Decruyenaere, V., Buldgen, A. and Stilmant, D. (2009). Factors affecting intake by grazing ruminants and related quantification methods: a review. *Biotechnology, Agronomy, Society and Environment*, 13: 559-573.
 6. Hosoda, K., Nishida, T., Park, W.Y. and Eruden, B. (2006). Influence of *mentha×piperita* L. (peppermint) supplementation on nutrient digestibility and energy metabolism in lactating dairy cows. *Asian-Australasian Journal of Animal Sciences*, 18: 1721-1726
 7. Ibrahim, S.A.M., Omer, H.A.A., Abedo, A.A., Ali, F.A.F. and Abdel-Magid, S.S. (2011). Ginger root (*Zingiber officinalis*) as feed additive in rabbit diets with two level of protein. *American-Eurasian Journal of Agricultural & Environmental Sciences*, 10: 906-916.
 8. Jain, P., Mohini, M., Singhal, K.K. and Tyagi, A.K. (2011). Effect of herbal mixture supplementation on methane emission and milk production in cattle. *Indian Journal of Animal Nutrition*, 28: 377-384
 9. Jobling, M. (2010). Are compensatory growth and catch-up growth two sides of the same coin? *Aquaculture International*, 18: 501-510.
 10. Kumar, A., Pattanaik, A.K., Baliyan, S., Jadhav, S.E., Dutta, N. and Patel, B.H.M. (2014). Behavioral and metabolic response to a low dose administration of bacterial endotoxin for early detection of illness in goats. *Pakistan Veterinary Journal*, 34: 297-300.
 11. Martin, G.B. and Kadokawa, H. (2006). “Clean, green and ethical” animal production. case study: reproductive efficiency in small ruminants. *The Journal of Reproduction and Development*, 52: 145-152
 12. Mohammed, N., Ajisaka, N., Lila, Z.A., Hara, K., Mikuni, K., Kanda, S. and Itabashi, H. (2004). Effect of Japanese horseradish oil on methane production and ruminal fermentation in vitro and in steers. *Journal of Animal Science*, 82: 1839–1846
 13. Plata Salamán, C.R. (1998). Cytokine induced anorexia: behavioral, cellular, and molecular mechanisms. *Annals of the New York Academy of Sciences*, 856: 160-170
 14. Po, E., Horsburgh, K., Raadsma, H.W. and Celi P. (2012). Yerba Mate (*Ilex paraguayensis*) as a novel feed supplement for growing lambs. *Small Ruminant Research*, 106: 131-136.
 15. Reeds, P.J. and Jahoor, F. (2001). The amino acid requirements of disease. *Clinical Nutrition*, 20 (Suppl. 1): 15-22.
 16. Rietschel, E. T., Brade, L., Holst, O., Kulshin, V. A., Lindner, B., Moran, A. P., Schade, U. F., Zahringer, U. and Brade, H. (1990). Molecular structure of bacterial endotoxin in relation to bioactivity. In: Nowotny, A., Spitzer, J. J. and Ziegler, E. J. eds. *Cellular and Molecular Aspects of Endotoxin Reactions*. Amsterdam, Elsevier Science, pp.15-32
 17. Sahoo A. (2020). Clinical nutrition and therapeutic diets: new opportunities in farm animal practice. *EC Veterinary Science*, 5: 12-29.
 18. Snedecor, G.W. and Cochran, W.G. (1994). *Statistical Methods*, 8th ed. Oxford and IBH Publishing Company, New Delhi, India

Received : November 2023; Revised : December 2023; Accepted : January 2024



RESPONSE OF INTEGRATED NUTRIENT MANAGEMENT ON QUALITY PARAMETERS OF BROCCOLI (*BRASSICA OLERACEA* L. VAR. *ITALICA*) CV. PUSA KTS-1

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Abstract

The present investigation was carried out to study the response of integrated nutrient management on quality parameters of broccoli (*Brassica oleracea* L. var. *italica*) CV. Pusa KTS-1. The field experiment was conducted at Horticultural Research Farm, Department of Horticulture, Ch. Charan Singh University Campus, Meerut (U.P) India, during the years 2019-20 and 2020-21. The experiment was laid out in Randomized Block Design. The treatments involved in the study were twelve in numbers i.e. T₁ (Control), T₂ (RDF 150:100:100 N.P.K), T₃ (Azospirillum @ 5 kg), T₄ (VC @ 10 t/ha), T₅ (80% NPK + Azospirillum @ 1 kg), T₆ (60% NPK + 2t/ha VC + Azospirillum @ 1 kg), T₇ (60% NPK + Azospirillum @ 2 kg), T₈ (60% NPK + 4 t/ha VC), T₉ (40% NPK + Azospirillum @ 3 kg), T₁₀ (30% NPK + 7t/ha VC), T₁₁ (20% NPK + Azospirillum @ 4 kg), T₁₂ (20% NPK + 8t/ha VC). The investigation indicated that a judicious combination of organic manures, inorganic fertilizers and biofertilizer i.e. 60% NPK + 2t/ha VC + Azospirillum @ 1 kg gave the maximum vitamin A (2452.07 IU) and protein content (3.53 %). Maximum vitamin C (98.28 mg/100g) was recorded under soil application of 60 % NPK + 4 t/ha Vermicompost which was found statistically at par with the treatments 60% NPK + Azospirillum @ 2 kg and 60% NPK + 2t/ha VC + Azospirillum @ 1 kg. However, the minimum vitamin A content (2369.24 IU), vitamin C value (51.79 mg/100g) and protein content (2.58 %) was observed under control treatment during two consecutive years of experimentation.

Keywords: Broccoli, NPK, vermicompost and Biofertilizer and vitamin A, vitamin C and protein.

Introduction

Broccoli (*Brassica oleracea* L. var. *italica*) is an important vegetable crop among cole group. It belongs to the family Brassicaceae. Broccoli is also known as *Hari gobhi* in Hindi. Broccoli (*Brassica oleracea* var. *italica*) has originated in the Mediterranean region. The name broccoli resulting from the Latin word brachium and Italian word brocco meaning an “arm” or “branch”. In the world, India has the second rank in the vegetables production, followed by china. India shares about 13.38% total vegetable production of the world. In India, production of vegetable crops

is 200.44 million tonnes with an area of 10859 thousand hectares in 2020-2021 (Horticulture Statistics Division). Broccoli is not more popular vegetable in villages due to the lack of knowledge and scientific information about broccoli cultivation but in the current time, it becomes more popular in metro cities like Delhi, Mumbai, Kolkata, etc. Cultivated broccoli is also available in three types i.e., green, purple and white colour headed out of which green forms are more popular and carry high nutritional values. In the world market, about 40% broccoli is use fresh and remaining 60 percent use as frozen. Broccoli

mainly used to make curries, soups, pickles, eaten as a salad and cooked as a single or mixed vegetable with potato for making various delicious dishes (Thamburaj and Singh, 2001).

In India, broccoli mainly cultivated in hilly areas of Himachal Pradesh, Jammu and Kashmir, Nilgiri hills, Tamil Nadu and northern plains of India (Chadha, 2001). Broccoli is a fast growing annual plant which grow 60 -90 cm tall that is prized for its crown of tender edible green flower buds and its stalks are also edible. Broccoli produce large flower heads of green colour, which have arranged in a tree like structure. Mass of flower heads is surrounding by leaves. 20-25° C temperature is the ideal temperature for vegetative growth of broccoli while 15-20° C temperature required for its head growth. Broccoli is well-known as the “Crown of Charm Nutrition” due to the good source of vitamins and minerals. Broccoli is highly nutritious, it has 4, 2.5 and 2 times more riboflavin, calcium and vitamin C content as compared to cauliflower, respectively. Per 100 g of edible part of broccoli contain 5.5 g carbohydrates, 3.3 g protein, 3500 IU vitamin-A, 0.05 mg thiamine, 0.12 mg riboflavin, 137 mg ascorbic acid, 80 mg calcium and 79 mg phosphorus (Hazara and Som, 1999). Dark green broccoli contains high amount of carotene. It is also rich source of sulforaphane, a compound associated with reducing the risk of cancer (Thamburaj and Singh, 2001). It is also reported that broccoli have good medicinal property to cure heart ailments and diabetes. Brassica vegetables possess both antioxidant and anticarcinogenic properties (Cartea *et al.*, 2008) provides effective support for the body's defensive systems and may prevent some diseases (Mc-Carty and Mark, 2008). Broccoli contains indole-3-carbinol which helps to fight breast and lung cancer.

The modern agriculture system mainly depends on the high uses of chemical fertilizers which deteriorate soil health continuously. Due to the faulty uses of chemical fertilizers, the productivity of soil is decreasing day by day because such nutrient rapidly converts into unavailable form to the plants. Thus to solve such type of problem for sustainable production system, integrated nutrient management (INM) may be a good way to solve such type of problem. The

application of organic along with inorganic sources of nutrients in combination can minimize use of costly fertilizer and improve the nutrient use efficiency (Sharma *et al.*, 2008). The conjunctive use of biofertilizer, chemical fertilizers and organic manures helps to sustain crop production as well as maintenance of soil health (Nanjappa *et al.*, 2001). Organic manures play direct role in plant growth as a source of all necessary macro and micronutrients in soluble forms during mineralization and improving physical and chemical properties of soils (Chatterjee *et al.*, 2005).

Materials and Methods

The present study was carried out to examine the response of integrated nutrient management on quality parameters of broccoli (*Brassica oleracea* L. var. *italica*) CV. Pusa KTS-1 at Horticulture Research Farm, Department of Horticulture, Chaudhary Charan Singh University, Meerut during 2019-20 and 2020-21. The treatments involved in the study were twelve in numbers *i.e.* T₁ (Control), T₂ (RDF 150:100:100 N.P.K), T₃ (Azospirillum @ 5 kg), T₄ (VC @ 10 t/ha), T₅ (80% NPK + Azospirillum @ 1 kg), T₆ (60% NPK + 2t/ha VC + Azospirillum @ 1 kg), T₇ (60% NPK + Azospirillum @ 2 kg), T₈ (60% NPK + 4 t/ha VC), T₉ (40% NPK + Azospirillum @ 3 kg), T₁₀ (30% NPK + 7t/ha VC), T₁₁ (20% NPK + Azospirillum @ 4 kg), T₁₂ (20% NPK + 8t/ha VC). The experiment was laid out in randomized block design (RBD) and replicated thrice. The soil of the experimental field was well drained, sandy loam having good moisture and heat absorbing capacity. Farm yard manure applied ten days before transplant of seedlings and properly mixed in the soil while vermicompost and biofertilizers (Azospirillum) were mixed in soil 2-3 days before transplanting. In case of inorganic fertilizers (NPK), half doses of nitrogen and full dose of phosphorus and potash, were applied as a basal dressing at the time of transplanting. The remaining dose of nitrogen (N) was applied in two split doses *i.e.* 30 and 60 days after transplant of seedlings. Nitrogen, phosphorus and potash were given by the source of urea, single super phosphate (SSP) and murate of potash (MOP), respectively. 30 days old, vigour, healthy, stocky and uniform seedlings of broccoli were transplanted in the experimental field (Plots)

in straight lines with keeping a distance of 60 cm (row to row) and 45 cm (plant to plant) during second week of October in two successive years i.e., 2019-20 and 2020-21. All needed practices such as weeding, irrigation and plant protection measures were adopted timely to ensure healthy crop production. All biochemical analysis for quality parameters were conducted in the laboratory of the Department of Horticulture and Department of Microbiology, Ch. Charan Singh University Campus, Meerut (U.P). Heads of broccoli were used to analysis of all quality parameters such as vitamin A, vitamin C and protein content. Vitamin A and vitamin C were calculated by using the technique proposed by Ranganna (1995).

Results and Discussion

The data related to quality parameters exhibited in table-1 shown that the application of integrated nutrient management gave a major impact on vitamin A, Vitamin C and protein content during both the years of investigation. Vitamin A plays a vital role in retaining body growth, vision, reproductive health and immune function of humans. The maximum vitamin A content 2453.02 IU and 2451.11 IU were recorded under the treatment T₆ (60% NPK + 2t/ha VC + Azospirillum @ 1 kg) followed by T₅ (2448.05 and 2447.02 IU) during 2019-20 and 2020-21, respectively. While minimum value of vitamin A content (2370.30 and 2368.17 IU) was recorded with T₁ (control). The similar findings are in the line with the findings of Bahadur *et al.* (2006). Many researches prove that the application of organic manures and biofertilizers alone or in a combination significantly enhanced vitamin A content. The Azospirillum bacteria fixes and accumulate the atmospheric nitrogen in the soil and readily available to the plants. The enhanced colonies of bacteria like Azospirillum due to the presence of high organic matter in the soil provide better mobilization, and continuous supply of available plant nutrients, which needed for several vital functions, and good utilization of sugar & starch, and better root growth. The high accessibility of various micro-nutrients also increased vitamin A content in broccoli heads.

Vitamin C is very important for human body which is a water-soluble and found in broccoli with a sufficient amount. Vitamin C works as an antioxidant and have a good impact on skin health. It also improves immune function. Of the nutrient treatments applied in the present study, the maximum vitamin C 97.65 mg/100g and 98.91 mg/100g content were noted under the soil application of 60% NPK + 4 t/ha VC (T₈) which were found at par with the treatments 60% NPK + Azospirillum @ 2 kg (T₇) and 60% NPK + 2t/ha VC + Azospirillum @ 1 kg (T₆) during the two successive years of investigation. While the minimum value of vitamin C content (51.39 and 52.19 mg/100g) was recorded with T₁ (control) during the two successive years of investigation. The observed result of current investigation also relate with the finding of Wani *et al.* (2011). The increased quantity of organic manures and biofertilizers leads to a higher vitamin C content because when a plant is treated with more nitrogen, it enhances protein production and decreases carbohydrate production due to the dilution effect (Bahadur *et al.*, 2006).

Protein needed for making building blocks in the human body, it's necessary for muscle growth and maintain muscle mass. The Maximum protein content 3.53 % & 3.52% was noted under treatment T₆ (60% NPK + 2t/ha VC + Azospirillum @ 1 kg) as compared to all other treatments. However, the minimum value of protein content 2.57 % and 2.60 % was noted in control (T₁) during the investigation years 2019-20 and 2020-21. The similar results also observed by Wani *et al.* (2011), Choudhary *et al.* (2012). Ujjwal *et al.* (2020) also recorded maximum protein content (3.46 %) under the soil application of 75% RDF + 25% Vermicompost + PSB + Azospirillum when they were studied to examine the effect of integrated nutrient management practices on broccoli. The reason of increasing the protein content due to the combined application of biofertilizers and organic manure which increases the enzymes activity involved in protein synthesis. Additionally, the increased activity of nitrate reductase, which is responsible for the synthesis of several amino acids and proteins, is the source of the rise in protein content.

Table 1 :- Response of integrated nutrient management on vitamin A , vitamin C and protein content of broccoli (*Brassica oleracea* L. var. *italica*) CV. Pusa KTS-1.

Notation	Treatments	Vitamin A (IU)			Vitamin C (mg/100g)			Protein (%)		
		2019-20	2020-21	Mean	2019-20	2020-21	Mean	2019-20	2020-21	Mean
T ₁	Control (Absolute)	2,370.30	2,368.17	2369.24	51.39	52.19	51.79	2.57	2.60	2.58
T ₂	RDF (150:100:100) NPK	2,432.76	2,430.90	2431.83	89.80	87.69	88.74	3.18	3.10	3.14
T ₃	Azospirillum @ 5 kg	2,426.26	2,421.54	2423.90	81.72	85.71	83.71	3.03	2.96	2.99
T ₄	VC @ 10 t/ha	2,402.99	2,403.24	2403.11	71.78	74.43	73.10	2.82	2.85	2.83
T ₅	80% NPK + Azospirillum @ 1 kg	2,448.05	2,447.02	2447.54	93.32	94.55	93.94	3.37	3.34	3.35
T ₆	60% NPK + 2t/ha VC + Azospirillum @ 1 kg	2,453.02	2,451.11	2452.07	95.11	96.31	95.71	3.53	3.52	3.53
T ₇	60% NPK + Azospirillum @ 2 kg	2,444.07	2,442.05	2443.06	95.88	96.00	95.94	3.35	3.31	3.33
T ₈	60% NPK + 4t/ha VC	2,439.11	2,440.16	2439.64	97.65	98.91	98.28	3.28	3.28	3.28
T ₉	40% NPK + Azospirillum @ 3 kg	2,437.07	2,436.31	2436.69	92.51	91.48	92.00	3.19	3.18	3.18
T ₁₀	30% NPK + 7t/ha VC	2,412.27	2,414.07	2413.17	77.21	80.26	78.73	2.90	2.93	2.91
T ₁₁	20% NPK + Azospirillum @ 4 kg	2,394.07	2,392.14	2393.11	63.63	66.51	65.07	2.79	2.76	2.77
T ₁₂	20% NPK + 8t/ha VC	2,386.44	2,386.09	2386.27	55.22	56.50	55.86	2.62	2.68	2.65
C.D. at 5%		3.175	3.688		2.930	2.916		0.167	0.145	
SE(m) ±		1.076	1.250		0.993	0.986		0.056	0.049	

Conclusion

Present experimental findings clearly show that the combination of organic, inorganic and biofertilizers as soil application gave a beneficial impact on quality parameters of broccoli. As per the present findings it may be concluded that the soil application of 60% NPK through the chemical fertilizers with the combination of vermicompost @ 2t/ha and Azospirillum @ 1 kg is the best treatment to obtained high values of vitamin A, vitamin C and protein content in case of broccoli.

References

- Bahadur, A., Singh, J., Singh, K.P., Upadhyay, A. K. and Rai, M. (2006). Effect of organic amendments and bio fertilizers on growth, yield and quality attributes of Chinese cabbage. *Indian Journal of Agricultural Sciences*, 76(10): 596-598.
- Cartea, M.E. Pablo-Velasco, S.O. and Guillermo Padilla, A. H. (2008). Seasonal variation in glucosinolate content in brassica oleracea crops grown in northwestern Spain. *Photochemistry*, 69: 403–410.
- Chadha, K.L. (2001). "Handbook of Horticulture". Directorate of information and publications of Agriculture, ICAR, New Delhi.
- Chatterjee, B., Ghanti, P. Thapa, U. and Tripathy, P. (2005). Effect of organic nutrition in sprouting broccoli (*Brassica oleracea* L. var. *italica* Plenck). *Vegetable Science*, 33(1): 51-54.
- Choudhary, S., Soni, A.K. and Jat, N.K. (2012). Effect of organic and inorganic sources of nutrients on growth, yield and quality of sprouting broccoli cv. CBH-1. *Indian Journal of Horticulture*, 69(4): 550-554.
- Hazara, P. and Som, M.G. (1999). "Technology for vegetable production an improvement". Nutritive value of different vegetables. *Naya Prakash, Calcutta*, pp. 31.
- Mc-Carty and Mark, F. (2008). Scavenging of peroxynitrite derived radicals by flavonoids may support endothelial no synthases activity, contributing to the vascular protection associated with high fruit and vegetable intakes. *Medical hypotheses*. 70: 170–181.
- Nanjappa, H.P, Ramchanrappa, B.K. and Mallikarjuna, B.O. (2001). Effect of integrated nutrient management on yield and nutrient balance in maize. *Indian Journal of Agronomy*, 46(4), 668-701.
- Ranganna S. (1995). Handbook of analysis and quality control for fruit and vegetable products. 2nd edition. *Tata McGraw Hills Education Private Limited*. New Delhi.
- Sharma, A., Parmar, D.K., Kumar, P., Singh, Y. and Sharma, K.C. (2008). Azotobacter soil amendment integrated with cow manure reduces need for NPK fertilizers in sprouting broccoli. *International Journal of Vegetable Science*, 14(3): 273-285.

11. Thamburaj, S. and Singh, N. (2001). Vegetables, tuber crops and spices. *Directorate of information and publications of Agriculture*, ICAR, New Delhi.
12. Ujjwal, V., Singh, M.K., Naresh, R.K., Dev, P. and Singh, S. (2020). Effect of Integrated Nutrient Management on Quality Parameters of Broccoli (*Brassica oleracea* L. var. *italica*) in Light Textured Soil of Western Uttar Pradesh. *International Archive of Applied Sciences and Technology*; 11 (1): 106-110
13. Wani A.B.J, Narayan, R., Ahmed, N., Singh, A.K., Chattoo, M.A. and Sumati, N. (2011). Influence of organic and inorganic sources of nutrients on growth, yield and quality of cauliflower (*Brassica oleracea* L. Var. *botrytis*). *Environment and Ecology*, 29(4A): 1941-1947.

Received : September 2023; Revised : October 2023; Accepted : January 2024



FRUITING, YIELD AND QUALITY ATTRIBUTES OF BER AS INFLUENCED BY NAPHTHALENE ACETIC ACID AND GIBBERELIC ACID

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Abstract

To investigate the fruiting, yield and quality attributes of ber as influenced by Naphthalene acetic acid and Gibberellic acid, an investigation was carried out in the Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during the year 2021-22 on ber cv. Banarasi Karaka fruit. From the experiment, it is reported that the foliar spray of NAA @ 30 ppm resulted in minimum fruit drop (85.55%) and maximum number of fruit set (165.50), maximum fruit retention (14.45%), fruit weight (18.32g), yield (44.02 kg/tree), fruit volume (16.17 cc), length (4.36cm), diameter (2.56cm), pulp weight (16.12g), total soluble solids (15.48°Brix) and total sugars (10.32%) as compared to control plants. Similarly, the application of GA₃ @ 30 ppm resulted in minimum fruit drop (89.16%) with maximum number of fruit sets (160.00), maximum fruit retention (10.84%), fruit weight (15.95g), yield (36.78kg/tree), volume (14.15cc), length (3.90cm), diameter (2.43cm), pulp weight (12.73g), total soluble solids (14.15°Brix) and total sugars (9.56%) The combined application of NAA and GA₃ @ 30 ppm produced highest fruit retention (16.24%), volume of fruits (16.70cc), length (4.47cm), diameter (2.61cm), pulp weight (17.55 g) and total sugars (10.59%), while non-significantly results showed for number of fruit set (167.00), minimum fruit drop (83.76%), maximum fruit weight (19.40g), fruit yield (45.70 kg/tree) and total soluble solids (16.62°Brix) with the application of NAA and GA₃ @ 30ppm as compared to control plants. This study revealed that for obtaining higher fruiting, yield and quality of ber plants should be spread with the combination of GA₃ and NAA @ 30ppm under north Indian plains of Uttar Pradesh, India.

Keywords: GA₃, NAA, Ber, Fruiting, Yield, Physico-chemical.

Introduction

The ber (*Ziziphus mauritiana* Lamk.) is an energetic developing, spreading tree with nearly plant-like hanging branches, that belongs to the family Rhamnaceae. This species is evergreen and leaves are thickly tomentose on their undersurface. The ber fruits are borne in the axil of leaves on the young growing shoots of the current year. Subsequently, standard yearly pruning is important to initiate solid development which will give a most extreme fruit-bearing area on the tree. With wide commercialization, numerous physiological issues connected with blossoms and

and fruit drop, embryo abortion, poor flowering and fruit setting, abnormal and small size fruits, etc. were observed which caused huge losses to the growers. In order to minimize these issues, over the years many experiments and advancements have been done, and among them, the use of NAA and GA₃ are quite possibly hormones and are utilized to improve flowering, fruiting, yield and quality of many fruits.

PGRs (Plant Growth Regulators) are engaged with various physiological cycles, including vegetative spread, enlistment of seed lessness, increased fruit set, prevention of pre-harvest fruit drop, blooming regulation, fruit size inhibition,

and flower and fruit thinning. NAA (Auxin) improved the quality of various fruits by decreasing fruit drops, and increasing fruit sets. Auxin concentration in the plant is increased to prevent abscission. Fruit drop is also prevented by NAA (Auxin), which strengthens the pedicle. Fruit drop is prevented by a high auxin level in the abscission zone.

Gibberellins have mostly been utilized to control various physiological occasions and are economically utilized to expand the quality of fruit in crops such as berries, grapes, citrus, cherries, and apples, etc. In fruit crops, three physiological peculiarities have been featured: rachis cell elongation, blossom thinning, and berry development. Apart from that GA₃ is the most effective in breaking dormancy and causing quick germination of seeds. Gibberellin influences bolting by stimulating cell division and cell elongation in the sub-apical meristems. Gibberellins have been seen as very reliable in creating parthenocarp. Keeping there in view, the present investigation was carried out in the plains of north India.

Materials and Methods

The experiment was carried out in the Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) during 2021-2022. The experiment involved 16 treatments with four doses of NAA (0, 10, 20 and 30 ppm) and GA₃ (0, 10, 20 and 30 ppm) under a completely randomized block design (factorial) with three replications. Forty-eight-year-old well-established, healthy and uniform plants of ber cultivar 'Banarasi Karaka' planted at 10×10 meters spacings were used for the investigation work. Foliar applications of the treatments were consistently sprayed all over the labeled branch in the morning hours with the assistance of a fine spout foot sprayer. The observations were recorded from each treatment of all three replications *viz.*, initial fruit sets, fruit drop (%), retention (%), length (cm), diameter (cm), volume (cc), weight (g), yield (kg/tree), pulp weight (g), total soluble solids (°Brix) and total sugars (%). Physical parameters were analyzed using standard methodology and chemical parameters using methods as suggested in AOAC (1980).

Results and Discussion:

Fruiting attributes:

Application of NAA and GA₃ significantly influenced fruiting attributes *viz.*, Initial fruit set, drop (%), and retention per cent (Table 1). With NAA treatment enhanced initial fruit set (165.50) was recorded in the plant which was treated with NAA @ 30 ppm (N₃) closely followed by 160.50 with a spray of NAA @ 20 ppm (N₂). However, minimum fruit set (151.75) was found in plants that were kept as control (N₀) without any application. The enhancement of the initial fruit set was indicated in a range from 151.75 to 165.50 and the improvement of the fruit set was increased by 9.06 % and 5.76% due to sprays of NAA @ 30 ppm. These results corroborate the finding of **Tiwari et al. (2017)** in aonla, **Badal and Tripathi (2021a)** in guava. The initial fruit set was significantly influenced by different concentrations of gibberellic acid. Foliar feeding of GA₃ @ 30ppm resulted in the maximum initial fruit set (160.00) followed by 159.25 in plants treated with GA₃ @ 20ppm (G₂), while minimum fruit set (156.75) was recorded in plants kept under control (G₀) without any treatment. It most likely may be expected to give the right dose of GA₃ during experimentation causing enhancement of vegetative development of the plants and GA₃ hastening the creation of more photosynthesis towards the fruit-bearing region which added to the expanded initial fruit set in plants. These results collaborated with the findings of **Tripathi and Shukla** in strawberry (2008), **Anushi et al. (2021)** in mango.

An interaction impact among different concentrations of NAA and GA₃ was found non-significant. Maximum fruit set (167) was recorded with a spray of NAA and GA₃ @ 30ppm (N₃G₃ treatment) followed by 166 with NAA @ 20ppm and GA₃ @ 30ppm (N₂G₂). The minimum initial fruit set (150) was recorded in plants kept as control (N₀ G₀) without any treatment. These findings are collaborated with the reports of **Bankar and Prasad (1990)**.

Foliar use of NAA and GA₃ gradually minimized fruit drops and increased fruit retention as compared to control. The application of NAA @ 30 ppm significantly reduced fruit drop (85.55%) and increased fruit retention (14.45%) followed by NAA @ 20 ppm noting 89.70% fruit drop and 10.30% fruit retention. Significantly maximum fruit drop (94.16%) with minimum fruit retention (5.84%) was recorded in plants kept under control (N₀). Reduction in fruit drop results due to sprays of NAA treatments by 9.12 and 4.71% over control (N₀). At the point when the auxin content of the fruits turns out to be low, fruit drop occurs because of the development of an abscission layer and retention of fruit is eventually decreased. The exogenous use of NAA could have expanded the concentration of auxin in plants

which possibly induced the reduction of fruit drop and increased fruit retention. These findings are in accordance with the reports of **Kumar and Tripathi (2009)** on strawberry, **Lal et al. (2016)** in litchi, **Tripathi and Viveka Nand (2022)** in aonla, **Badal and Tripathi (2021a)** in guava, **Tiwari et al. (2017)** in aonla, **Tripathi and Viveka Nand (2022)** in aonla.

Gibberellic acid additionally positively and consistently impacted fruit retention and drop in ber and plants treated with GA₃ @ 30ppm significantly reduced fruit drop (89.16%) with increased retention (10.84%) and followed by GA₃ @ 20 ppm (90.20% and 9.98%, respectively). Significantly greatest amount of fruit drop (91.35%) and least retention (8.65%) was recorded from plants that were kept as control (G₀) without any treatment. As a result of this, fruit drop was reduced by 2.38 and 1.24% as compared to control (G₀) with increased fruit retention by 13.31 to 25.35%. The use of GA₃ might have upgraded auxin production, which has prevented fruit drop in the present study. The increase in fruit retention and decreased fruit drop may be because of the viability of various synthetics as well as GA₃ on the metabolic action of the plant and further developed source-sink relationship which well affected the metabolic status bringing about better check of fruit drop and improved retention of the more number of fruits on the plants. These findings are supported by **Bhadauria et al. (2018)** in Aonla and **Anushi et al. (2021)** in mango, and **Yadav and Chaturvedi (2005)**. Interaction between NAA and GA₃ was found to be significant and the combined treatment of N₃ × G₃ expressed a significantly minimum 83.76% fruit drop and maximum fruit retention (16.24%) followed by N₃ G₂ (85.19% and 14.81%, respectively). Significantly maximum noted under controlled (N₀ G₀) recording 94.88% fruit drop and 5.12% of fruit retention. These results are in accordance with reports of **Chaurasiya et al. (2019)** in ber.

Physical attributes:

The physical attributes viz., fruit length (cm), diameter (cm) and volume (cc) of ber were significantly affected by NAA treatment and plant treated with NAA @ 30ppm proved most effective and increased fruit length (4.36cm), diameter

(2.56cm) and fruit volume (16.17cc), whereas, reduction in fruit length (3.17cm), diameter (2.15cm) and volume (11.92cc) were recorded in fruits which were produced from the plants kept under control (N₀) without any treatment. The increment in these parameters might be its role in cell division, cell elongation and decreased intracellular space in monocarpic cells, all of which could have improved plant health and resulted in healthier and bigger fruit. These findings are in line with the reports of **Badal and Tripathi (2021b)** in guava, **Tripathi et al. (2019)** in mango, **Tripathi and Viveka Nand (2022)** in aonla and **Tiwari et al. (2017)** in aonla.

Gibberellic acid also affected positively in terms of fruit length, diameter and volume and treatment with GA₃ @ 30ppm (G₃) significantly enhanced fruit length (3.90cm), diameter (2.43cm) and volume (14.55cc). Fruits produced from untreated plants (G₀) gave minimum values for these parameters i.e., 3.62cm, 2.35cm and 13.45cc, respectively. The expansion in fruit size brought about by GA₃ treatment could be credited to an extensive expansion in cell division and cell lengthening. These discoveries are connected to the dynamic photosynthesis in the plant, with photosynthesis being moved to the fruits, probably bringing about bigger sizes of fruits. **Shukla et al. (2011)**, **Tripathi et al. (2018)** in aonla, **Dubey et al. (2017)**, **Tripathi and Shukla (2007)** in strawberry. The interaction effect of NAA × GA₃ was found non-significant with respect to fruit length i.e., NAA × GA₃ @ 30ppm (N₃ × G₃) produced maximum fruit length (4.47cm) as compared to control (N₀ G₀) in which minimum fruit length (3.07cm) was recorded, whereas, fruit diameter and volume had significant positive effect, showing maximum fruit diameter (2.61cm) and volume (16.70cc) as compared to control (N₀ G₀) which showing the minimum value of 2.11cm and 11.40cc, respectively. These findings are consistent with **Tripathi et al. (2019)** in mango.

Application of NAA and GA₃ significantly decreases the length of stone and diameter of stone in ber. Plants treated with NAA @ 30ppm (N₃) significantly minimized the length of stone and diameter of stone (1.53 and 0.84cm, respectively) as compared to control (N₀) where these were found maximum (2.63 and 1.13cm, respectively).

These findings are in agreement with the reports of **Singh et al. (2001)** in ber and **Rathod et al. (2019)** in aonla.

Gibberellin consistently and positively minimizes stone length and stone diameter in ber. GA₃ @ 30ppm (G₃) concentration proved most effective (1.89 and 0.94cm, respectively) as compared to the control (G₀) which proved maximum stone length and diameter (2.18 and 1.1 cm, respectively) during the present investigation. These results may have been associated with the active performance of photosynthesis in the plant and they were translocated to the stones which caused to decrease in stone size. These findings are in line with reports of **Tripathi et al. (2018)** in aonla. The interactive effect of NAA associated with GA₃ did not differ significantly but further improvement was observed over mean values and combined treatment of N₃ × G₃ recorded minimum stone length (1.42cm), whereas maximum stone length (2.79cm) was recorded under control (N₀ G₀). In respect of stone diameter was found positively significant and plants treated with NAA and GA₃ @ 30ppm (N₃G₃) significantly minimized the diameter of stone (0.80cm). The maximum diameter of stone (1.17cm) was recorded under control (N₀ G₀).

Yield Attributes:

Foliar feeding of NAA and GA₃ significantly enhanced fruit weight, pulp weight and fruit yield of ber {Fig. 1 (a) and (b)}. The fruit weight (18.32g), pulp weight (16.12g) and fruit yield (44.02kg/tree) were enhanced significantly when the plant was treated with NAA @ 30ppm, whereas, the lowest values of fruit weight (11.95g), pulp weight (7.04g) and fruit yield (22.82kg/tree) were found in plants kept under control (N₀). In this study, the growth regulator NAA may have boosted the synthesis of additional photosynthates and their translocation to the fruits, resulting in higher fruit and pulp weight which ultimately enhanced the yield. These results are in agreement with the respects of **Singh et al. (2005)** in mango, **Tiwari et al., (2017)** in Aonla, **Kumar and Tripathi (2009)** in strawberry, **Tripathi and Viveka Nand (2022)** in aonla.

All the yield attributory parameters *i.e.*, fruit weight, pulp weight and fruit yield were improved with different doses of gibberellic acid and GA₃ @

30ppm emphatically improved fruit weight (15.95g), pulp weight (12.73g) and fruit yield (36.78 kg/tree) as compared to control (G₀), which show minimum fruit weight (14.30g), pulp weight (10.39g) and fruit yield (31.75 kg/tree). These findings are in support of the reports of **Tripathi et al. (2018)** in aonla, **Dubey et al. (2017)** in strawberry.

The interaction effect between NAA × GA₃ was recorded as non-significant in terms of fruit weight, pulp weight and fruit yield. However, plants treated with the combination of NAA and GA₃ @ 30ppm (N₃ G₃) produced maximum fruit weight (19.40g), pulp weight (17.55g) and fruit yield (45.70 kg/tree) closely followed by treatment N₃ G₂ which expressed fruit weight of 18.70g, pulp weight of 16.59g and fruit yield of 44.49 kg/tree. Significantly minimum fruit weight (11.10 g), pulp weight (5.75g) and fruit yield (20.78 kg/tree) were recorded under control (N₀ G₀). These findings are in line with reports of **Kale et al. (2000)** in ber.

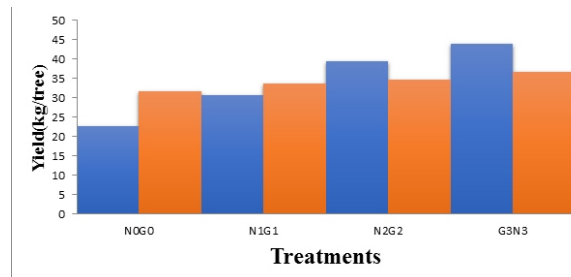


Fig. 1(a): Effect of NAA and gibberellic acid on yield (kg/tree)

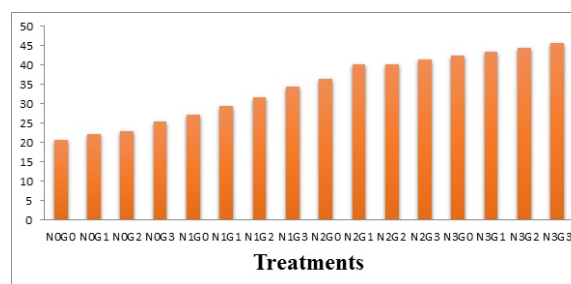


Fig. 1(b): Yield (kg/tree) of fruit as influenced by the use of NAA, GA₃ and their interaction

Chemical Quality Parameters-

NAA and GA₃ significantly enhanced the chemical quality of fruits *i.e.*, TSS and total sugars when plants were treated with different concentrations of these hormones. Significantly maximum TSS (15.48°Brix) and total sugar (10.32%) was recorded from NAA @ 30ppm (N₃) treated plants followed by treatment of NAA @ 20ppm (N₂), which exhibited TSS of 14.43°Brix

and total sugars of 9.62%. The plants kept under the control exhibited a minimum TSS (12.39°Brix) and total sugars (8.39%). The application of the growth regulators (NAA) may have produced a redirection of more solid metabolites towards developing fruits, boosting amylase activity, and therefore increasing total soluble solid content by converting starch into simple sugar. **Kumar and Tripathi (2009)** in strawberry, **Badal and Tripathi (2021b)** in guava.

Different concentrations of GA₃ also improve TSS and total sugars content in fruits and GA₃ @ 30ppm dose (G₃) was found most effective in respect of TSS and total sugars, which exhibited a maximum value of TSS (14.45°Brix) and total sugars (9.56%) followed by GA₃ @ 20ppm (G₂), which exhibited values of 13.93°Brix and 9.43%, respectively. Significantly minimum TSS (13.59°Brix) and total sugars (9.06%) were recorded under control (G₀). GA₃ may cause an increase in the inactivation of the amylase enzyme, which is responsible for the conversion of starch to sugar and is linked to an increase in TSS and total sugars content of fruit. These findings collaborated with the findings of **Verma et al. (2021)** in strawberry, **Shukla et al. (2011)**, **Tripathi et al. (2018)** in aonla and **Anushi et al. (2021)** in mango.

The interaction effect between NAA x GA₃ produced significant effect on TSS and total sugar content and a combination of NAA and GA₃ @ 30ppm (N₃×G₃) was recorded to be the most effective, which gave maximum TSS of 16.62°Brix and total sugars (10.59%) followed by N₃G₂ which produced fruits having TSS of 15.24°Brix and total sugars content i.e., 10.42% over control (N₀G₀), which showed minimum values 12.15°Brix and 8.11%, respectively. These findings are in line with the reports of **Ram et al. (2005)** in Ber.

Table 1: Fruit set, drop, retention, weight and volume of Ber as influenced by the use of NAA, GA₃ and their interaction

Treatments	Initial fruit Set	Fruit drop (%)	Fruit retention (%)	Fruit weight (g)	Fruit volume (cc)
N ₀	151.75	94.16	5.84	11.95	11.92
N ₁	156.25	92.17	7.83	13.97	13.25
N ₂	160.50	89.70	10.30	16.00	14.72
N ₃	165.50	85.55	14.45	18.32	16.17
S.E (m)±	0.05	0.28	0.23	0.28	0.08

CD at 5% level	1.45	0.83	0.67	0.83	0.24
G ₀	156.75	91.35	8.65	14.30	13.45
G ₁	158.00	90.87	9.13	14.72	13.85
G ₂	159.25	90.20	9.80	15.27	14.22
G ₃	160.00	89.16	10.84	15.95	14.55
S.E (m)±	0.50	0.28	0.23	0.28	0.08
CD at 5% level	1.45	0.83	0.67	0.83	0.24
N ₀ G ₀	150	94.88	5.12	11.10	11.40
N ₀ G ₁	151	94.52	5.48	11.70	11.70
N ₀ G ₂	153	93.97	6.03	12.20	12.20
N ₀ G ₃	153	93.28	6.72	12.80	12.40
N ₁ G ₀	154	92.82	7.18	13.50	12.60
N ₁ G ₁	156	92.38	7.62	13.60	13.10
N ₁ G ₂	157	92.01	7.99	14.10	13.50
N ₁ G ₃	158	91.48	8.52	14.70	13.80
N ₂ G ₀	159	90.94	9.06	15.20	14.20
N ₂ G ₁	160	90.08	9.92	15.80	14.50
N ₂ G ₂	161	89.66	10.34	16.10	14.90
N ₂ G ₃	162	88.15	11.85	16.90	15.30
N ₃ G ₀	164	86.77	13.23	17.40	15.60
N ₃ G ₁	165.1	86.50	13.50	17.80	16.10
N ₃ G ₂	166	85.19	14.81	18.70	16.30
N ₃ G ₃	167	83.76	16.24	19.40	16.70
S.E(m)±	1.01	0.57	0.46	0.57	0.17
CD at 5% level	NS	NS	1.34	NS	0.48

Table 2: Fruit length, diameter, pulp weight, TSS and TS of Ber as influenced by the use of NAA, GA₃ and their interaction

Treatments	Fruit length (cm)	Fruit diameter (cm)	Pulp weight (g)	T.S.S. (°Brix)	Total sugars (%)
N ₀	3.17	2.15	7.04	12.39	8.39
N ₁	3.53	2.35	10.00	13.42	8.96
N ₂	4.00	2.56	12.90	14.42	9.62
N ₃	4.36	2.56	16.12	15.48	10.32
S.E (m)±	0.05	0.05	0.12	0.18	0.05
CD at 5% level	0.14	0.15	0.36	0.54	0.15
G ₀	3.62	2.35	10.39	13.59	9.06
G ₁	3.72	2.40	11.08	13.74	9.24
G ₂	3.82	2.43	11.85	13.93	9.43
G ₃	3.90	2.43	12.73	14.45	9.56
S.E (m)±	0.05	0.05	0.12	0.18	0.05
CD at 5% level	0.14	0.15	0.36	0.54	0.15
N ₀ G ₀	3.07	2.11	5.75	12.15	8.11
N ₀ G ₁	3.13	2.13	6.70	12.24	8.32
N ₀ G ₂	3.21	2.16	7.49	12.38	8.52
N ₀ G ₃	3.28	2.19	8.24	12.80	8.62

N ₁ G ₀	3.36	2.22	9.17	13.12	8.75
N ₁ G ₁	3.48	2.36	9.55	13.28	8.90
N ₁ G ₂	3.60	2.39	10.24	13.57	9.04
N ₁ G ₃	3.71	2.42	11.04	13.72	9.18
N ₂ G ₀	3.82	2.56	11.79	14.17	9.36
N ₂ G ₁	3.94	2.58	12.59	14.31	9.51
N ₂ G ₂	4.07	2.62	13.11	14.54	9.75
N ₂ G ₃	4.17	2.49	14.12	14.68	9.87
N ₃ G ₀	4.26	2.52	14.86	14.93	10.03
N ₃ G ₁	4.34	2.55	15.48	15.14	10.25
N ₃ G ₂	4.40	2.58	16.59	15.24	10.42
N ₃ G ₃	4.47	2.61	17.55	16.62	10.59
S.E (m)±	0.10	0.10	0.25	0.37	0.10
CD at 5% level	0.28	0.30	0.72	NS	0.30

Conclusion

In light of the outcomes of the experiment, it is concluded that the consolidated application of NAA and GA₃ @ 30ppm during the pea stage of fruit development should be done to enhance fruit set, fruit length, diameter, retention, volume, weight, pulp, yield, total sugar and TSS, has been most appropriate under agro-climatic conditions of plains in north India. The recommendations of the investigation are of paramount importance and have extraordinary possibilities in working on the economy and success of the state as well as the country.

Reference

1. A.O.A.C. (1980). Official Methods of Analysis. Association of Official Analytical Chemists, Washington DC.
2. Anushi, Tripathi, V. K., Awasthi, V. and Yashasvi, G. N. (2021). Impact of pre-harvest application of plant bio-regulators and micronutrient on fruit retention, yield and quality of mango (*Mangifera Indica* L.). *Frontiers in Crop Improvement*, 9(Special Issue-III):1026-1030.
3. Badal, D. S. and Tripathi, V. K. (2021a). Influence of foliar feeding of NAA and Boron on growth, flowering, fruiting, and yield of winter season guava (*Psidium guajava* L.) cv. L-49. *Biological Forum-An International Journal*, 13(3): 387-391.
4. Badal, D. S. and Tripathi, V. K. (2021b). Effect of foliar application of NAA and Boron on physico-chemical parameters of winter season guava (*Psidium guajava* L.) cv. Lucknow-49. *The Pharma Innovation Journal*, 10(9): 928-932.
5. Bankar, G. S. and Prasad, R. N. (1990). Effect of gibberellic acid and NAA on fruit set and quality of fruit in ber cv. Gola. *Progressive Horticulture*, 22 (1-4): 60-62.
6. Bhadauria, A. S., Tripathi, V. K., Singh, A. and Gupta, S. (2018). Effect of foliar application of plant bio-regulators and micronutrients on fruit retention, yield and quality attributes of aonla. *Progressive Research-An International Journal*, 13 (3): 216-219.
7. Chaurasiya, Gangadhar, R., Sharma, A., Tiwari, S., Goyal, G., Bhadauria, A. S., Singh, A.P. and Yadav, A. (2019). Influence of foliar application of GA₃ with and without NAA on fruit drop, growth, yield and quality of ber (*Zizyphus mauritiana* Lamk.). *International Journal Current Microbiol Applied Science*, 8: 45-56.
8. Dubey, Vishal, Meena, M. L. and Tripathi V. K. (2017). Effect of plant bio-regulators and micronutrient on vegetative growth, yield and quality of strawberry cv. Chandler. *Progressive Research-An International Journal*, 12 (3): 330-332.
9. Kale, V.S., Dod, V. N., Adpawar, R.N. and Bharad, S.G. (2000). Effect of PGR on fruit characters and quality of ber. *Crop Research*, 20 (2): 327-333.
10. Kumar, R., and Tripathi, V.K. (2009). Influence of NAA, GA₃ and Boric Acid on growth, yield and quality of strawberry cv. Chandler. *Progressive Horticulture*, 41 (1): 113-115.
11. Lal, D., Tripathi, V. K., Nayyar, M. A., Kumar, S., Ahmed, M. and Siddiqui, M. W. (2016). Pre-harvest spray of Gibberellic Acid, NAA, and Calcium Nitrate on fruit retention, yield and quality of Kinnow Mandarin. *Environment & Ecology*, 34 (4C): 2288-2292.
12. Ram, R. B., Pandey, Sharad and Akhilesh, K. (2005). Effect of plant growth regulators on fruit retention, physico-chemical parameters and yield of ber cv. Banarasi karaka. *Biochemical and Cellular Archive*, 5 (2):229-232.
13. Rathod R. K., Ramdevputra, M. V., Jadeja S. R., Parmar, L. S. and Jivani L. L. (2019). Effect of foliar application of micronutrients and growth regulator on fruit yield of Aonla (*Emblica officinalis* Gaertn.) cv. Gujarat Aonla-1. *Journal of Pharmacognosy and Phytochemistry*, 8 (5): 133-137.
14. Shukla, H.S., Kumar, V. and Tripathi, V. K. (2011). Effect of Gibberellic Acid and Boron on development and quality of aonla fruits 'Banarasi'. *Acta Horticulturae*, 890:375-380.
15. Singh, K., Randhawa, and Singh, K. (2001). Effect of growth regulators and fungicides on fruit drop, yield and quality of fruit in ber cv. Umran. *Journal Research, PAU*, 38(3-4): 181-185.
16. Singh, N. P., Malhi, C.S. and Sharma, R. C. (2005). Effect of plant bioregulators (PBRs) on flowering, fruit yield and quality in mango cv. Dashehari. *Horticultural Journal*, 18:10-12.
17. Tiwari, P., Tripathi, V. K. and Singh, A. (2017). Effect of foliar application of plant bio-regulators and micronutrients on fruit retention, yield and quality attributes of aonla. *Progressive Research-An International Journal*, 12(Special-IV): 2565-2568.
18. Tripathi, V. K. and Shukla, P.K. (2007). Influence of plant bio-regulators, boric acid and zinc sulphate on yield and fruit characters of strawberry cv. Chandler. *Progressive Horticulture*, 39 (2): 154-158.

19. Tripathi, V. K. and Shukla, P. K. (2008). Influence of plant bio-regulators and micronutrients on flowering and yield of strawberry cv. Chandler. *Annals of Horticulture*, 1(1), 45-48.
20. Tripathi, V. K., Pandey, S. S., Kumar, A., Dubey, V. and Tiwari, P. (2018). influence of foliar application of gibberellic acid, calcium and boron on fruit drop, yield and quality attributes of aonla (*Emblica officinalis*) cv. NA7. *Indian Journal of Agricultural Sciences*, 88(11): 1784-8.
21. Tripathi, V. K. and Viveka Nand (2022). Effect of foliar application of Boron, Zinc and NAA on fruit retention, yield and quality attributes of aonla. *Progressive Horticulture*, 54(1): 76-81.
22. Tripathi, V. K., Singh, A., Bhadauria, A. S. and Gupta, S. (2019). Influence of GA₃ and Naphthalene Acetic Acid alone and in combination on fruit drop, yield and quality of mango cv. Amrapali. *Progressive Research-An International Journal*, 14(1): 10-13.
23. Verma, S., Dwivedi, A.K. and Tripathi, V. K. (2021). Effect of gibberellic acid and boron on growth, yield and yield attributory traits in strawberry (*Fragaria x ananassa* Duch.) under North Gangetic Plains. *Biological Forum-An International Journal*, 13 (3): 262-267.
24. Yadav, D. N. and Chaturvedi, O. P. (2005). Influence of GA₃ and trace elements on fruit drop, growth and quality of Ber (*Zizyphus mauritiana* Lamk.) cv. Banarasi Karaka. *Farm Science Journal*, 14: 27-28.

Received : October 2023; Revised : November 2023; Accepted : January 2024



INNOVATIVE TECHNOLOGIES AND CULTIVATION METHODS IN GREENHOUSE HORTICULTURE

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ABSTRACT

The growing need for effective and sustainable farming methods has spurred tremendous developments in greenhouse horticulture in recent years. In order to help growers, maximize crop yield, use the fewest resources possible, and improve sustainability all around, this summary gives a general overview of the cutting-edge technologies and cultivation techniques that have transformed greenhouse horticulture. Technology advancements in lighting have been extremely important to greenhouse horticulture. Due to its energy economy, controllability, and spectral specificity, light-emitting diodes (LEDs) have become the preferred lighting source. LEDs may be configured to emit particular wavelengths of light, enabling farmers to improve photosynthesis, optimize lighting conditions for various growth phases, and modify plant shape. Furthermore, dynamic lighting regimes that mimic natural light cycles and enhance crop performance have been made possible by the integration of artificial intelligence and machine learning algorithms in lighting control systems.

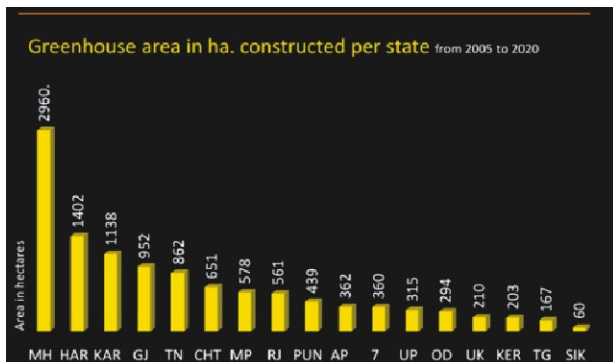
Keywords: Sustainable farming, Greenhouse horticulture, Artificial intelligence and Crop performance.

Introduction

Greenhouse horticulture has long been recognized as an excellent way for raising a wide variety of plants in controlled surroundings. Recent technological and cultivation method improvements, on the other hand, have revolutionized the business, bringing novel options to optimize crop output, resource usage, and overall sustainability. India is the second largest producer of vegetables next to China. During 2021-22 the area under vegetables is 11.35 million hectares with a production of 204.84 million tons (**GOI 2022**). India's share in the world vegetable market is around 11.2 per cent. Total area greenhouses built in various periods from 2006 to 2011 was 2,640 ha., from 2012 to 2016 was

6,163 ha. And from 2017 to 2021 was 5,563 ha. This introduction provides an overview of the exciting advancements in greenhouse horticulture, stressing the transformative impact of modern technologies and growing practices. Fresh food is increasingly in demand on a global scale due to factors like population increase, urbanization, and shifting nutritional habits. The increased demand for sustainable food production has prompted greenhouse horticulture to emerge as a possible remedy to these problems. In contrast to conventional open-field agriculture, greenhouses offer a regulated setting where essential factors like temperature, humidity, light, and CO₂ may be adjusted to create the ideal growing conditions for a variety of crops. Integrating cutting-edge climate control

technologies is one of the industry's major accomplishments in greenhouse horticulture. These systems use automation, data analytics, and sensor technology to track and control the greenhouse's environmental conditions. Growers can create the optimum microclimate for crop growth by precisely controlling variables like temperature and humidity. Aeroponics and hydroponics in particular have transformed greenhouse horticulture. Soil-less cultivation techniques have also revolutionized this field. These techniques do away with the need for conventional soil-based farming by allowing plants to grow in nutrient-rich water suspensions or solutions. Numerous benefits, such as increased disease management, less water use, and higher resource efficiency are provided by hydroponics and aeroponics. Increased agricultural output and quicker growth rates are also effects of the capacity to precisely supply nutrients to plant roots.



Needs to Horticulture Greenhouse

Protected cultivation has made a significant contribution to a better understanding of growth factor requirements and inputs for enhancing crop productivity in open fields and will continue to do so [1]. This is because protected cultivation permits some control over wind velocity, moisture, temperature, mineral nutrients, light intensity, and atmospheric composition. The many benefits are the reason it is done.

- The productivity of greenhouses is considerably higher than that of open fields.
- Pest and disease resistance in higher-quality crops
- Young adulthood; Year-round cultivation; Possibility of growing even in hostile conditions.

- By adjusting temperature, humidity, and light levels in accordance with the needs of the plant, you can create a microclimate that will maximize plant performance.
- The cultivation of crops during the off-season when open-field farming is impractical.
- Tropical vegetables like cucurbits, capsicum, brinjal, okra, and others aren't prevalent in mountainous places, but they can be grown there in a greenhouse.
- In the greenhouse, growing crops of exceptional quality for export is simple.
- It is possible to advance the availability and raise the nursery earlier using a greenhouse. Greenhouse provide early nursery.
- The greenhouse makes it possible to cultivate and preserve valuable planting materials.
- In addition to growing high-quality fruit, the greenhouse can also be used to grow flowering plants, strawberries, and grapes.
- The greenhouse controls moisture better than an open field.
- Weed and pest management are easier to manage in a greenhouse. The frequency of watering plants is thereby decreased.
- Using the right crop sequences can increase productivity per area and hour.

Limitation

- Creation of parthenocarpic hybrids and variations, as well as manual or hand pollination of cross-pollinated crops like cucurbits.
- Materials for cladding are pricy, limited in quantity, and have a short lifespan.
- The expense of the initially seems excessively high.
- A lack of appropriate tools and equipment.
- Farmers who can afford it risk-free choose not to adopt it.

Summary of the special issue

This Special Issue compiles the most recent research findings on a variety of greenhouse horticulture-related subjects. Two key subjects can be broadly divided up into the following papers: Three reviews and four original research articles about growing techniques are included along with five original research articles about new

technologies.

1. Advancements in Greenhouse Horticulture Technology

One of the first agricultural industries to employ modern technologies extensively has been greenhouse horticulture. Due to growing globalization, the need for more resource-efficient use of those resources, as well as the demand for more sustainable farming practices, this has increased. New technologies that are anticipated to support more digital, automatic, and sophisticated greenhouse horticultural production are reviewed by Castro *et al.* in their article from [2] including enhanced cover materials, light-emitting diode (LED) illumination, alternative nutrient resources, and sensors.

Energy expenses need to be reduced significantly in greenhouse horticulture because it accounts for a sizable portion of the entire cost of production. Ntinis *et al.* [3] examined and quantified a higher crop yield and enhanced quality of hydroponic tomato planted in a greenhouse utilizing the novel technology of dyesensitized solar cells (DSSC) for the glass cover of the greenhouse in response to the foregoing. Comparing the DSSC greenhouse to a reference greenhouse with a glass cover and a conventional electrical source that was supplied by the grid (CONV greenhouse), the DSSC greenhouse used all of the solar energy harvested with the DSSC to cover a portion of the electrical consumption. The outcomes from the DSSC greenhouse over the summer were excellent since shading improved the qualitative traits of the tomato fruit of two hybrids used to make commercial table tomatoes. Furthermore, the photo selective DSSCs installed in the greenhouse roof covering exploited extra light, particularly in the summer when it is not required for plant growth, to generate electricity. Future research will analyses the DSSC greenhouse year-round with a wintertime emphasis.

Among the most important growth-restraining elements in crop production are water and nitrogen shortage stressors. The effects of water and nitrogen deficiency conditions on plants have often been quantified using fairly complicated and challenging techniques. A model based on the classification tree (CT) method was created by

Elvanidi *et al.* [4] to analyse complicated reflectance index datasets and produce visual evaluations of plant water and nitrogen shortage stress. The combined use of MSAVI (Modified soil-adjusted vegetation index), mrNDVI (Modified red edge normalised difference vegetation index), and PRI (Photochemical reflectance index) had the ability to identify water and nitrogen deficit stress with classification accuracy values of 89.6% and 91.4% for the training and testing samples, respectively. These findings show promise for continued development of a clever decision-support system for improved irrigation and climate control.

Artificial lighting is a frequent practice in commercial greenhouses since light is one of the most crucial elements for plant growth and development. Light emitting diode (LED) technology is quickly displacing conventional lighting sources. Gibberellic acid (GA3) is a hormone produced in small levels by plants, hence synthetic GA3 is frequently employed in commercial agriculture to manipulate growth and development. The aforementioned variables and combinations on potted ornamentals were investigated by Mills-Ibibofo *et al.* [5]. The findings demonstrated that light and GA3 work in concert to promote the growth of plants and flowers. In order to manage plant development and flowering, more study must be done with a variety of species utilising a variety of LED lights with various spectra in conjunction with the plant hormone GA3. This is because effects may vary depending on the species. In many regions of the world, urban agriculture is enjoying a renaissance in popularity. It has the potential to significantly improve the sustainability of food systems by encouraging the recycling of nutrient waste and urban waste streams. By combining anaerobic digestion with substrate-based soilless agriculture, Riera-Vila *et al.* [6] examined the integration of brewery wastewater treatment. The output of three crops treated with digested wastewater was higher than it was with raw wastewater or a no-fertilizer control, showing that nutrients from brewing wastewater may be recovered for food production and diverted from pollution establishments for treating municipal trash. The work demonstrated how to address some of the technological and agronomic issues

associated with this integration, but additional research is required to address the social, economic, and legal issues associated with this decentralised urban system.

Although silicon (Si) is not necessary for horticultural plants, interest is growing in its use as a supplement in soilless medium. In order to ascertain the effects of diatomaceous earth (DE) as a Si supplement on three potted ornamentals under well-watered and water-stressed situations, Mills-Ibibofori *et al.* [7] undertook a study. Application of DE increased a number of growth and blooming traits, depending on the rate and application technique. Increased height, width, shoot dry weight, stem diameter, and bloom size were all advantages of DE. Future research should assess the use of DE on various crops and stress situations.

2. Cultivation Methodologies for Advanced Greenhouse Horticulture

Vox *et al.* [8] assessed greenhouse horticultural cultivation as a particularly intensive form of agriculture that has the potential to be unfavourable to the environment. As a result, it is crucial to utilise unique, appropriate growing techniques to avoid issues arising from this kind of production.

Irrigation management, which balances water supply with crop need, is probably the growers' most delicate daily task. For soil-based crops, a grower's estimation of daily irrigation needs may be used to determine irrigation schedules, whereas estimations for soilless systems necessitate shorter time intervals. Using artificial intelligence to model and track the soil-plant-atmosphere, Nikolaou *et al.* [9] presented a thorough review of irrigation management in soil and soilless crop production in greenhouses

The use of biochar, a carbon-rich substance produced from biomass, has recently been demanded more frequently in crop production systems for horticulture. Hunag and Gu [10] investigated the methods utilised to produce biochar, how it affects the properties of container substrates, and how it affects plant development when used as a substrate for containers. In order to improve the pyrolysis process and add formulae for various container substrates, more research will be required to evaluate biochars. This is

because first results have been encouraging.

Light is crucial for plants, as was previously noted; however, covering materials in greenhouses change the amount of light that is available to plants, which could cause an issue with light intensity in greenhouses in circumpolar locations. When it comes to bacterial and fungal diseases, biocontrol agents, and the phyllobiome, Alsanious *et al.* [11] evaluated the effects of light quality on plant-microbe interactions. With reference to ecological theories, pertinent molecular pathways governing light-quality-related bacterial functions are outlined. Knowledge gaps are also explored.

Greenhouses are useful for organic agriculture since they can control the sheltered environment. Nine new leek cultivars were compared by Golubkina *et al.* [12] in a greenhouse using conventional and organic methods. The findings demonstrated that organic farming produced crops with the same cultivar ranking as for conventional management, but with higher dry matter, sugar, ascorbic acid, and potassium contents than conventional farming. Nitrates in the pseudo-stems were, however, reduced. In breeding programmes for both conventional and organic management systems in greenhouses, knowledge of the significant correlations between quality, antioxidant, and mineral components in leek plants may open up a wide range of possibilities.

It is usual practise to select a soilless culture system (SCS) in order to maximise the advantages of the greenhouse environment. Along with aeroponics and aquaponics, SCS is frequently practised in the hydroponic method. Aeroponic nutrition film technique (NFT) systems and hydroponic NFT systems were contrasted by Li *et al.* [13] for their effects on lettuce growth and root properties. The findings demonstrated that aeroponic cultivation greatly enhanced root growth metrics, including root biomass, root/shoot ratio, total root length, root area, and root volume. But because there was a shortage of nutrients and water in the aeroponic system, there was no increase in shoot growth when compared to hydroponic cultivation. For the aeroponic system to increase the continuous supply of nutrients and water for lettuce growing, more research is required to identify the appropriate pressure, droplet size, and misting intervals.

Grafting is a widely used method for growing watermelon that is safe for users and customers, environmentally beneficial, and may prevent biotic and abiotic illnesses. However, using high quality grafted seedlings is a requirement in order to benefit from grafting. Based on the foregoing, Bantis *et al.* [14] conducted a study to establish essential thresholds for objective measures of the quality categories of grafted watermelon seedlings and to recommend the most precise and practical among them for implementation by the end users (industry and gardeners). They came to the conclusion that key metrics for classifying grafted watermelon seedlings included stem diameter, shoot and root dry weights as well as shoot DW/L, and Dickson's quality index.

Consumer interest in alternative crop species that are a source of bioactive substances and have distinctive visual appearances and tastes has recently increased. Due to the aforementioned, two wild populations of hedge mustard were assessed by Guarise *et al.* [15] for their potential as a leafy vegetable. Numerous physiological factors and chemical components (such as sugars, ascorbic acid, total phenols, anthocyanins, and nitrate) were measured. The outcomes showed that the two wild populations of Brassicaceae may be successfully cultivated in a greenhouse while retaining nutritional content and quality traits similar to those of the most widely used commercial leafy vegetables. To assess postharvest quality and appropriate storage conditions, more research will be needed.

Conclusion

In conclusion, new cultivation techniques and technological advancements are revolutionizing greenhouse horticulture, enabling effective and sustainable food production. Significant advantages provided by these developments include higher crop yields, resource efficiency, and less environmental impact. To address issues with cost-effectiveness, scalability, and integration of these technologies into current greenhouse systems, more study and development are necessary.

Future food security and environmental sustainability may be significantly improved by greenhouse horticulture if innovation and

cooperation are sustained. Furthermore, greenhouse horticulture is being transformed by the use of modern data analytics and artificial intelligence (AI). Growers may optimize production operations, enhance crop quality, and improve supply chain logistics by gathering and analyzing data from numerous sources, such as climate sensors, crop monitoring systems, and market trends. For managing pest and disease outbreaks, allocating resources, and forecasting crop yields, AI-powered algorithms can offer insightful analysis and predictive models.

References

1. Huang, L.; Gu, M. Effects of Biochar on Container Substrate Properties and Growth of Plants—A Review. *Horticulturae* 2019, 5, 14.
2. Castro, A.J.; López-Rodríguez, M.D.; Giagnocavo, C.; Gimenez, M.; Céspedes, L.; La Calle, A.; Gallardo, M.; Pumares, P.; Cabello, J.; Rodríguez, E.; et al. Six Collective Challenges for Sustainability of Almería Greenhouse Horticulture. *Int. J. Environ. Res. Public Health* 2019, 16, 4097.
3. Ntinias, G.K.; Kadoglidou, K.; Tsivelika, N.; Krommydas, K.; Kalivas, A.; Ralli, P.; Irakli, M. Performance and Hydroponic Tomato Crop Quality Characteristics in a Novel Greenhouse Using Dye-Sensitized Solar Cell Technology for Covering Material. *Horticulturae* 2019, 5, 42.
4. Elvanidi, A.; Katsoulas, N.; Kittas, C. Automation for Water and Nitrogen Deficit Stress Detection in Soilless Tomato Crops Based on Spectral Indices. *Horticulturae* 2018, 4, 47.
5. Mills-Ibibofori, T.; Dunn, B.L.; Maness, N.; Payton, M. Effect of LED Lighting and Gibberellic Acid Supplementation on Potted Ornamentals. *Horticulturae* 2019, 5, 51.
6. Riera-Vila, I.; Anderson, N.O.; Hodge, C.F.; Rogers, M. Anaerobically-Digested Brewery Wastewater as a Nutrient Solution for Substrate-Based Food Production. *Horticulturae* 2019, 5, 43.
7. Mills-Ibibofori, T.; Dunn, B.L.; Maness, N.; Payton, M. Use of Diatomaceous Earth as a Silica Supplement on Potted Ornamentals. *Horticulturae* 2019, 5, 21. *Horticulturae* 2021, 7, 15 of 5
8. Vox, G.; Teitel, M.; Pardossi, A.; Minuto, A.; Tinivella, F.; Schettini, E. Sustainable Greenhouse Systems. In *Sustainable Agriculture: Technology, Planning and Management*; Salazar, A., Rios, I., Eds.; Nova Science Publishers Inc.: New York, NY, USA, 2010; pp. 1–79.
9. Nikolaou, G.; Neocleous, D.; Katsoulas, N.; Kittas, C. Irrigation of greenhouse crops. *Horticulturae* 2019, 5, 7.
10. Huang, L.; Gu, M. Effects of Biochar on Container Substrate Properties and Growth of Plants—A Review. *Horticulturae* 2019, 5, 14.

11. Alsanius, B.W.; Karlsson, M.; Rosberg, A.K.; Dorais, M.; Naznin, M.T.; Khalil, S.; Bergstrand, K.-J. Light and Microbial Lifestyle: The Impact of Light Quality on Plant–Microbe Interactions in Horticultural Production Systems—A Review. *Horticulturae* 2019, 5, 41.
12. Golubkina, N.A.; Seredin, T.M.; Antoshkina, M.S.; Kosheleva, O.V.; Teliban, G.C.; Caruso, G. Yield, Quality, Antioxidants and Elemental Composition of New Leek Cultivars under Organic or Conventional Systems in a Greenhouse. *Horticulturae* 2019, 5, 39.
13. Li, X.; Li, Q.; Tang, B.; Gu, M. Growth Responses and Root Characteristics of Lettuce Grown in Aeroponics, Hydroponics, and Substrate Culture. *Horticulturae* 2018, 4, 35.
14. Bantis, F.; Koukounaras, A.; Siomos, A.; Menexes, G.; Dangitsis, C.; Kintzonidis, D. Assessing Quantitative Criteria for Characterization of Quality Categories for Grafted Watermelon Seedlings. *Horticulturae* 2019, 5, 16.
15. Guarise, M.; Borgonovo, G.; Bassoli, A.; Ferrante, A. Evaluation of Two Wild Populations of Hedge Mustard (*Sisymbrium officinale* (L.) Scop.) as a Potential Leafy Vegetable. *Horticulturae* 2019, 5, 13.

Received : November 2023; Revised : December 2023; Accepted : January 2024



EFFECT OF ORGANIC MANURES ON VEGETATIVE GROWTH AND FLOWERING OF TOMATO (*SOLANUM LYCOPERSICUM* L.) CV. PUSA RUBY

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Abstract

Tomato (*Solanum lycopersicum* L.) is one of the important vegetables crop grown worldwide due to its use in a number of dishes and high nutritive value. Most of the vegetables are consumed in fresh conditions but indiscriminate use of chemical fertilizers of pesticides in crop production leads toxic effect in produce which may cause various kinds of health hazards. Hence there is need to produce food free of contaminants through the use of organic inputs. Viewing these facts, a field experiment was conducted during the 2021-22 to analyze the effect of organic manures on vegetative growth and flowering of tomato cv. Pusa Ruby. Farmyard manure (FYM), vermicompost and poultry manures were applied as sole and in combinations to analyze the effect of different organic manures. The treatments applied for the research purpose were seven in number that is T₁ (Control), T₂ (FYM 24.0 t/ha), T₃ (Vermicompost 6.0 t/ha), T₄ (Poultry manure 2.0 t/ha), T₅ (FYM 12.0 t/ha + Vermicompost 3.0 t/ha), T₆ (FYM 12.0 t/ha + Poultry manure 1.0 t/ha), T₇ (Vermicompost 3.0 t/ha + Poultry manure 1.0 t/ha). The present investigation clearly indicate that combined soil application of Vermicompost 3.0 t/ha + Poultry manure 1.0 t/ha (T₇) gave the better effect on vegetative parameters viz. plant height (85.03 cm), number of branches per plant (8.4), number of leaves per plant (41.77), number of flowers per cluster (12.3) as compared to all other treatments. However, FYM and Poultry manure also significantly increase vegetative growth of tomato.

Keywords: Tomato, FYM, Vermicompost and poultry manure.

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the important vegetables crop in the world as well as in India and it is the second most important vegetable crop next to potato. It is one of the most popular salad vegetables and taken with great relish. It is widely employed in cannery and made into soups, pickles, ketchup, sauces, juice etc. It is often called poor man's orange or wolf apple because of its high nutritive value. Tomato is a savory, typically red, edible fruit and is an excellent source of valuable nutrients (Singh *et al.*, 2014) and secondary metabolites namely foliate, potassium, vitamin A, B, and E (Vallejo *et al.*, 2002), essential amino acids, sugars, dietary fibers which are essential for human health.

Cultural practices including the proper nutrition of vegetable crops play significant roles in improving the yield as well as the quality traits. Application of nutrients through chemical fertilizers is not much affordable by the Indian farmers as well as these fertilizers have negative effects on physical and chemical properties of soil and food quality. Therefore, there is an urgent need to utilize other sources of plant nutrients for sustainable and safe tomato production. The answer lies in the use of different form of organic manures which have a potential to provide primary, secondary and micronutrients besides building a strong organic matter base resulting in improvement of soil structure and better

establishment of beneficial micro-organism colonies. Vegetables produced through the organic strategy devoid of most of the harmful residues and such type of produce are much preferred in market at premium price due to their delicious flavor, taste, luster and nutritive value. Variations in tomato growth and yield might be due to differences in nutrient management under similar as well as varying agro-climatic conditions.

Organic manures are a good source of major and micro nutrients and provide good crop stand by improving the physical, chemical, and biological characteristics of the soil (Singh *et al.* 2017). Several scientific research revealed that balance amount of macronutrients and micronutrients is essential for proper growth and development of tomato. The majority of the time, biologically active soils with sufficient organic matter provides enough of these nutrients (Singh and Kushwah, 2006). Organic matter in soil is essential for better colonization of beneficial bacteria which helps in fixing atmospheric nitrogen, converting unavailable form to available form of nutrients etc.

In India, farmyard manure is mostly available organic manure in livestock based farming systems. Farmyard manures are the major source of nutrient supply (Fageria, 2012) and has long been considered a desirable soil amendment. Vermicompost contain higher percentage of both macro and micronutrients than the garden compost. Hidalgo *et al.* (2006) and helps in producing higher biomass and yield of plant crops. Beside increase organic carbon status of the soils, vermicompost also enhance the soil water holding capacity, flocculation of soil and availability of nutrients (Rajkhwa *et al.*, 2002), microbial population and soil enzyme activities. Vermicompost also helps in increasing of soluble nutrients in soil. Among bulky organic manures, poultry manure more preferred by the farmers due to its good concentration in macro nutrients. Poultry manure acts as a good soil amendment and provides good amount of macro nutrients (Duncan, 2005).

Materials and Methods

The present experiment was undertaken at Horticulture Research Farm of Chaudhary Charan Singh University Campus, Meerut during 2021-22. Geographically, Meerut city lies about 70 Km. N.E of National capital New Delhi. The climatic condition of this region is sub-tropical. The topography of the field on which the experiment was conducted fairly uniform. On the basis of soil analysis, the soil was found loam with slightly alkaline in pH reaction, low in organic carbon, and fair in nitrogen, phosphorus and potassium levels. The experimental field was laid out in a randomized block design with three replications, comprising of ten treatments viz. T₁ (Control), T₂ (FYM 24.0 t/ha), T₃ (Vermicompost 6.0 t/ha), T₄ (Poultry manure 2.0 t/ha), T₅ (FYM 12.0 t/ha + Vermicompost 3.0 t/ha), T₆ (FYM 12.0 t/ha + Poultry manure 1.0 t/ha), T₇ (Vermicompost 3.0 t/ha + Poultry manure 1.0 t/ha). Farmyard manure, vermicompost and poultry manure were incorporated treatment wise before one week of tomato seedling transplanting. Thirty days old seedlings were subjected to transplanting. Five plants were randomly selected from each replication to record the data on various vegetative parameters. The observations were recorded in randomly taken five plants per plot and tagged plants from each replication on morphological traits viz. plant height (cm), number of branches per plant, number of leaves per plant and number of flowers per cluster. To cultivate a good crop, all other recommended cultural practices were followed. The data recorded during the course of investigation were statistically analyzed.

Result and Discussion

The data recorded on vegetative growth and flowering of tomato are presented in table-1 which clearly indicated that plant height, number of branches per plant, number of leaves per plant and number of flowers per cluster were significantly

influenced by the soil application of organic manures. In the present investigation the results clearly indicated that maximum plant height (85.03 cm) was recorded statistically higher with the treatment T₇ (Vermicompost 3.0 t/ha + poultry manure 1.0 t/ha) followed by FYM 12.0 t/ha + Poultry manure 1.0 t/h (78.06 cm). This result supported by the findings of Ujjwal *et al.*, 2022 in case of brinjal. This might be due to high rate of cell division, cell elongation and long inter-node length. Cell division and cell expansion depends on some phyto-hormones such as auxins and gibberellin and nutrient status of plant. Research has revealed the vermicompost contains many micro nutrients in addition to some of the growth regulators like indole 3-acetic acid, gibberellic acid, kinetin (Ravindran *et al.* 2016).

The maximum number of branches per plant (8.4) was recorded under the treatment T₇ (Vermicompost 3.0 t/ha + Poultry manure 1.0 t/ha) followed by FYM 12.0 t/ha + Poultry manure 1.0 t/ha (7.5). The results also agreed to the findings of Ujjwal *et al.* 2022 in case of brinjal. The probable reason for enhanced more number of branches might be due to organic manures specially vermicompost and poultry manure improve soil biological, physical and chemical properties which helps to regular supply of essential nutrients to the plant for vigorous growth. Soil application of poultry manure enhances concentration of water soluble salts in soil. Beside providing essential macro nutrients and micro nutrients, organic manures also helps in better metabolism of plants for high biomass production due to high rate of photosynthesis.

Number of leaves of a plant is one of the most important phenotypic parameter describing its development, growth and yield potential. The maximum number of leaves per plant (41.77) were recorded with the treatment T₇ (Vermicompost 3.0 t/ha + Poultry manure 1.0 t/ha) followed by treatment FYM 12.0 t/ha + Poultry manure 1.0 t/ha (30.99). However, minimum number of leaves per plant (15.22) was observed under control treatment. Similar findings were obtained by

Terry *et al.* (1995) and Meena *et al.* (2010) in tomato. The probable reasons of more number of leaves per plant is due to regular supply of nutrients and water and high rate of metabolism of the plant. Application of organic manures to the soil improve physical and chemical conditions which helps in proper supply of nutrient and water to the plant. Vermicompost is enriched with plant available forms of macro (nitrogen, phosphorus and potassium) and micro (iron, copper, zinc, etc.) nutrients as reported by Chaulagain *et al.* (2017). Enhancing of plant growth utilizing vermicompost might result from the effect of its nutrients and biological active substances (Warman and AngLopez, 2010). Poultry manure contains the most nitrogen, phosphate, and potassium of any animal manure.

Statistically, maximum number of flowers per cluster (12.3) was recorded under the treatment T₇ (Vermicompost 3.0 t/ha + poultry manure 1.0 t/ha) followed by treatment FYM 12.0 t/ha + Poultry manure 1.0 t/ha (8.5), Poultry manure 2.0 t/ha (7.6) and FYM 12.0 t/ha + Vermicompost 3.0 t/ha (7.2). The results also agreed to the findings of Dixit *et al.* (2018), Geetharani and Partibhan. (2014). The positive effect of vermicompost and poultry manure in enhancing the number of flower per cluster might be due to the fact that the net assimilation rate of nitrogen fed plants was accelerated by their increased chlorophyll content and absorbed nitrogen helped the formation of food reserves due to higher photosynthetic activity and thus increased the number of flower per cluster. The beneficial effects of vermicompost and poultry manures application in soil have been well documented in several studies. Plant respond to vermicompost application like 'hormonal induced activity' as it contain indole 3-acetic acid, gibberellic acid, kinetin (Ravindran *et al.* 2016), nutrients, humic acids and humates (Edwards and Burrows, 1988). The positive effect of vermicompost application is to stimulate flowering, increase in the number and biomass of flowers (Arancon *et al.*, 2008)

Table 1: Effect of organic manures on vegetative growth and flowering of tomato (*Solanum lycopersicum* L.) cv. Pusa Ruby

Treatment	Notation	Plant height (cm)	Number of branches per plant	Number of leaves per plant	Number of flowers per cluster
Control (no manure)	T ₁	45.65	3.3	15.22	5.2
FYM 24.0 t/ha	T ₂	60.63	4.4	21.23	6.4
Vermicompost 6.0 t/ha	T ₃	62.11	4.3	23.21	6.3
Poultry manure 2.0 t/ha	T ₄	65.45	5.2	26.62	7.6
FYM 12.0 t/ha + Vermicompost 3.0 t/ha	T ₅	63.11	4.3	24.42	7.2
FYM 12.0 t/ha + Poultry manure 1.0 t/ha	T ₆	78.06	7.5	30.99	8.5
Vermicompost 3.0 t/ha + Poultry manure 1.0 t/ha	T ₇	85.03	8.4	41.77	12.3
CD at 5%		2.213	1.174	2.520	1.613
SEm		0.710	0.377	0.809	0.518

References

- Arancon, N.Q., C.A. Edwards, A. Babenko, J. Cannon, P. Galvis, and Metzger, J.D. 2008. Influences of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse. *Applied Soil Ecology*; 39: 91-99.
- Chaulagain, A., Dhurva, P. & Gauchan and Lamichhane, J. (2017). Vermicompost and its Role in Plant Growth Promotion. *International Journal of Research*; 4(8): 849-864.
- Dixit, P.S., Prasad, V.M., Kasera, S. and Singh, S. (2018). Effect of various inputs on growth and its attributes of tomato (*Solanum lycopersicum* L.) cv. GS-600 under polyhouse condition. *International Journal of Chemical Studies*; 6: 2537-2539.
- Duncan, J. (2005). Composting chicken manure. WSU Cooperative Extension, King County Master Gardener and Cooperative Extension Livestock Advisor
- Edwards, C.A. and Burrows, I. (1988). The potential of earthworms composts as plant growth media. In: *Earthworms in Waste and Environmental Management* (Edward, C.A., Neuhauser, E.F., Eds.), *SPB Academic Publishing*; The Hague, The Netherlands, 21-32.
- Fageria N. K. (2012). Role of soil organic matter in maintaining sustainability of cropping systems. *Communications in Soil. Science and Plant Analysis*; 43: 2063-2113.
- Geetharani, P. and Partibhan, S. (2014). Effect of organic manures on growth and yield of tomato. *The Asian General of Horticulture*, 9: 281-282.
- Hidalgo, P.R., Matta, F. B. and Harkess, R.L. (2006). Physical and Chemical Properties of Substrates Containing Earthworm Castings and Effects on Marigold Growth. *HortScience*, 41(6): 1474-1476.
- Meena, R.K., Kumar, S., Maji, S., Kumar, D. and Kumar, M (2010). Effect of organic manures and bio-fertilizers on growth, flowering, yield and quality of tomato cv. Pusa Sheetal. *International Journal of Agricultural Sciences*; 10(1):329-332.
- Rajkhowa, D. J., Saikia, M. and Rajkhowa, K.M. (2002), Effect of Vermicompost with and Without Fertilizer in Green Gram. *Legume Research*; 25 (4):295-296.
- Ravindran, B., Wong, J.W.C., Selvam, A. and Sekaran, G. (2016). Influence of microbial diversity and plant growth hormones in compost and vermicompost from fermented tannery waste. *Bioresource Technology*; 4: 217-200
- Singh, S.P. and Kusjwah V.S. (2006). Effect of integrated use of organic and inorganic sources of nutrients on potato (*Solanum tuberosum*) production. *Indian Journal of Agronomy* 51(3):236-238.
- Singh, V., Prasad, V.M., Kasera, S., Singh, B.P. and Mishra S. (2017). Influence of different organic and inorganic fertilizer combinations on growth, yield and quality of cucumber (*Cucumis sativus* L.) under protected cultivation. *Journal of Pharmacognosy and Phytochemistry*; 6 (4):1079-1082.
- Singh, D.P., Chaubey, T., Singh, B., Mishra, U.C. and Chaubey, P.K. (2014). Balance nutrition in tomato through nutrient management for quality production of fruits. *Vegetable Science*, 41(2): 198-201.
- Terry, E., Pino-M-De-Los, A. and Medina, N. (1995). Bio-fertilizer application in early season tomato (*Lycopersicum esculentum* Mill.) cultivation. *Cultivar Tropical's*; 16(3):69-71.
- Vallejo, F., Barberan, T.F.A. and Viguera, G.C. (2002). Potential bioactive compounds in health promotion from broccoli cultivars grown in Spain. *Journal of the Science of Food and Agriculture*; 82:1293-1297.
- Warman, P.R. and AngLopez, M.J. (2010). Vermicompost derived from different feedstocks as a plant growth medium. *Bioresource Technology*; 101:4479-4483.
- Ujjwal, V., Dev, P., Kumar, S., Malik, A. and Kumar, R. (2022). Effect of Organic Manures and Bio-Fertilizers on Vegetative and Yield Parameters of Brinjal (*Solanum melongena*) CV. Pant Rituraj. *Flora and Fauna*; 28(1):27-30.



MULTI-TIER CULTIVATION OF HORTICULTURAL CROPS

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ABSTRACT

Multitier cropping, also known as multistoried or layered cropping, is an innovative agricultural practice that optimizes vertical space by growing multiple horticultural crops at different heights on the same land. This system leverages the complementary light, water, and nutrient needs of various crops to enhance resource efficiency and productivity. Key advantages include increased biodiversity, improved soil health, and diversified income streams for farmers. However, the system poses challenges such as complex management requirements, higher initial investments, and intricate pest and disease control. Despite these challenges, multitier cropping offers a sustainable and economically viable approach to horticulture, particularly in regions with limited land resources. Its potential to maximize output from a given area while promoting ecological balance makes it an attractive strategy for modern sustainable agriculture.

Keywords: Multi-tier cropping, horticultural crops, biodiversity, ecological balance and sustainable approach.

Introduction

The annual consumption of vegetables and fruits in India has increased to meet the nutritional needs of an estimated 1.5 billion people by 2030. Despite gains in productivity, it will not suffice to feed the growing population due to rising demand. Approximately 85% of Indian farmers are small and marginal, and available farmland will decrease due to factors like population growth, urbanization, hydroelectric projects, infrastructure development, and land degradation. By 2050, it's projected that over 95% of landholdings in India will belong to small and marginal farmers (Agrawal R.L., 1995). To tackle this issue, the multi-storied cropping system presents a viable and efficient solution to ensure food, nutrition, and income security for India's expanding population (Awasthi O.P. *et.al.*, 2008). Multitier cropping systems are dynamic and

interactive practices designed to sustainably optimize production resources such as soil, water, air space, solar radiation, and other inputs. This approach combines multiple species of crops, both annual and perennial, providing a modern alternative for sustainable productivity in horticultural crops on small and marginal lands, with the potential for higher economic returns per unit area. While mono-cropping is the exception, a mixture of species is the norm in nature. In intercropping and multitier systems, the efficient use of resources like sunlight, nutrients, and water leads to increased biological diversity and greater production stability. The multi-tier cropping system offers several benefits, including protection against market oversupply of a single commodity and the ability to grow crops based on market demand. It helps maintain ecological balance, generates higher income per unit area, ensures

food and nutritional security for farming families, and provides regular employment. Growing plants of varying heights in the same field simultaneously is known as multi-layer cropping. This practice is also referred to as multistoried cropping or multi-tier farming.

In multi-storied cropping, annual and perennial vegetable crops such as cluster bean, cowpea, French bean, fenugreek, coriander, turmeric, ginger, sweet potato, elephant foot yam, and cucurbits are used to produce a variety of food products, ensuring a sustainable farm income. This system is typically practiced in the agro-climatic regions of the Western Ghats and North-East India, where tropical and humid climates prevail. This review article focuses on the concept and suitable species for this system, based on horticultural crops, and aims to identify shortcomings in terms of tools, thereby proposing new ideas to popularize this approach. This system primarily includes an upper layer of trees or shrubs with a lower layer of economic or forage crops, spaced to allow sufficient light for the crops below. "Forest Farming" falls under this category. Multistoried cropping systems are particularly suitable for horticultural crops as they encompass a variety of plants like trees, shrubs, climbers, annuals, and shade-tolerant species. These systems are widely practiced in coastal regions of India and other parts of the world, predominantly featuring horticultural crops. (Desai A.R. *et al.* 2015)

Objectives of Multi-Layer Cropping systems:

1. Optimal Resource Utilization:

- **Light Utilization:** Different crops with varying light requirements are grown together to maximize sunlight capture. Tall crops intercept lighter while understory crops thrive in partial shade.
- **Water Efficiency:** Efficient use of water resources through shared irrigation systems and moisture retention in the soil due to ground cover provided by lower-tier crops.
- **Nutrient Management:** Diverse root structures of different crops reduce competition for nutrients and enhance soil fertility through the addition of organic matter from leaf litter and root biomass.

2. Increased Productivity:

- **Higher Yield per Unit Area:** By utilizing vertical space, multitier cropping allows for increased overall crop yield from the same plot of land compared to monocropping.
- **Continuous Harvest:** Different crops have varying maturity periods, enabling year-round harvesting and a continuous supply of produce.

3. Enhanced Biodiversity:

- **Ecosystem Stability:** Growing a variety of crops together enhances biodiversity, leading to a more stable and resilient ecosystem. This diversity can reduce the prevalence of pests and diseases.
- **Habitat Creation:** Multitier cropping provides habitats for beneficial insects, birds, and other wildlife, promoting ecological balance.

4. Economic Benefits:

- **Diversified Income:** Farmers can grow and sell multiple crops, reducing the risk associated with market fluctuations of a single crop and ensuring a more stable income.
- **Value Addition:** Different crops can be processed into value-added products, further increasing profitability.

5. Soil Health Improvement:

- **Soil Fertility:** Different crops contribute to soil fertility through organic matter deposition, nitrogen fixation (in the case of legumes), and improved soil structure.
- **Erosion Control:** The ground cover provided by lower-tier crops helps prevent soil erosion and maintains soil moisture levels.

6. Climate Change Mitigation:

- **Carbon Sequestration:** Multitier systems, especially those involving trees and shrubs, contribute to carbon sequestration, helping mitigate the effects of climate change.
- **Microclimate Regulation:** The diverse plant canopy creates a microclimate that can buffer temperature extremes and protect crops from adverse weather conditions.

7. Sustainability and Resilience:

- **Reduced Input Dependency:** The system promotes organic farming practices, reducing

the reliance on chemical fertilizers and pesticides.

- **Adaptation to Climate Variability:** Multitier cropping systems are more resilient to climate variability, ensuring food security in changing climatic conditions.
8. **Efficient Land Use:**
- **Land Optimization:** Maximizes the use of limited land resources, making it particularly beneficial for smallholder farmers and regions with high population density.
 - **Urban and Peri-urban Agriculture:** Suitable for urban and peri-urban areas where space is limited, contributing to urban food security and greening.

Principles of Multi-Layer Cropping Systems:

- A cropping system generally refers to the arrangement of crops in terms of time and space, along with the management of soil, water, and vegetation, to optimize biomass production per unit area, time, and input. The success of a multi-storied cropping system relies on using crops with diverse characteristics—such as varying growth habits, root depths, and crop durations—like coriander, radish, beetroot, cluster bean, and cowpea. By growing multiple crops simultaneously in the same field, farmers can reduce soil erosion, a major issue with monoculture systems. Multi-storied cropping enhances sustainable productivity and achieving higher income per unit area.

The basic principles of multi storied cropping system are:

- Multilayer Farming relies on high-density planting to make the most efficient use of manure, water, land, labor, and vertical space.
- This cropping system aims to reduce production costs and input use while promoting an organic and sustainable farming approach to minimize chemical use and ensure food and nutritional security for each household.
- In multilayer farming, it is possible to grow four to five different crops simultaneously on the same land, which can boost the farmer's

income.

Crops Nature in Multi-Layer Cropping systems:

- Crops that are planted on the soil surface should be leafy, and they should be harvested by uprooting them directly.
- Plants that grow straight should be pruned to save space, and they should be harvested after the other crops have been collected.
- The base crop should be a tall, widely spaced perennial, with a root system of varying depths to access nutrients from different soil layers.
- Climbing plants should be properly staked to support their growth and development. As these plants can reach up to the roof structure, they should be managed carefully with appropriate training.

Vegetable Crop Based Multi-Tier Cropping Systems

Vegetables having high-yield potential and short-duration in nature are the most suitable multitier intercrops. It provides income, employment and enough food for consumption, better and sustainable use of the inputs, i.e. soil, water, air, space, solar radiation etc. It also reduces insecurity of mono-cropping. Higher production, economic return and resource utilization occur with this system. This system channelizes the dynamic energy of rural youth towards conventional farming for higher income generation and livelihood security.

Profitable vegetable crops like beet root, radish, cluster bean, beans, coriander, and greens can be selected for intercrop as well as for multitier cropping system in cotton. This will ensure the regular income from the field at periodical intervals apart from reducing the weed growth.

Examples of patterns:-

1. Okra+ radish+ cluster bean+ beet root
2. Spinach+ radish+ onion
3. Pointed guard+ elephant foot yam+ cucumber+ cauliflower
4. Okra + Radish + Beetroot + Coriander
5. Potato + Sweet Corn + Okra
6. Ash gourd+ leafy vegetables (spinach, coriander)

Some successful model of multi-story cropping system on the horticultural crop basis

Cropping system	Place of report	Remarkable outcome of the system	Reference
Coconut + Cocoa + Banana + Drumstick+ Pineapple	AICRP, Aliyarnagar	This cropping system with 75% NPK + organic recycling with Vermicompost recorded highest nut yield of 182 per palm and highest net income (Rs. 3.80 lakhs per ha) and B:C ratio (2.71)	Nimbolkar <i>et al.</i> (2016)
Coconut + Cocoa + Lime +Banana + Drumstick	AICRP, Arasikere	With all physical and chemical quality of coconut, this system recorded net income of Rs. 294810 per ha compared to mono crop (Rs. 68200 per ha.)	Roy <i>et al.</i> (2001)
Mango + Cowpea + Indian mustard	Todapur Research orchard of Horticulture Division, IARI, New Delhi	This system recorded significantly highest values of system productivity, gross returns, net returns and B: C ratio during both the crop seasons	Mirjha and Rana (2016)
Mango + Phaseolus acutifolius + Pigeon pea	Mango orchard in the Soconusco, Chiapas, Mexico	The biomass of <i>Cajanus cajan</i> and Phaseolus acutifolius and their incorporation to the ecosystem produced positive effect on the quality and yield of mango.	Agreda <i>et al.</i> (2006)
Mango + Cowpea(kharif) + Bengal gram(Rabi)/ Mango + Pigeon pea + Tomato	Madhya Pradesh	First system gave maximum productivity per ha whereas second system came up with maximum monetary returns.	Baghel <i>et al.</i> (2003)
(Aonla + Ber + Cluster bean + fennel), (Aonla + Bael + Cluster bean +Coriander), (Aonla + Khejri + Cluster bean + Ajowain)	Arid region of Rajasthan	These systems were reported as sustainable and remunerative under the arid ecosystem	Hare Krishan <i>et al.</i> (2013)
(Aonla + Ber + Karonda + Cluster bean + Brinjal), (Aonla + Ber + Karonda + Mothbean + Indian mustard)	Arid region of Rajasthan	Plant height, number of branches per plant, fruits per plant and yield was found to be superior in these multi species cropping system as compared to sole cropping.	Arya <i>et al.</i> (2010)

Establishing Multi-Tier Cropping System

1. Planning and Crop Selection

a. Identify Objectives:

- Determine the primary goals (e.g., maximizing yield, improving soil health, enhancing biodiversity).

b. Analyze Environmental Factors:

- Evaluate climate, soil type, water availability, and other local conditions.

c. Select Compatible Crops:

- Choose crops with complementary growth habits, light, water, and nutrient requirements.

Examples:

Upper Tier: Tall trees or plants (e.g., coconut, areca nut, papaya)

Middle Tier: Medium-height crops (e.g., coffee, cocoa, eggplant)

Lower Tier: Shorter plants and ground covers (e.g., spinach, lettuce, herbs)

2. Design and Layout

a. Spatial Arrangement:

- Plan the spatial layout to ensure adequate light distribution and minimize competition.
- Use contour planting or raised beds to optimize space.

b. Vertical Structures:

- Install supports like trellises or stakes for climbing plants in the middle or upper tiers.

3. Soil Preparation

a. Soil Testing:

- Conduct soil tests to determine nutrient levels and pH.
- Amend soil based on test results to ensure optimal conditions for selected crops.

b. Soil Enrichment:

- Add organic matter (e.g., compost, manure) to improve soil fertility and structure.
- Use mulch to retain moisture and suppress weeds.

4. Planting

a. Sequential Planting:

- Stagger planting times to ensure crops at different growth stages do not compete excessively.
- Begin with upper tier crops, followed by middle and lower tiers.

b. Proper Spacing:

- Maintain appropriate spacing to allow adequate air circulation and light penetration.

5. Water Management

a. Efficient Irrigation:

- Implement drip irrigation or other efficient watering systems to conserve water.
- Ensure all layers receive adequate moisture without waterlogging.

b. Water Harvesting:

- Use rainwater harvesting systems to supplement irrigation needs.

6. Nutrient Management

a. Fertilization:

- Apply fertilizers based on the specific nutrient needs of each crop.
- Use organic fertilizers to enhance soil health and sustainability.

b. Crop Rotation and Intercropping:

- Rotate crops and use intercropping techniques to maintain soil fertility and reduce pest and disease buildup.

7. Pest and Disease Management

a. Integrated Pest Management (IPM):

- Monitor for pests and diseases regularly.
- Use a combination of biological, cultural, mechanical, and chemical controls to manage issues.

b. Beneficial Insects:

- Encourage beneficial insects (e.g., pollinators, predators) by planting insectary plants.

8. Harvesting and Post-Harvest Handling

a. Timely Harvesting:

- Harvest crops at the optimal time to ensure peak quality and yield.
- Use staggered harvesting to manage labor efficiently.

b. Post-Harvest Processing:

- Implement proper post-harvest handling and storage practices to minimize losses and maintain quality.

9. Monitoring and Evaluation

a. Regular Monitoring:

- Continuously monitor crop performance, soil health, and overall system productivity.

b. Record Keeping:

- Keep detailed records of inputs, outputs, and any issues encountered to inform future planning and adjustments.

10. Training and Knowledge Sharing

a. Farmer Training:

- Provide training on multitier cropping techniques, pest management, and sustainable practices.

b. Community Involvement:

- Encourage knowledge sharing and collaboration among farmers to improve system performance and adoption.

Establishing a multitier cropping system in horticultural crops involves careful planning, crop selection, and management to optimize resource use and achieve sustainable productivity. By following these steps and continually monitoring and adapting practices, farmers can create resilient and productive agricultural systems. Here is the example of multitier cropping system

in Horticultural crops:

A cotton-based multi-tier intercropping system with vegetables was developed after rigorous testing of eight different cotton-based systems. These were compared to sole cotton cultivation under irrigated conditions in the southern zone using Bt hybrids. Two prominent systems demonstrated economic viability and sustainability. These recommended systems are discussed in detail in the bulletin, highlighting their advantages over sole cotton cultivation.

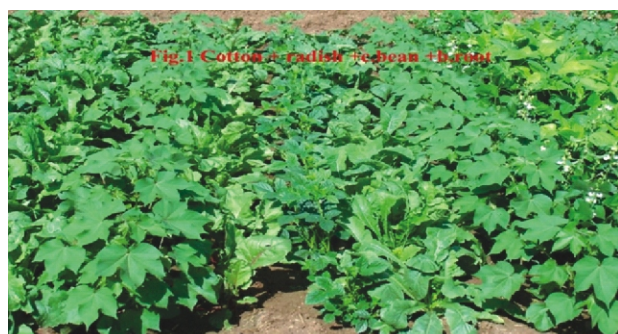


Fig 1. Cotton +radish + cluster bean+ beet root



Fig 2. Cotton +radish + beetroot +coriander

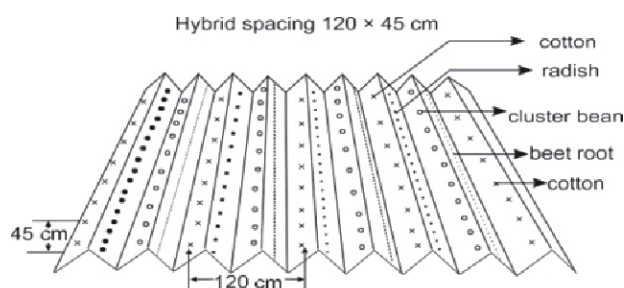


Fig 3. Method of planting in multi-tier cropping system in Bt cotton

Evaluating the Performance of Multi-Storey Cropping Systems

The sustainability of a multi-story cropping

system depends on its level of crop diversity and the positive interactions among the different components.

Land Equivalent Ratio (LER)

LER is a crucial tool for assessing intercropping systems. It is calculated using the formula $LER = \sum (Y_{pi}/Y_{mi})$, where Y_{pi} is the yield of each crop in the polyculture, and Y_{mi} is the yield of each crop in monoculture. An LER greater than 1 indicates a yield advantage, equal to 1 suggests no gain or loss, and less than 1 indicates a yield loss (Willey R., 1979).

Relative Yield Total (RYT)

RYT is a key index for determining the biological advantage in a replacement series. The formula for RYT when two species are intercropped is $RYT = X_{mix}/X_{sole} + Y_{mix}/Y_{sole}$, where X_{mix} and Y_{mix} are the yields of species X and Y in the mixture, and X_{sole} and Y_{sole} are their yields as sole crops. An RYT greater than 1 indicates that the species have different resource demands or avoid competition, while an RYT less than 1 indicates mutual antagonism. An RYT of 1 suggests that the species fully compete for the same limiting resource without any antagonism (Mead R., 1986).

Advantages of Multi-Tier Cultivation:

- Increased yield: Growing multiple crops together boosts yields as their roots nourish each other, and more plants collectively produce more food.
- Faster growth: Many crops grow more quickly when planted together, especially when spaced closely and watered regularly.
- Increased biodiversity: Growing different types of plants together in one area enhances biodiversity, providing ideal habitats for birds, bees, and other insects crucial for pollination and other ecological processes necessary for healthy ecosystems.
- Soil moisture preservation: This method helps maintain soil moisture and improves nutrient use efficiency. One of the main advantages of multi-tier cropping is its resilience to climate change impacts. This system restores ecological balance and provides valuable ecosystem services to rural and poor farmers.

- Better crop quality: Adopting standard cultivation practices results in better and more consistent crop quality. Effective weed control ensures higher production when the cultivation process is optimized.
- Space optimization: Multi-layer farming is highly efficient in utilizing limited space. It is particularly beneficial for confined areas like balconies or small gardens, allowing for the cultivation of diverse crops within a single area.
- Harvest diversity: With multiple crops growing simultaneously, farmers can enjoy a diverse and continuous harvest throughout the growing season, benefiting households and local markets with a wider selection of fresh produce.
- Erosion and landslide mitigation: The extensive root systems of diverse crops help stabilize soil, reducing the risk of erosion and landslides, and contributing to sustainable land management.

Challenges in Multitier Cropping System in Horticultural Crops

1. Complex Management:

- Requires in-depth knowledge of different crop species, their growth patterns, and compatibility.
- Coordinating planting, watering, and harvesting schedules for various crops is challenging.

2. Initial Investment:

- Higher initial costs for planting materials, infrastructure, and setup compared to monocropping.
- Need for training and education for farmers to effectively implement the system.

3. Pest and Disease Management

- Increased complexity in managing pests and diseases affecting multiple crops.
- Necessitates integrated pest management (IPM) strategies to handle diverse pest and disease issues.

4. Resource Competition:

- Potential competition between crops for light, water, and nutrients.

- Requires careful crop selection and arrangement to minimize competition and enhance complementary interactions.

5. Labor Intensive:

- More labour-intensive due to the need for frequent monitoring, maintenance, and harvesting.
- Additional labour costs may impact overall profitability.

6. Climate and Environmental Constraints:

- Suitability of multitier cropping may vary based on local climate and environmental conditions.
- Some regions may face limitations in water availability, soil fertility, or temperature ranges.

7. Market Access and Demand:

- Ensuring a market for the diverse range of crops produced is essential.
- Fluctuating market demand for certain crops can affect the profitability and sustainability of the system.

Summary and Conclusion

Multitier cropping, also known as multi-storeyed or layered cropping, involves growing different crops at various heights on the same piece of land. This practice is highly beneficial for horticultural crops as it maximizes vertical space and optimizes the use of light, water, and nutrients. Advantages of multitier cropping include efficient resource utilization, increased biodiversity, and economic benefits for farmers. However, it demands careful planning and management to overcome complexities. This system is especially useful in areas with limited land resources, enhancing productivity and sustainability, and is becoming increasingly important in sustainable agriculture.

References

1. Agrawal, R.L. (1995). Indian Farmers Digest, 10, 20-23.
2. Agreda F M, Pohlen J, Marc J and Janssens J. (2006). Effect of Legumes Intercropped in Mango Orchard in the Soconusco, Chiapas, Mexico. Conference on International Agricultural Research for Development. 1-6.
3. Arya R, Awasthi O P, Singh J and Arya C K. (2010). Comparison of fruit based multi species cropping system under arid region of Rajasthan. Indian Journal of Agriculture Science. 80 (5):423-426.

4. Awasthi O. P. and Pareek O. P. (2008). Range Management and Agroforestry, 29(2), 67-75.
5. Baghel BS, Tiwari R and Gupta N. (2003). Productivity and profitability of mango based intercropping system under rainfed agro-climatic conditions of Madhya Pradesh. *South Indian Horticulture*. (1-6):1-4.
6. Desai A.R. (2015). Multi storied cropping system in Horticulture- A Perspective Approach for Sustainable productivity. In: Proceedings of winter school on multistoried cropping system and canopy architecture management in horticultural crops from 28th Sept. to 18th Oct. 2015, College of Horticulture, Sirsi, Karnataka, pp. 50-56.
7. Hare Krishan, Singh IS, Bhargav R and Sharma S K.(2013). Fruit based cropping system for sustainable production. *ICAR News*; 9(2):9-15.
8. Koley T. K., Singh N. R and Kumar U. (2019). Role of conservation agriculture in horticultural crops. *Conservation Agriculture for Climate Resilient Farming & Doubling Farmers' Income*. ICAR Research Complex for Eastern Region, Patna Training Manual No.; c. pp. 246.
9. Meena, R. S., Malhotra, S. K. and Vashishtha, B. B. (2017). Fruit based seed spices diversified cropping models, Development Quality and Export of Seed and Spices. pp. 181-189.
10. Mirjha P R and Rana D S. (2016). Yield and yield attributes, system productivity and economics of mango based intercropping system as influenced by mango cultivars and nutrient levels. *Indian Journal of Agronomy*. 61(3):307-314.
11. Nimbolkar P K, Awachare C, Chander S and Husain F. (2016). Multi storied cropping system in Horticulture-A Sustainable Land Use Approach. *International Journal of Agriculture Science*. 8(55):3016-3019.
12. Peyre, A., A. Guidal, K .F. Wiersum and F. Bongers. (2006). Dynamics of home garden structure and function in Kerala, India. *Agroforestry Syst*. 66: 101-115.
13. Roy S, Raj S, Choudhary M, Dey S K and Nazeer M A. (2001). Intercropping of banana and pineapple in rubber plantation in Tripura. *Indian Journal of Natural Rubber Research*.; 14(2):152-158.
14. Sankaranarayanan K., Nalayini P. and Praharaj C. S. (2012). Multi-tier cropping system to enhance resource utilization, profitability and sustainability of Bt cotton (*Gossypium hirsutum*) production system. *Indian Journal of Agricultural Sciences*. 82 (12): 1044–50.
15. Sharma A., Chaudhary N., Sharma R. and Anjanawe S. (2020). Multi storied cropping system in horticulture- An approach for more crop per unit area of land. *Journal of Pharmacognosy and Phytochemistry*. Pp- 25-28 .
16. Singh N.(2020). Multi-layer farming: an advance Inter cropping. *Just Agriculture*. 1(4):49-52.
17. Singh, R P., Bhushan ., S, Kumar ., S, and Shanker R. (2013). Yield assessment of elephant foot yam grown under multilayer vegetable cropping system. *The Bioscan*..8(4):1237-1239.
18. Sultana S, Roy R, Das B, Mondal A and Rahman F H. (2020). Vegetable-Based Multitier Cropping System: A Model for Higher Income for the Farmers in Old Alluvial Soils of West Bengal. *Advances in Research*. 21(6):30- 34.
19. Thomas G, Krishnakumar V, Maheshwarappa HP, Bhat R and Balasimha D. (2011). Arecanut based Cropping/ Farming Systems. *Central Plantation Crops Research Institute, Kasaragod ICAR*, 2011; 138.

Received : October 2023; Revised : November 2023; Accepted : January 2024



EFFECT OF PLANT BIOREGULATORS ON YIELD PARAMETERS OF OKRA (*ABELMOSCHUS ESCULENTUS* L. MOENCH) CV. ARKA ANAMIKA

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Abstract

A field experiment was conducted under the title of “Effect of plant bioregulators on yield parameters of okra (*Abelmoschus esculentus* L. Moench) cv. Arka Anamika” at Horticulture Research Farm, Department of Horticulture, Chaudhary Charan Singh University, Campus, Meerut, Uttar Pradesh India, during the year 2019. The treatments involved in the study were ten in numbers *viz.* T₁ (Control distilled water), T₂ (NAA @ 50 ppm), T₃ (NAA @ 100 ppm), T₄ (NAA @ 150 ppm), T₅ (IAA @ 50 ppm), T₆ (IAA @ 100 ppm), T₇ (IAA @ 150 ppm), T₈ (GA₃ @ 50 ppm), T₉ (GA₃ @ 100 ppm) and T₁₀ (GA₃ @ 150 ppm). The experimental field was laid out in Randomized Block Design. The soil of the experimental field was well drained, sandy loam, having good moisture and heat absorbing capacity. All the yield parameters were significantly influenced by the foliar application of plant bioregulators. Results revealed that among all the treatments of yield parameters *viz.* minimum days to 50 % flowering (41.00) and maximum number of flowers per plant (27.20), number of fruits per plant (23.58), fruit set per cent (86.69), fruit length (14.98 cm), fruit diameter (1.55 cm), fresh weight of fruit (14.76 g) and fruit yield (159.11q/ha) were recorded under the foliar application GA₃ @ 150 ppm as compared to other treatments.

Keywords: Okra, NAA, IAA, and GA₃, vegetative growth.

Introduction

Vegetables are called protective food as their consumption can improve digestive system and prevent from diseases. Vegetables are indispensable part of daily diet particularly in India, where large section of population is vegetarian. Vegetables supply considerable quantities of vitamins and minerals. Among vegetables, okra (*Abelmoschus esculentus* L. Moench) is one of the most important and popular fruit vegetable in India. In Hindi, okra is known as *Bhindi*. Okra prefers warm-moist season and thrives successfully both in the plain and hill areas. It is a short duration crop and grown as spring-summer and rainy season crop in northern India. Almost all parts of okra plant are consumed, like fresh okra fruits are used as vegetable, roots and stem are used for clearing the cane juice

(Chauhan, 1972). The green fruits of okra are rich sources of vitamins, calcium, potassium and other minerals. Okra is a popular health food due to its high fiber and folate content.

Plant bioregulators have been known to be one of the quick means of increasing vegetative growth and yield attributing parameters. The dynamic role of plant bioregulators in various physiological and biochemical processes of plant is well known, which not only enables a rapid change in the phenotype of the plant by accelerating germination or growth but also helping in the augmentation of the produce. Auxins such as indole acetic acid (IAA) and naphthalene acetic acid (NAA) are important plant bioregulators which can accelerate growth and yield potential of plants when used in small concentration (depends on species). IAA and NAA play key role in cell elongation, cell division, vascular tissue,

differentiation, root initiation, apical dominance, leaf senescence, leaf and fruit abscission, fruit setting ratio, prevent fruit dropping, promote flower sex ratio and flowering in various crops.

Gibberellin is another important plant bioregulator which controls major aspects of plant growth such as germination, elongation growth, flower development, and flowering time. Probably, the most conspicuous and well know effect of GA₃ is stem elongation due to its major role in cell division and cell elongation in plants. Various scientific studies revealed that foliar application of GA₃ had positive impact on reproductive parameters such as number of flowers, fruit set, number of fruits and pod yield of okra. Concentration of these plant bioregulators play a key role in their regulating the growth, physiological, and biochemical processes of plant.

Methods and Materials

The present experiment was conducted at the Horticultural Research Farm, Department of Horticulture, Chaudhary Charan Singh University Campus, Meerut (U.P). Geographically, Meerut is located between 29.01° North latitude and 77.43° East longitudes at an elevation of 222 meter above mean sea level. The climate of this track is humid subtropical and characterized by hot summers. The soil of experimental field was Sandy loam, which was natural in reaction (7.87 pH), low in organic carbon (0.37 %) and medium in available nitrogen, phosphorus and potassium. The experiment was designed in randomized block design (RBD) with three replications. Three plant bioregulators in different concentration were used for the experimental study. So, a total number of ten treatments viz. T₁ (Control distilled water), T₂ (NAA @ 50 ppm), T₃ (NAA @ 100 ppm), T₄ (NAA @ 150 ppm), T₅ (IAA @ 50 ppm), T₆ (IAA @ 100 ppm), T₇ (IAA @ 150 ppm), T₈ (GA₃ @ 50 ppm), T₉ (GA₃ @ 100 ppm) and T₁₀ (GA₃ @ 150 ppm) were involved in the study. Two sprays of each treatment were applied after 30 and 60 DAS with the hand sprayer. Okra cultivar Arka Anamika was used in the experiment. The harmonized seeds of Okra were sown treatment wise by hand dibbling method on maintained row to row distance of 45 cm and plant to plant distance of 30 cm. Data on

pertaining yield parameters namely: days to 50 % flowering, number of flower per plant, number of fruit per plant, fruit set per cent, fruit length, fruit diameter, fresh weight of fruit/plant and fruit yield were recorded for the analysis. Six plants were randomly selected from each replication to record the data of above mentioned parameters. The data recorded during the course of investigation were statistically analyzed by using analysis of variance (ANOVA) technique (Fisher and Yates, 1949) for drawing conclusion.

Result and Discussion

It is clear from the present findings that plant bioregulators significantly influenced the yield parameters. The minimum days to 50 per cent flowering (41.00) was recorded with the foliar spray of GA₃ @ 150 ppm followed by GA₃ @ 100 ppm (42.00). The findings are confirmed with the findings of Rani *et al.* (2013) who recorded minimum number of days to 50 per cent flowering (36.60) under the treatment of GA₃ @ 50 ppm in case of okra. The induction of early flower bud initiation might be influenced by narrowing of the significant accumulation of carbohydrates. The result on earliness in flowering in this experiment goes with the report by Singh and Mukherjee (2000) in chili.

The maximum number of flower per plant (27.20), number of fruits per plant (23.58) and fruit set (86.69 %) were recorded under the foliar application of GA₃ @ 150 ppm. The findings are closely conformed with the findings of Dev *et al.* (2017) evaluated the impact of foliar application of bioregulators on the reproductive parameters of okra cv. Prabhani Kranti and recorded the maximum number of flower per plant (22.88), number of fruits per plant (20.68) and fruit set per cent (90.34 %) with foliar application of GA₃ @ 75 ppm. In case of okra, foliar spray of GA₃ @ 150 ppm resulted the maximum number of flower per plant (22.26) and number of fruits per plant (18.20) reported by Mainty *et al.* (2016). Increase in the number of flower per plant might be due to effect of gibberellic acid and auxins to increase cell division and cell elongation which help better establishment of premodium cell. GA₃ and NAA well known to increase the metabolization of photosynthesis and also reduce sugar there by

bringing a change in membrane permeability (Shukla *et al.* 1997). Gibberellic acid stimulated the activity of sub-apical meristem during new growth and the apical meristem during bud development reported by Little and Mac Donald, 2003. The increase in fruit set by foliar application of GA₃ and auxins is possibly due the fact that these hormones are reported to increase male and female organs and computability besides reducing the embryo abortion in plants.

In the present investigation, foliar spray of GA₃ @ 150 ppm showed prominent effect on fruit length (14.98 cm) and fruit diameter (1.55 cm). The finding are in the line of the findings of Dev *et al.* (2017) who reported that foliar application of GA₃ @ 75 ppm significantly increased fruit length (20.63 cm) and fruit diameter (1.77 cm). Similar findings are also observed by Singh *et al.* 2017 in case of okra cv. Arka Abhay. The stimulative effect of GA₃ on pod size may be due to the fact that bioregulators particularly gibberellins are known as influence both cell enlargement and cell division (Kamijima 1981). GA₃ used in a 90 mg/L treatment as flower injection increased pod size as reported by Khandaker *et al.* (2018)

The data revealed that the fresh weight of fruit

(14.76 g) and fruit yield (159.11 q/ha) showed significant effect due to the foliar application GA₃ @ 150 ppm, followed by GA₃ @ 100 ppm. When assimilated the effect of the both auxins *i.e.* NAA and IAA, it was found that foliar application of NAA shows more pronounced effect in increasing the fruit yield of okra as compared to IAA. Lower concentrations of NAA *i.e.* 100 ppm and 50 ppm performed better to increase fruit yield as compared to relatively higher concentration of NAA @ 150 ppm. These findings are in the agreement with the finding of Singh *et al.* 2012 and Ayyub *et al.* 2013. Dev *et al.* (2017) while studying the response of various growth promoters had also observed maximum increase in fruit yield of okra under the foliar spray of GA₃ and NAA. The findings of Suryanarayana and Arifuddin (1980) also confirmed the results of this study and observed an increase in yield of okra when foliar spray of GA₃ @ 150 ppm was applied. GA₃ and auxins have been found to enhance photosynthetic and enzymatic activity and also chlorophyll biosynthesis which could be the possible reason for higher fruit yield of okra. GA₃ have a unique ability to better diversion of photosynthesis to the fruit and better accumulation of food reserves in the fruit seeds (Bhat and Singh 1997).

Table-1: Effect of Plant Bioregulators on Yield Parameters of Okra (*Abelmoschus esculentus* L. Moench) cv. Arka Anamika

Treatments	Days taken to 50% flowering	Number of flower per plant	Number of fruit per plant	Fruit set per cent	Fruit length (cm)	Fruit diameter (cm)	Fresh weight of fruit (g)	Yield (q/ha)
Control (Distilled water)	46.00	22.20	18.16	81.79	10.87	1.22	10.79	120.14
NAA @ 50 ppm	44.33	26.10	22.42	85.89	13.47	1.51	13.37	148.53
NAA @ 100 ppm	43.33	26.50	22.82	86.11	13.81	1.53	13.70	151.56
NAA @ 150 ppm	44.83	25.60	21.91	85.58	13.00	1.46	12.91	144.50
IAA @ 50 ppm	45.33	24.20	20.33	84.01	12.26	1.38	12.18	134.92
IAA @ 100 ppm	44.66	24.80	20.96	84.51	12.59	1.41	12.50	138.86
IAA @ 150 ppm	42.66	25.00	21.15	84.60	13.07	1.42	12.94	141.47
GA ₃ @ 50 ppm	43.66	26.40	22.65	85.80	13.92	1.51	13.78	151.18
GA ₃ @ 100 ppm	42.00	26.90	23.24	86.39	14.52	1.54	14.34	155.96
GA ₃ @ 150 ppm	41.00	27.20	23.58	86.69	14.98	1.55	14.76	159.11
CD at 5%	0.907	0.623	0.503	0.599	1.086	0.047	1.300	1.689
SEm (±)	0.303	0.208	0.168	0.200	0.363	0.016	0.434	0.564

Conclusion

On the basis of experimental results, it is to be concluded that foliar application of gibberellins found to be more effective than IAA and NAA for improving the vegetative and reproductive parameters of okra. Among different concentrations of GA₃, the use of GA₃@150 ppm as foliar application found to be the best for better growth and yield of okra.

Bibliography

1. Ayyub, C.M.; Ahmad, S. and Akhtar, N. 2013. The effect of pre sowing magnetic treatment of okra seed on growth. *Lambert Academic Publishing, Germany*.
2. Bhat, L.K. and Singh, A.K. 1997. Effect of different levels of phosphorus, gibberellic acid and pickings on seed production of okra. *Vegetable Science*, 24(1): 4-6.
3. Chauhan, D.V.S. 1972. Vegetable Production in India. *Ram Prasad and Sons, Agra (India)*, p. 275.
4. Dev, P.; Prakash, S.; Singh, M.; Kumar, V. and Bhadana, G. 2017. Study on the impact of foliar application of bioregulators and nutrients on the reproductive parameters of okra (*Abelmoschus esculentus* (L.) Moench) cultivation. *Journal of Pharmacognosy and Phytochemistry*, SP (1): 449-452.
5. Fisher, R.A. and Yates, F. 1949. Statistical tables for biological, agricultural and medical research, No. Ed. 3.pp. vii + 112 pp.
6. Kamijima, O. 1981. Consideration on the mechanism of expression of dwarf genes in rice plants. II. The actions of dwarf genes on cell division and cell elongation in parenchyma of internodes. *Japanese Journal of Breeding*. 31: 302-315.
7. Khandaker, M.M.; Azam, H.M.; Rosnah, J.; Tahir, D. and Nashriyah, M. 2018. The effect of application of exogenous IAA and GA₃ on the physiological activities and quality of *Abelmoschus esculentus* (okra) var. Singra 979. *Pertanika Journal Tropical Agricultural Science*, 41 (1): 209-224.
8. Little, C.H.A. and Macdonald, J.E. 2003. Effect of exogenous gibberellins and auxin on shoot elongation and vegetative bud development in seedling of *Pinus sylvestris* and *Picea glauca*. *Tree physiology Heron publishing-Victoria, Canada*. 23: 73-83.
9. Mainty, U.; Dutta, P. and Layek, B. 2016. Effect of plant growth regulators on growth, yield and quality of okra [*Abelmoschus esculentus* (L.) Moench]. *Journal of Agroecology and Natural Resource Management*, 3 (3): 251-253.
10. Rani, M.U.; Jyothi, K.U. and Kumar, M.K. 2013. Response of plant growth regulators and micronutrients on growth and yield of okra (*Abelmoschus esculentus* L. Moench) cv. Arka Anamika. *Indian Journals.com*, 10 (3B): 1079-1081.
11. Shukla, A.C.; Singh, O.P. and Samaiya, R.K. 1997. Effect of foliar spray of plant growth regulators and nutrient complex on productivity of soybean var. JS 79-89. *Crop research*, 213-125.
12. Singh, L. and Mukherjee, S. 2000. Effect of foliar application of urea and NAA on yield and attributes of chilli (*Capsicum annum* L.) var. Longum. *Agriculture science Digest*. 20: 116-117.
13. Singh, J.; Singh, B.K.; Singh, A.K.; Panwar, M. and Singh, B. 2012. Effect of foliar spray of GA₃ and IBA on plant characters and yield of okra. *Environmental and Ecology*. 30 (4): 1351-1353.
14. Singh, D.; Vadodaria, J.R. and Morwal, B.R. 2017. Effect of GA₃ and NAA on yield and quality of okra (*Abelmoschus esculentus* L.). *J Krishi Vigyan*, 6 (1): 65-67.
15. Suryanarayana, V. and Arifuddin, M. 1980. Effect of pre-treatment of seed with GA and NAA on growth and yield of okra var. Pusa Sawani. *Vegetable Science*, 7 (1): 55-59.

Received : November 2023; Revised : December 2023; Accepted : January 2024



INFLUENCE OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH YIELD AND QUALITY OF AONLA CV. NA-7

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ABSTRACT

An experiment was carried out in the Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, (U.P.), India during 2022, to study the influence of integrated nutrient management on growth, yield and quality of Aonla cv. NA-7, using nine treatments viz., T₁: 100% RDF (Control), T₂: 75% RDF + 2kg Vermicompost, T₃: 75% RDF + 4kg Vermicompost, T₄: 75% RDF + 2kg Vermicompost + 100g *Azospirillum*, T₅: 75% RDF + 4kg Vermicompost + 100g *Azospirillum*, T₆: 75% RDF + 2kg Vermicompost + 100g *PSB*, T₇: 75% RDF + 4kg Vermicompost + 100g *PSB*, T₈: 75% RDF + 2kg Vermicompost + 100g *Azospirillum* + 100g *PSB*, T₉: 75% RDF + 4kg Vermicompost + 100g *Azospirillum* + 100g *PSB* which were replicated thrice in Randomized Block Design (RBD). Observations on plant morphological characters and yield attributes were recorded at maturity of twenty-one years old aonla trees. Maximum fruit set (40.25%), fruit retention (32.61%), fruit yield (160.72kg/per plant) with maximum fruit length (3.95cm), fruit width (4.80cm), fruit weight (48.21g), fruit volume (44.99cc), pulp weight (46.26g) along with minimum fruit drop (67.39%), seed weight (1.95g). As far as the quality characters are concerned the highest TSS (12.91°Brix), total sugars (6.29%), ascorbic acid (559.27mg/100g pulp), TSS: acid ratio (9.28) with minimum titratable acidity (1.39%) were found with application of 75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB* (T₉). These observations suggested that for getting better fruiting, substantial higher yield with qualitative fruits, the plants of aonla should be treated with an integrated dose of 75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB* in the plains of Northern India.

Key Rords: Aonla, Integrated Nutrient Management, Vermicompost, *Azospirillum*, *PSB*, Growth, Yield, Quality.

Introduction

Aonla (*Phyllanthus emblica* L.) a member of family Euphorbiaceae, is one of the most important minor fruit crop in our country. This fruit is highly nutritious and is the richest source of vitamin-C (400-1300mg 100-1 g fruit pulp), is also known as Indian gooseberry, Malacca tree, Amritphal, Scared tree and sometime called Myrobalan tree. It is one of the important indigenous fruits of the Indian subcontinent which is native to the subtropical region of South East Asia, particularly central and southern India.

Aonla is also naturally found in other tropical countries of the world viz., Ceylon, Cuba, Puerto Rico, Hawaii, Florida, Iran, Iraq, Java, West Indies, Trinidad, Pakistan, Malaya, and China. In India, aonla fruit is spreading very fast in the semi-arid regions of Maharashtra, Gujarat, Rajasthan, Andhra Pradesh, Karnataka, Tamil Nadu, the Arawali hills in Haryana, the Kandi area in Punjab, and Himachal Pradesh. The area under aonla cultivation in the state of Uttar Pradesh, particularly in Pratapgarh, Raebareli, Varanasi, Jaunpur, Sultanpur, Kanpur Nagar,

Etawah, Agra, and Mathura districts of Uttar Pradesh is increasing day by day due to its prospects under wasteland circumstances, particularly on salt-affected soils. Aonla appears in the Vedas, Ramayana, Charak Samhita and other classical Indian works that mentioned valuable its fruits are as food, medicine, and hair color. The aonla is prized for its high nutritional content, therapeutic characteristics, processing into the variety of value-added products like; preserves, pickles, candy, and herbal medicines. The fruit are also used as a blood purifier, antioxidant, laxative, liver tonic, and antibiotic and very effective remedy for diarrhea, jaundice, cough, cold, asthma, diabetes, and chronic dysentery. It is an essential ingredient in the ayurvedic remedies of Triphala, Chavanprash, and others (Kulkarni *et al.*, 2017).

Soil type, fertility and nutrient management play important roles in obtaining higher growth and yields of aonla. Now a days, using various chemical fertilizers results regularly harms the soil, pollutes the land and degrades the quality of the fruits, to solve these issues, the implementation of integrated nutrient management techniques is the best way in the present scenario. By using these techniques, we can maximize resource efficiency and increase crop production. Due to poor physical properties of soil, it becomes very hard during dry season and crops suffer due to deficiency of major plant nutrients. With the discovery of an aerobic N-fixer clostridium and nonsymbiotic free living aerobic organism *Azospirillum* and PSB it was made possible to sustain productivity of different non-legumes under normal pressure of oxygen (Ray *et al.*, 2007). Vermicompost is being commercialized as potting mixture for different fruit plants and for raising rootstocks for grafting and budding. Vermicompost provides essential nutrients to the plants and allows plants to quickly absorb nutrients. The growth characters were significantly higher in plants amended with enriched vermicompost systematic studies have been made so far to determine the requirement of manures and fertilizers in an integrated manner for aonla in the state of Uttar Pradesh. Hence, the present investigation was undertaken to study the influence of different organic and biofertilizer combination with chemical fertilizers for better

fruiting and higher return of aonla fruit in the plains of Northern India.

Materials and Methods

A field trial was conducted during February 2022 on twenty-one-year-old aonla trees in the Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur- 208002 (U.P.). The trial was laid out in Randomized Block Design with nine treatments *viz.*, T₁: 100% RDF (Control), T₂: 75% RDF + 2kg Vermicompost, T₃: 75% RDF + 4kg Vermicompost, T₄: 75% RDF + 2kg Vermicompost + 100g *Azospirillum*, T₅: 75% RDF + 4kg Vermicompost + 100g *Azospirillum*, T₆: 75% RDF + 2kg Vermicompost + 100g PSB, T₇: 75% RDF + 4kg Vermicompost + 100g PSB, T₈: 75% RDF + 2kg Vermicompost + 100g *Azospirillum* + 100g PSB, T₉: 75% RDF + 4kg Vermicompost + 100g *Azospirillum* + 100g PSB) and each treatment was replicated thrice. Observations on fruiting characters *viz.*, fruit set, fruit retention, fruit drop, and yield attributes such as fruit weight, fruit length, fruit width, fruit volume, seed weight and biochemical attributes *i.e.*, TSS, total sugars, ascorbic acid, and titratable acidity were recorded at harvest maturity as per methods suggested in A.O.A.C. (1990). The experimental data were analysed statistically with analysis of variance method given by Panse and Sukhatme (1985).

Results and Discussion

Fruit set (%): The maximum fruits set (40.25%) was recorded under T₉ (75% NPK + 4kg Vermicompost + 100g *Azospirillum* + 100g PSB) followed by T₈ (75% RDF + 2kg Vermicompost + 100g *Azospirillum* + 100g PSB), Whereas, the minimum fruit set (24.13%) was recorded under control (T₁) treatment (Table 1). This increased fruit set during present experimentation period might be due to improvement in the emergence of a greater number of female flowers per shoot and reduced fruit drop resulting in higher number of fruits per shoot. These findings agree with Tripathi *et al.*, (2010 and 2016) in strawberry, Tripathi *et al.*, (2015) in aonla; Singh and Tripathi (2020) in papaya.

Fruit Drop (%): In the present investigation, the minimum fruit drop (67.39%) was recorded

when the application of 75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB* (T₉) followed by T₈ (75% RDF + 2kg vermicompost + 100g *Azospirillum* + 100g *PSB*). While, the maximum fruit drop (83.42%) was recorded under T₁ (control) treatment, which received the 100% RDF of NPK (Table 1). The reduction of fruit drop might be associated with the higher photosynthesis, translocation of photosynthates and plant growth promoter particularly auxin. These findings are agreed with Tripathi, *et al.*, (2015 and 2017) in strawberry.

Fruit Retention (%): The maximum fruit retention (32.59%) was recorded with T₉ which plants treated with 75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB*, followed by T₈ (75% RDF + 2kg vermicompost + 100g *Azospirillum* + 100g *PSB*), whereas, the minimum fruit retention (16.56%) was recorded under (T₁) control *i.e.*, 100% RDF of NPK (Table 1). The combination of NPK, vermicompost, and bio-fertilizers (*Azospirillum* and *PSB*) are very useful in supplying proper nutrition which might result in achieving higher fruit retention during present experimentation period. The supply of nutrients and their proportion right from starting of the experiment to the harvesting of the crop induced more flowering and retention of fruit due to production and supply of photosynthates at critical requirements. These findings agree with Gupta and Tripathi (2012) in strawberry, Tripathi *et al.*, (2015) in aonla.

Fruit yield (kg): The maximum fruit yield (160.72kg/plant) was recorded with application of 75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB* (T₉) closely followed by T₈ (75% NPK + 2kg vermicompost + 100% *Azospirillum* + 100g *PSB*), whereas, the minimum fruit yield (132.44kg/tree) was recorded under control (T₁) treatment (Table 1). The yield was better in the treatment combination of NPK, vermicompost and bio-fertilizers, which may probably be due to better growth and development of the plants and vermicompost provides more C/N ratio and more essential nutrients found which required for better metabolic activities in the plant and increase protein and carbohydrate synthesis and finally increased the fruit yield. The present findings are in conformity with the earlier work by

Gupta and Tripathi (2012); Awasthi *et al.*, (2021) in strawberry and Tripathi *et al.*, (2014 and 2016) in strawberry.

Fruit length (cm): In the present investigation the fruit length, significantly affected by different integrated dose of NPK, vermicompost and *biofertilizer* (*Azospirillum* and *PSB*). The maximum fruit length (3.95cm) was recorded with the application of 75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB* (T₉), followed by treatment T₈ (75% RDF + 2kg vermicompost + 100g *Azospirillum* + 100g *PSB*) and lowest fruit length was recorded under (T₁) control (Table 1). The maximum fruit length gain is due to greater mobility of the metabolites into the developing fruits, which acted as strong metabolic sink as compared to the treatments involving higher dose of NPK, vermicompost and bio-fertilizers (*Azospirillum* and *PSB*). These findings were agreed with Mishra and Tripathi (2011) in strawberry, Katiyar *et al.*, (2012) in ber.

Fruit width (cm): The maximum fruit width (4.80 cm) was recorded with T₉ treatment which was plants treated with application of 75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB* followed by (75% RDF + 2kg Vermicompost + 100g *Azospirillum* + 100g *PSB* (T₈), whereas, the minimum fruit width (4.15 cm) was recorded under control (T₁) treatment (Table 1). Nitrogen leads to increased fruit width with the nitrogen increased the efficiency of metabolic process of the plants and encouraged the growth of the plant and consequently increases the fruit size and fruit weight. The integration of organic and biofertilizers sources of nutrients greater mobility of nutrients to the developing fruits which act as strong metabolic sink. Similar, results were also obtained by Nayyer *et al.* (2014) and Tripathi (2017) in the banana, Ram and Rajput (2000) in guava; Bhandari *et al.*, (2018) in acid lime.

Fruit weight (g): The maximum fruit weight (48.21g) was found with T₉ (75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB*) followed by treatment T₈ (75% RDF + 2kg vermicompost + 100g *Azospirillum* + 100g *PSB*), while, lowest fruit weight was recorded under control (T₁) treatment (Table 1). The maximum fruit weight gain was due to greater mobility of the metabolites into the developing fruits, which act as

strong metabolic sink as compared to the treatments involving higher dose of NPK, vermicompost and bio-fertilizers. There was increase in average fruit weight due to the integration of organic and biofertilizers sources of nutrients which accelerated mobility of photosynthesise from source to sink as influenced by the growth hormones. These finding was agreed with Gupta and Tripathi (2012) in strawberry and Bhandari *et al.*, (2018) in acid lime.

Fruit volume (cc): The maximum fruit volume (4.80cc) was recorded under T₉ (75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB*) followed by application of 75% RDF + 2kg vermicompost + 100g *Azospirillum* + 100g *PSB* (T₈), whereas, the minimum fruit volume (4.15cc) was recorded under T₁ (control) treatment (Table 1). The increasing of fruit volume might be due to improved fertilizer use efficiency with application of NPK, vermicompost, and bio-fertilizers to help in increase fruit volume and it is highly correlated with dry matter content and balanced level of hormones. These finding was agreed Singh *et al.*, (2012) in aonla; Sutariya *et al.*, (2018) in phalsa.

Pulp weight (g): The highest pulp weight (46.26g) was found under T₉ treatment which was plants treated with 75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB* followed by T₈ (75% RDF + 2kg vermicompost + 100g *Azospirillum* + 100g *PSB*) was recorded under T₁ (control) treatment (Table 2). Nitrogen increased the efficiency of metabolic process of the plants and increased the growth of the plant and consequently increased the fruit size and fruit weight than increasing pulp weight. These finding was agreed with Tarai and Ghosh (2005) in aonla Nayyer *et al.* (2014) and Tripathi (2017) in the banana.

Seed weight (g): The minimum seed weight (1.95g) was recorded under T₉ treatment, plants which received the doses of 75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB* followed by T₈ (75% RDF + 2kg vermicompost + 100g *Azospirillum* + 100g *PSB*), whereas, the maximum seed weight was recorded under T₁ (control) treatment, which plants received the doses of 100% RDF of NPK (Table 2). This might be due to the maximum gain fruit size and fruit weight, these effect on the minimum seed weight.

The similar results were also reported by Patel and Naik (2010) in sapota; Katiyar *et al.*, (2012) in ber.

Total Soluble Solids (°Brix): The TSS (12.91°Brix) was recorded highest under T₉ (75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB*) followed by application of 75% RDF + 2kg vermicompost + 100g *Azospirillum* + 100g *PSB* (T₈), whereas, the minimum T.S.S. (11.13°Brix) was recorded under T₁ (control) treatment, which plants received the 100% RDF of NPK (Table 2). The TSS contents with application of *Azospirillum* and *PSB* may be due to the quick metabolic transformation of starch and pectin into soluble compounds and rapid translocation of sugars from leaves to the developing fruits. The vermicompost play important role of the plant nutrient and plant hormones, which are directly or indirectly involved in enhancing fruit quality, these results also corroborate the findings of Tarai and Gosh (2005) in aonla, Mishra and Tripathi (2011), Kumar and Tripathi (2020) in strawberry.

Titrateable acidity (%): Based on present investigation, the minimum titrateable acidity (1.39%) was recorded under treatment T₉ (75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB*) followed by 75% RDF + 2kg vermicompost + 100g *Azospirillum* + 100g *PSB* (T₈), while, maximum acidity (2.10%) was recorded under treatment (T₁) control (Table 2). The titrateable acidity decreases due to the increasing of total soluble solids and total sugars. The results reported by Ram *et al.*, (2012) in phalsa; Nurbhanej *et al.*, (2016) in acid lime are in agreement with the present findings.

Total sugars (%): The maximum sugars (6.29%) were recorded with T₉ (75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB*) followed by application of 75% RDF + 2kg vermicompost + 100g *Azospirillum* + 100g (T₈), whereas, minimum sugars (5.48%) were recorded under (T₁) control (Table 2). This might be due to the application of balanced dose of NPK, vermicompost along with bio-fertilizers. The Nitrogen content has various energy sources like; amino acids and amino sugars which increase the sugar level in fruit. The similar results were also reported by Nayyer *et al.* (2014) and Tripathi (2017) in the banana, Patel and Naik (2010) in

sapota; Ram *et al.*, (2012) in phalsa, Kumar and Tripathi (2020) in strawberry.

Ascorbic acid (mg/100g of pulp): Significantly influenced of ascorbic acid with the application of 75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB* (T₉) gave highest ascorbic acid content (559.27 mg/100g of pulp) followed by T₈ (75% NPK + 2kg vermicompost + 100g *Azospirillum* + 100g *PSB*), while, the lowest ascorbic acid content (530.67mg/100g of pulp) under control (Table 2). The possible reasons for increased ascorbic acid may be due to the conversion of soluble sugars into ascorbic acid. The increased level of NPK, vermicompost and biofertilizers are induced the functioning of number of enzymes in the physiological process, vermicompost and biofertilizers supply major and some essential micronutrient and proper supply of nutrients to stimulates the photosynthesis, carbohydrate and sugar metabolisms which improve the quality and ascorbic acid in fruit. Similar trends were also observed by Ram *et al.* (2012) in phalsa; Yadav *et al.*, (2011) in mango.

CONCLUSIONS:

Based on the findings of present study, we can conclude that application of NPK, vermicompost and biofertilizers on aonla fruits resulted in significant improvement of fruiting and yield behaviour, which ultimately leads to biochemical parameters of aonla. The application of 75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB* is more effective compared to control and remaining other treatments. It appears from the investigation that application of 75% NPK + 4kg vermicompost + 100g *Azospirillum* + 100g *PSB* per tree is beneficial for increased fruiting as well as improving yield and yield attributing characters and biochemical characters as improving the quality of Aonla cv. NA-7 in the plains of Northern India.

References

- A.O.A.C. (1990). *Official Methods of Analysis*. Association of Official Analytical Chemists, Washington DC.
- Awasthi, V., Tripathi, V. K., Yashasvi, G. N. and Anushi (2021). Impact of *Azotobacter* and vermicompost on growth, flowering, yield and quality traits of strawberry. *Frontiers in Crop Improvement*, 9(Special Issue-III): 1046-1050.
- Bhandari, J., Kanpure, R. N., Singh, O. P., Kachouli, B. and Patidar, D. K. (2018). Effect of organic and inorganic nutrient sources on growth, yield, and quality of Acid lime (*Citrus aurantifolia* Swingle). *International Journal of Chemical Studies*, 6(1): 1635-1639.
- Gupta, A. K. and Tripathi, V. K. (2012). Efficacy of *Azotobacter* and vermicompost alone and in combination on vegetative growth, flowering and yield of strawberry (*Fragaria × ananassa* Duch.) cv. Chandler. *Progressive Horticulture*, 44(2):256-261.
- Katiyar, P. N., Tripathi, V. K., Sachan, R. K., Singh, J. P. and Ram, C. (2012). Integrated nutritional management affects the growth, flowering, and fruiting of rejuvenated ber. *Hort Flora Research Spectrum*, 1(1): 38-41.
- Kulkarani, P., Pandey, H., Sharma, A. K. and Joshi, D. C. (2017). Physicochemical properties of aonla fruit and juice. *Chemical Science Review Letters*, 6:1343-1347.
- Kumar, A. and Tripathi, V. K. (2020). Effect of *Azotobacter*, PSB and vermicompost on growth, flowering, yield and quality of strawberry (*Fragaria x ananassa* Duch.) cv. Chandler. *Progressive Horticulture*, 52(2):157-161.
- Mishra, A. N. and Tripathi, V. K. (2011). Influence of different Levels of *Azotobacter* and *PSB* alone and in combination on vegetative growth, flowering, yield and quality of strawberry cv. Chandler. *International Journal of Applied Agriculture Research*, 6(3): 203-210.
- Nayyer, M. A., Tripathi, V. K., Kumar, S., Lal, D. and Tiwari, B. (2014). Influence of Integrated Nutrient Management on growth, yield and quality of tissue cultured banana (*Musa × paradisiaca*) cv. Grand Naine. *Indian Journal of Agricultural Sciences*, 84 (6): 680–683.
- Nurbhanej, K. H., Patel, M. J., Barot, H. R., Thakkar, R. M. and Gadhave, A. V. (2016). Effect of integrated nutrient management on growth, yield and quality of acid lime (*Citrus*

- aurantifolia* Swingle) cv. Kagzi. *International Journal of Agricultural Science*, 8(51): 2360-2363.
- Panse, P. V. and Sukhatme, G. V. (1985). Statistical Methods for Agricultural Workers. ICAR, New Delhi, pp. 296.
 - Patel, D. R. and Naik, A. G. (2010). Effect of pre harvest treatment of organic manure and inorganic fertilizers on post-harvest shelf life of sapota cv. Kalipatti. *The Indian Journal of Horticulture*, 67(3):381-386.
 - Ram, R. A. and Rajput, M. S. (2000). Role of biofertilizers and manures in production of guava (*Psidium guajava* L.) cv. Allahabad Safeda. *Haryana Journal of Horticulture Science*, 29: 193-194.
 - Ram, R. B., Meena, M. L., Rubee, L. and Navaldey, B. (2012). Integrated nutrient management studies for some quality characters of phalsa. *Asian Journal of Horticulture*, 7(2): 385-387.
 - Singh, A. and Tripathi, V. K. (2020). Influence of integrated nutrient management on growth, yield, and quality parameters of papaya (*Carica papaya* L.). *Journal of Pharmacognosy and Phytochemistry*, 9(5): 2022-2026.
 - Singh, A. K., Singh, S. and Rao, V. V. (2012). Influence of organic and inorganic nutrient sources on soil properties and quality of aonla in hot semi-arid ecosystem. *Indian Journal of Horticulture*, 69(1): 50-54.
 - Sutariya, N. K., Patel, M. J., Patel, H. A. and Vasara, R. P. (2018). Effect of integrated nutrient management on bio chemical parameters of phalsa (*Grewia subinaequalis* L.) cv. local. *Journal of Pharmacognosy and Phytochemistry*, 7(5): 408-411.
 - Tarai, R. K. and Ghosh, S. N. (2005). Effect of nitrogen levels on yield, fruit quality and foliar NPK status of aonla grown on laterite soil. *Indian Journal of Horticulture*, 62(4): 394-395.
 - Tripathi V. K., Kumar, N., Shukla, H. S. and Mishra, A. N. (2010). Influence of *Azotobacter*, *Azospirillum* and PSB on growth, yield, and quality of strawberry cv. Chandler. Paper presented in National Symposium on Conservation Hort., during March 21-23, 2010, at Dehradun, pp-198-199.
 - Tripathi, V. K., Bahadur, S., Dubey, V. and Kumar, A. (2015). Influence of integrated nutrient management on yield and physicochemical parameters of Aonla cv. NA-7. *Progressive Research-An International Journal*, 10 (Special-VI): 3493-3496.
 - Tripathi, V. K., Jain, A., Dubey, V., Kumar, A. and Pandey, H. (2016). Effect of different levels of *Azotobacter*, *Azospirillum*, PSB and black polythene mulch on growth, yield and quality of strawberry cv. Chandler. *Progressive Research an International Journal*, 11 (Special-VIII): 5185-5188.
 - Tripathi, V. K., Jain, Ankita, Kumar, Sanjeev, Dubey, Vishal, Kumar, Abhinav (2017). Efficacy of bio-fertilizers and mulching on growth. yield and quality of strawberry (*Fragaria* × *ananassa*) cv. Chandler. *Indian Journal of Agricultural Sciences*, 87(9): 1179-83.
 - Tripathi, V. K., Kumar, S., Kumar, K., Kumar, S. and Dubey, V. (2016). Influence of *Azotobacter*, *Azospirillum* and PSB on vegetative growth, flowering, yield and quality of strawberry cv. Chandler. *Progressive Horticulture*, 48(1): 49-53.
 - Tripathi, V. K., Kumar, Sanjeev and Gupta, A. K. (2015). Influence of *Azotobacter* and Vermicompost on growth, flowering, yield and quality of strawberry cv. Chandler. *Indian Journal of Horticulture*, 72(2):201-205
 - Tripathi, V. K., Mishra, A. N., Kumar, S. and Tiwari, B. (2014). Efficacy of *Azotobacter* and PSB on vegetative growth, flowering, yield and quality of strawberry cv. Chandler. *Progressive Horticulture*, 46(1): 48-53.
 - Tripathi, V.K. (2017). Influence of Integrated Nutrient Management in ratoon crop of tissue cultured banana. *Progressive Research-An International Journal*, 12 (Special-IV): 2577-2580.
 - Yadav, A. K., Singh, J. K. and Singh, H. K. (2011). Studies on integrated nutrient management in flowering, fruiting, yield, and quality of mango cv. Amrapali under

high density orcharding. *The Indian Journal of Horticulture*, 68(4):453-460.

Table 1: Influence of Integrated Nutrient Management on fruit drop, retention, yield and yield parameters in aonla cv. NA-7.

Treatments	Fruit set (%)	Fruit retention (%)	Fruit drop (%)	Fruit length (cm)	Fruit Width (cm)	Fruit weight (g)	Fruit yield (kg/plant)
T ₁	24.14	16.58	83.42	3.31	4.15	38.82	132.44
T ₂	26.30	17.50	82.50	3.45	4.29	40.52	139.32
T ₃	28.56	18.55	81.45	3.55	4.33	41.75	142.64
T ₄	29.50	26.11	73.89	3.62	4.41	42.35	144.86
T ₅	32.50	26.81	73.19	3.68	4.52	43.30	147.55
T ₆	33.10	27.48	72.52	3.72	4.58	44.15	150.34
T ₇	35.45	28.65	71.35	3.80	4.65	45.32	153.98
80T ₈	37.55	31.65	68.35	3.85	4.72	46.56	155.45
T ₉	40.25	32.61	67.39	3.95	4.80	48.21	160.72
S.E. (m)±	0.45	0.41	0.97	0.061	0.06	0.76	2.72
C.D. at 5%	1.36	1.22	2.92	0.184	0.19	2.32	8.22

Table 2: Influence of Integrated Nutrient Management on Biochemical attributes of aonla cv. NA-7.

Treatments	Pulp weight (g)	Fruit Volume (cc)	Seed weight (g)	TSS (°Brix)	Total sugars (%)	Ascorbic acid (mg/100g)	Titrateable acidity (%)
T ₁	36.50	30.75	2.32	11.13	5.48	530.67	2.10
T ₂	37.97	31.25	2.28	11.33	5.62	536.99	2.02
T ₃	39.03	33.55	2.22	11.43	5.69	537.93	1.93
T ₄	40.17	36.20	2.18	12.05	5.82	541.88	1.85
T ₅	41.15	38.80	2.15	12.15	5.93	544.46	1.78
T ₆	42.05	39.20	2.10	12.25	5.98	546.30	1.69
T ₇	43.27	40.10	2.05	12.45	6.11	549.51	1.59
T ₈	44.56	43.25	2.00	12.65	6.24	555.43	1.49
T ₉	46.26	44.90	1.95	12.91	6.29	559.27	1.39
S.E. (m)±	0.74	0.58	0.03	0.12	0.09	1.22	0.02
C.D. at 5%	2.24	1.78	0.09	0.35	0.28	3.68	0.06

Received : September 2023; Revised : October 2023; Accepted : January 2024



EFFECT OF CHEMICAL PRESERVATIVES ON VASE LIFE OF CUT ROSE CV. TOP SECRET

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Abstract

An experiment was conducted in the laboratory of department of Horticulture, Ch. Charan Singh University Campus, Meerut (U.P.) India, during October 2020 under the title of effect of chemical preservatives on vase life of cut rose cv. Top Secret. The treatments involved in the study were nine in numbers viz. T₁ Control (distilled water), T₂ (Al₂SO₄@ 100ppm + 1% sucrose), T₃ (Al₂SO₄@ 200ppm + 2% sucrose), T₄ (Al₂SO₄@ 100ppm + 4% glucose), T₅ (Al₂SO₄@ 200ppm + 6% glucose), T₆ (AgNO₃@ 50ppm + 1% sucrose), T₇ (AgNO₃@ 100ppm + 2% sucrose), T₈ (AgNO₃@ 50ppm + 4% glucose) and T₉ (AgNO₃@ 100ppm + 6% glucose). Parameters studied in the experiment were fresh weight change (g), water uptake (ml/cut stem), flower diameter (cm) and vase life (days). Among all the preservatives, the maximum increase in fresh weight (+3.63 g) and maximum water uptake on 4th day and at senescence day (18 ml and 40.33 ml respectively) were recorded under the AgNO₃@50 ppm+1% sucrose while The maximum flower diameter (7.26 cm) and vase life (11.33 days) were recorded under the AgNO₃@100ppm + 6% glucose as compared to other treatments.

Keywords: Rose, Vase life, Sucrose, Glucose, Aluminium Sulphate, Silver Nitrate.

Introduction

Roses are the symbol of beauty, fragrance & are used to convey the message of love. Without roses gardens are not considered complete. Great diversity in plant growth, color of flowers, flower shape, fragrance, slow opening of flowers and good keeping quality made roses so popular. It is a top ranking cut flower in the flower trade on the basis of average production and consumption. In India roses are grown for cut flowers, making essential oil, rose water and gulkand. Dry petals of roses are also used for making incense sticks and sweetening milk. Rose hips are the round part of the flower just below the petals has been found to contain vitamin C, a potent antioxidant nutrient. If roses smell good, they will probably taste good, say food experts. Rose petals are also used to garnish summer beverages and fruit dishes. Top

secret variety is an important cultivar of cut rose. It is a red colored, slow opening, having good stem length (40-70 cm), and 8 - 10 days vase life.

Since sugars are the main nutritional supply for flowers and are necessary to power all biological and physiological processes once flowers separate from their mother plants, they play a significant role in maintaining the quality of cut flowers. As an energy source for respiration or as an osmotically active chemical, it also aids in flower development and opening by maintaining the turgidity of the growing corolla.

Silver nitrate and aluminium sulphate are well-known germicides that are typically used to manage the bacteria that are present in a plant's xylem. As a result, after silver nitrate and aluminium sulphate application in the holding solutions block, the xylem vessels will be clean,

allowing plants to more easily absorb the solution. Numerous investigations revealed that various germicides can successfully control pathogens found in the xylem and phloem. By limiting the production of ethylene, these germicides help to prevent senescence and increase the vase life of cut flowers.

Methods and Materials

The present investigation was carried out in the laboratory of Department of Horticulture, Choudhary Charan Singh University Campus, Meerut, (U.P.) India October- 2020. Meerut is situated at altitude of 28.98° N and longitude of 77.71° E with an elevation of about 222.5 M: above the mean sea level. Meerut region has a typical climate of semi-arid with the extremes of weather condition. It remains hot during summer season and cold with frost in winter season. The maximum temperature ranges 16 – 45° C & minimum ranges 4-27° C. The relative humidity is high in winter and rainy season. On average August is the most humid month and April is the least humid month. The average annual relative humidity is 49%. There were nine treatments viz. T₁ Control (distilled water), T₂ (Al₂SO₄@ 100ppm + 1% sucrose), T₃ (Al₂SO₄ @ 200ppm + 2% sucrose), T₄ (Al₂SO₄ @ 100ppm + 4% glucose), T₅ (Al₂SO₄ @ 200ppm + 6% glucose), T₆ (AgNO₃ @ 50ppm + 1% sucrose), T₇ (AgNO₃ @ 100ppm + 2% sucrose), T₈ (AgNO₃ @ 50ppm + 4% glucose) and T₉ (AgNO₃ @ 100ppm + 6% glucose) used for investigation. The cut flower having 45 – 50 cm stem length were harvested in the morning 8:00 am at bud stage, when only one or two petals had unfolded, with the help of a clean and sharp secateurs. Then the cut flowers were brought to the re-cut to uniform length of 40 cm. After the recording the fresh weight of all cut stems in the laboratory the cut flowers were kept in conical flask. Each conical flask contains 500 ml solution of different concentration of chemicals preservatives. The conical flasks were kept under ambient condition of 19± 2 ° C temperature and 65 – 70% relative humidity. The data related to fresh weight change (g), water uptake (ml/cut stem), flower diameter (cm) and vase life (days) were recorded for the analysis. The weight of flowers was recorded by using a digital weighing balance on 4th day in vase

and at senescence. Water uptake (ml/cut stem) during 4th day in vase and at senescence was measured with the help of measuring cylinder. Flower diameter (cm) was measured by scale as the maximum expansion of the flower on two perpendicular axis and the average of two values were taken. Flower diameter was measured on 4th day in vase. Vase life was recorded since the cut flowers were kept in the vase till senescence. The total period of vase life was noted in days. The end of useful vase life or senescence symptoms was marked either by appearance of bent neck, bluing of petals in case of the flowers, wilting, blackening, or drying of outer petals or opening at center petal drop and color fading etc. The data recorded during the course of investigation were statistically analyzed by using analysis of variance (ANOVA) technique (Fisher, 1958) for drawing conclusion.

Result and Discussion

The perusal of data clearly reveal that the flowers which were treated with chemicals by keeping them in holding solution shows more vase life as comparison to control (distilled water). It is clear that on 4th day the maximum increase in fresh weight (+3.63 g) was observed in the treatment AgNO₃ @ 50 ppm + 1% sucrose and followed by treatment AgNO₃ @ 100 ppm + 6% glucose (+3.03 g) over the control treatment (distilled water). Similarly the least reduction in the fresh weight at senescence day (-0.92 g) was recorded in treatment T₇ (AgNO₃ @ 100 ppm + 2% sucrose), followed by AgNO₃ @ 50 ppm + 1% sucrose (-1.12 g). However the control treatment show the maximum reduction in fresh weight of cut stem (-1.90 g) at senescence. It might be due to effect of AgNO₃ and Al₂SO₄, act as bactericide which inhabit the growth of bacteria, cause of blockage of xylem vessels stopped the supply of nutrients in solution from, is essential for all physiological activities like absorption of water, respiration, transpiration etc. Similar finding were also observed by Singh and Tiwari (2002).

Maximum water uptake (18 ml and 40.33 ml respectively) on fourth day and at senescence day were recorded under the treatment T₆ (AgNO₃@ 50 ppm+1% sucrose), followed by the treatment T₅ (Al₂SO₄@ 200ppm+6% glucose) in comparison to other treatments as well as control (distilled

water). These findings are close conformity with the findings of Mishra and Khanal (2019) who reported that vase solution 150ppm HQS + 150ppm AgNO₃ + 4% sucrose increase water uptake by gladiolus cut flower. It may be due to the effect of AgNO₃, reduction in stem conductivity is typically caused by blockage of cut stem ends and xylem conduits microbes, disruption of water columns in xylem vessels by cavitation and air embalm, where AgNO₃ act bactericides provides the energy for physiological activates like absorption of water, respiration, transpiration and maintains of integrity.

The maximum flower diameter (7.26 cm) was recorded with treatment T₉ (AgNO₃ @ 100ppm + 6% glucose) followed by treatment T₇ (7.23 cm). Where AgNO₃ acts as an ethylene inhibitor and enhanced the flower diameter and vase-life of cut rose flowers cv. Top Secret. Similarly the maximum vase life (11.33 days) of cut flower of rose cv. Top Secret was recorded under the treatment AgNO₃ @ 50ppm + 1% sucrose followed

by AgNO₃ @ 50ppm + 4% glucose and AlSO₄ @ 200 ppm + 6 % Glucose (both 9 days) as compared to other treatment. The findings are closely conferment with the findings of Elgimabi *et al.*, 2011 in rose and Malakar *et al.*, 2019 in gerbera. Kumar *et al.*, (2020) also reported that AgNO₃@125 ppm enhance vase life of rose. This might be due to regular energy supply, inhibiting ethylene action and microbial growth and as a result, the vase life could be increased. Silver nitrate helps in preventing ethylene activity by blocking the special receptors present on the cell membrane. As silver also has antimicrobial activities, it reduces the vascular tissues blockage by bacterial growth, increases water uptake and enhanced vase life. Similarly, sucrose is acts as a food source or respiratory substrate and delays the degradation of proteins and improves the water balance and as a result, vase life of cut flowers increase (Moon-Soo *et al.*, 2001). Al₂SO₄ helps in closing the stomata and reduces water less.

Table 1: Effect of chemical preservatives on the vase life of cut rose cv. Top Secret

Notations	Treatments	Fresh weight. Change at 4th day (g)	Change in fresh weight at senescence (g)	Water uptake on 4th day in vase (ml)	Water uptake at senescence (ml)	Flowers diameter (cm) on 4thday in vase	Vase life (days)
T ₁	Control (Distilled water)	+2.23	-1.90	9.13	13.26	5.90	4.33
T ₂	Al ₂ SO ₄ @100 ppm + 1% sucrose	+2.50	-1.56	14.33	20.86	5.93	7.00
T ₃	Al ₂ SO ₄ @200 ppm + 2% sucrose	+2.93	-1.83	15.10	29.96	6.26	7.66
T ₄	Al ₂ SO ₄ @100 ppm + 4% glucose	+2.93	-1.83	15.00	34.33	6.20	7.33
T ₅	Al ₂ SO ₄ @200 ppm + 6% glucose	+3.00	-1.56	13.86	39.96	6.83	9.00
T ₆	AgNO ₃ @ 50 ppm + 1% sucrose	+3.63	-1.12	18.00	40.33	6.36	11.33
T ₇	AgNO ₃ @ 100 ppm + 2% sucrose	+2.96	-0.92	15.00	24.33	7.23	7.00
T ₈	AgNO ₃ @50 ppm + 4% glucose	+3.00	-1.55	16.66	31.93	6.60	9.00
T ₉	AgNO ₃ @ 100 ppm + 6% glucose	+3.03	-1.70	15.60	27.66	7.26	7.66
	C.D	0.650	0.477	2.131	4.092	0.909	1.629
	SE(m)	0.215	0.158	0.705	1.353	0.300	0.539

Bibliography

1. Elgimabi, M. E. N. E. (2011) Vase life extension of rose cut flowers (*rosa hybrid*) as influenced by silver nitrate and sucrose pulsing. *American Journal of Agricultural and Biological Sciences*; 6(1): 128-133
2. Fisher, R.A. (1958). Statistical Method for Research Workers. *Oliver and Boyd Edinburgh*, London.
3. Kumar, M., Kumar, J. Dev, P., Choudhary, K., Agnihotri, K.M. and Kumar, A. (2020). Effect of Aluminum Sulphate and Silver Nitrate on Vase Life of Cut Rose CV. First Red. *International Journal of Current Microbiology and Applied Sciences*; SP 11: 3714-3718
4. Malakar, M., Acharyya, P. and Biswas, S. (2019). Effect of silver nitrate and sucrose on the vase life of Gerbera (*Gerbera jamesonii* H. Bolus) cut flowers. *Journal of Crop and Weed*; 15(2): 46-51

5. Moon-Soo, C., Fisun, G. C., Linda, D., Michael, S. R., (2001). Sucrose enhances the postharvest quality of cut flowers of *Eustoma grandiflorum* (raf.) shinn. In: Proc. VII Int. Symp. Postharvest Physiol. Ornamentals Eds. *Acta Horticulture*; p. 543.
6. Mishra, P. and Khanal, A. (2019). Vaselife analysis of gladiolus using different vase solutions. *Journal of Bioscience and Agriculture Research*; 21(01): 1749-1754
7. Singh, A.K, and Tiwari, A.K. (2002). Effect of pulsing on Post-harvest life of rose cv. Doris tystermann, *South Indian Horticulture*; 50(1-3): 140-144.

Received : October 2023; Revised : November 2023; Accepted : January 2024



VEGETABLE VERTICAL FARMING: EVOLUTION AND FUTURE PROSPECTS

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ABSTRACT

India's agricultural land is constantly moulting. In order to address the problems caused by the overpopulation, water scarcity, climate change, labour shortage, and urbanisation that is reducing the amount of arable land, newer technologies are being developed. Vertical farming, which involves cultivating and producing crops on vertically stacked layers and vertically inclined surfaces, may be an efficient approach to increase food production with less area. In 1915, Gilbert Ellis Bailey published a book titled "Vertical Agriculture" and created the term "vertical farming". It is necessary to construct such farms that require less land and less time to transport food produced in rural regions to urban areas in order to grow food there. The market for vertical systems is rapidly growing, and aeroponics and stacked containers both employ comparable techniques. Vertical agriculture is frequently explored in depth in the business and scientific areas. To ensure the secure growth of the chosen vegetables needed for a family, IIHR in India has designed a vertical garden structure that can be installed in the sun-bearing utility area, on the balcony, and on the terrace. Anyone who wants to cultivate vegetables, medicinal plants, and flower crops vertically can utilise this construction. In India, vertical farming has difficulties with mainstreaming, public awareness, farmers' involvement, technical skills, expense of operating vertical farm systems, and financial feasibility.

Keywords: Food Production, Structure, Vegetables, Vertical farming.

Introduction

The idea of vertical farming was developed in 1999 by Dickson Despommier at Columbia University using technological advancements. He also described how fish and chickens that consume plant waste may live on the lower floors while hydroponic vegetables could be produced on the top floors. The practise of "vertical farming" involves growing food and medication in layers that are piled vertically, on surfaces that are inclined vertically, or that are integrated into other buildings (like a skyscraper, an old warehouse, or a shipping container). The problems facing vertical farming in India include public awareness, the agricultural community's inclusion, technical know-how, costs associated

with maintaining and mainlining the vertical farm systems, as well as its financial feasibility (Sonwane, 2018).

Why Vertical Farming?

Since the arable land is small, with agricultural land covering 38% and arable land covering 11% of the total land area. Further, global projections indicate an increase of only another 2 percent of agricultural land by 2040. (FAOSTAT, 2012) and by 2050 ground water levels are going to be depleted severely, where scarcity of water for irrigation and even for drinking. Thus, we require such crop production system which may help to meet up the requirement of people with the use of less land area and also lesser utilization of natural resources.

Vertical farming has the potential to address environmental issues by allowing for the production of more food using fewer resources and using as little water as possible (through water recycling). This farming is quickly picking up speed in the science and modern networks (Al-Chalabi, 2015), which has prompted reliable conveyance of products to request trots, lessening the requirement for capacity and refrigeration.

Techniques of Vertical Farming

The techniques of vertical farming are hydroponics, aeroponics and aquaponics.

- a) **Hydroponics:** Hydroponics refers to the practice of growing plants without soil. The roots of plants in hydroponic systems are supported by inert (chemically inactive) materials like gravel, sand, or sawdust that are submerged in macronutrient-rich liquid solutions. Hydroponics has the advantage of reducing water consumption and increasing yield per area.
- b) **Aeroponics:** In contrast to conventional hydroponics and aquaponics, aeroponics does not necessitate the use of liquid or solid plants to grow plants. Instead, a liquid solution containing nutrients is misted into the air chambers where the plants are suspended. This idea of aeroponics was urged to track down proficient ways of developing plants in space during the 1990s by NASA's. Aeroponics is the most environmentally friendly method for producing without soil because it does not require cultivated medium to be replaced and uses up to 90% less water than conventional hydroponic systems.
- c) **Aquaponics:** In a closed-loop system that imitates nature, combine the production of aquatic organisms with that of terrestrial plants. The tanks' nutrient-rich wastewater is sent here through a solid removal unit to a bio-filter, where toxic ammonia is transformed into nutrient nitrate. The plants then, at that point, sanitize the wastewater, reused into the fish tanks, while engrossing supplements. Moreover, the plants drink carbon dioxide from fish and water gets warmth in the fish tanks and assists the nursery with keeping up with its night temperature to save energy.

Farming method	Key characteristics	Major benefits
Hydroponics	Water as growing medium for soilless crop production	Reduces, even eliminates, soil-related cultivation issues; significantly reduces the need for fertilisers or pesticides.
Aeroponics	A hydroponics replica in which plants roots are sprayed with nutrient solutions or mist.	Additionally, aeroponics uses less water than other methods of growing plants.
Aquaponics	Aquaponics and hydroponics are combined in this system	Creates mutually beneficial relationships among plants and fish by using fish tank refuse to fertigate hydroponics production beds, as well as a hydroponic bed also serve to safe water for the fish's pond.

Types of Vertical Farming System:

Some of the plants in vertical systems are on the ground, while others are stacked in rows on top of each other. Small crops like lettuce were tested, and the results were mixed. After being applied at the top, the nutrient solution drips through a substrate-filled bag. The bottom is where the water from the drain is deposited. The primary objective of this approach is to maximize yield per square meter by maximizing space utilization.

- a) **Despommier Skyscrapers-** This concept of the vertical farm emerged in 1999 at Columbia University (Manoj and Sreedhar, 2019). Despommier proposed that plant life is mass produced within hermetically sealed, artificial environments that have little to do with the outside world.
- b) **Mixed use scyscrapers-** It was propped by architect Ken Yeang. these skyscrapers integrate traditional agricultural activities with the vertical farming concept (Manoj and Sreedhar, 2019). It requires less initial investment compared to Despommier skyscrapers, which requires the entire environment within the building to be controlled and monitored according to the crop's requirements (Yeang, 2002).
- c) **Stackable shipping containers-** in this method, shipping containers are used to grow leafy green vegetables, gourmet mushrooms and strawberries. (Markham, 2015).

Vertical Towers:

A vertical hydroponics system with an A-Frame hydroponic system, a hydroponic wall, and bottle cascades is known as a tower garden or window farm. It very well may be utilized for developing different harvests like lettuce, Swiss chard, spices, spinach, kale and broccoli. In the event that lights are given over the pinnacle, it can likewise be utilized to develop plants inside, which is normal in metropolitan regions with restricted space for cultivating. You can change the design to your liking. For instance, pinnacles can be dangled from the top and can deplete to a solitary tank to gather the supplement arrangement (Dunn, 2017).

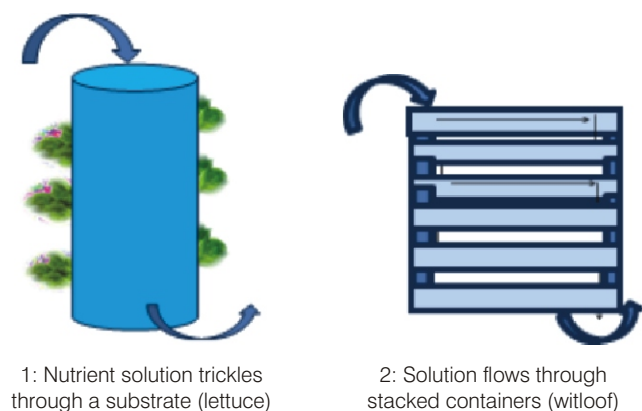


Fig.1. Vertical towers

Research Highlights

A study was conducted with the research titled “A review on scope and potentiality of vertical farming in India” discusses the need to maximize food production per unit area to address the rising population. It introduces vertical farming as a solution to utilize vertical space efficiently, enabling the cultivation of fresh, nutritious vegetables. The study highlights the benefits of growing salad vegetables in vertical farming systems and emphasizes the importance of health-conscious food choices. Various advanced methods like aeroponics and hydroponics are mentioned as techniques to enhance productivity in vertical farming.

Another study titled “Vertical Farming Using Hydroponic System: Toward a Sustainable Onion Production in Nueva Ecija, Philippines” explores the applicability of Vertical Farming using Hydroponic Technology for onion production in the

Philippines. Through field experiments and analysis, the study assesses the sustainability and acceptability of this technology among onion farmers in Nueva Ecija. The conclusion of the study indicates that the Vertical Farming and Hydroponics (VFH) technology showed significant differences in the growth of onion bulbs per week compared to conventional farming. It was found to be acceptable to most onion farmers, with the main concern being the initial investment cost, suggesting a need for government subsidies to make this sustainable technology more accessible to ordinary onion growers in the region. (Pascual M.P *et al*, 2018)

Table 1: Increase in bulb size of onion grown in Vertical Farming along with hydroponics

Days	Average diameter of onion bulb (cm)	Days	Average diameter of onion bulb (cm)
1	2	16	2.8
2	2	17	2.9
3	2.1	18	2.9
4	2.1	19	3
5	2.2	20	3.1
6	2.2	21	3.2
7	2.3	22	3.2
8	2.4	23	3.3
9	2.5	24	3.5
10	2.5	25	3.6
11	2.6	26	3.8
12	2.6	27	4.1
13	2.7	28	4.1
14	2.7	29	4.2
15	2.8	30	4.3

Present status of vertical farming in India-

In India, the vertical farming is under testing period. Although, on a small scale it has been implemented in some major cities like West Bengal, Punjab, New Delhi, Mumbai etc. The researchers has been also looking for the feasibility of the skyscraper in different metro cities of India like, Chennai, New Delhi, Kolkata etc. (Sonawane M.S., 2018).

If the vertical took up pace in India, then it might help peoples to get fresh cut vegetables easily throughout the year, helps the growers to gain high profits and this will definitely affect the national GDP in positive direction. So to achieve

this, integrating vertical farming and hydroponics is one of the best options (**Kumar A, 2019**).

The ICAR is looking into the possibility of vertical urban agriculture." The farming would be accomplished without the use of land, and it will meet the demand for fresh vegetables in cities that are growing taller as a result of the proliferation of multistory buildings. The Crop Science Deputy Director General of ICAR.

Scientists from Bidhan Chandra krishi Vishwa Vidyalaya Nadia have made initial progress on brinjal and tomatoes at a small scale, but a larger-scale implementation would require additional funding. In Punjab, where researchers initially achieved success in soil reduction and controlled potato, fruit, and vegetable cultivation, productive vertical farming efficiency was tested.

Major company of vertical farming in India

The following is a list of major Indian start-ups that are pioneering indoor farming and introducing novel farming techniques.

- **Agritech Letcetra:** In its 150 square meters, Goa's first indoor hydroponics farm produces between 1.5 and 2 tons of high-quality, pesticide-free vegetables, including a variety of lettuce and herbs. Ajay Naik, a software engineer turned hydroponics farmer, is the founder of the startup. In order to assist rural farmers, he quit his IT job. Junga Fresh n Green and Infra Co Asia Development Pvt. have collaborated on an agri-tech startup called Junga.
- **Fresh n Green.Ltd.** (IAD) this year to improve India's hydroponic farming practices. The undertaking began with the improvement of a 9.3-hectare tank-farming based horticultural office at Junga in Himachal Pradesh's Shimla locale.
- **Future Farms:** It is based in Chennai, designs efficient and easily accessible farming kits for hydroponics, which help the environment while producing produce that is cleaner, fresher, and healthier. The company creates cost-effective indigenous systems and solutions made of premium food-grade materials.
- **Greenopiais:** It is a startup based in Bengaluru that sells kits that include seeds, enriched soil, and smart, self-watering pots. The pots with sensors in them add water to the soil as needed and tell you when you need to add water outside.
- **UrbanKisaan:** It takes pleasure in generating 30 times more produce than conventional farming while using 95% less water especially in the area of Bangalore and Hyderabad.
- **365Dfarms:** It is located in Pune. It's the first Indian movable vertical farm, built in a shipping container. This farm produce lettuce all year round using high-tech.

Benefits of Vertical farming

- **Increased Crop Production** Crops can be grown year-round indoors. Contingent upon the yield, the entire season cultivating expands the efficiency of the cultivated surface by a component of 4 to 6. Because crops won't need to be transported between production and sale, they won't be sold in the same infrastructures where they were grown. This means that they won't spoil, get infected, or use as much energy as they would in traditional farming.
- **Protection from Issues Caused by the Weather:** Because it provides a stable climate, vertical plant farming's production can be largely weather-independent and protected from severe weather.
- **Environment-friendly:** Reduces costs, energy use, and carbon footprint by significantly reducing travel distance.
- **Growing Produce of a Higher Quality:** Produce is of a higher quality, has a greater nutritional value, and has a longer shelf life because toxic pesticides and herbicides are not required.
- **Protection of Assets:** Because of overpopulation, vertical cultivating would wipe out the requirement for new farmland, saving numerous regular assets. Farming infringement on regular biomes will bring about deforestation and desertification, which would be forestalled.
- **Flexibility:** Over 80 different leafy greens

and micro greens can be grown in vertical structure which may work on non-arable land and in close proximity to major markets or cities. From small to very large food operations, it's scalable.

Compared to traditional farming V/S vertical farming

- The yields are approximately five times higher than the typical volume of field crop production.
- Only 8% of the water normally used to irrigate field crops is required by vertical crops.
- High levels of food safety because the growing process is enclosed.
- Huge working and capital expense investment funds over field agribusiness.
- It limits respect to ozone depleting substance discharges, soil debasement and so on.

Estimated yield of a Vertical Farm compared to traditional agriculture

Crops	Yield in VF due to tech. (tons/ ha)	Field Yield (tons/ ha)	Factor increase due to Technology
Carrots	58	30	1.9
Radish	23	15	1.5
Potatoes	150	28	5.4
Tomatoes	155	45	3.4
Pepper	133	30	4.4
Peas	9	6	1.5
Cabbage	67	50	1.3
Lettuce	37	25	1.5
Spinach	22	12	1.8
Total (average)	71	28	2.5

Source: Designed in a CE study by the author at DLR Bremen

SWOT Analysis of vertical farming-

Strength	Weakness
• Increases productivity & yields • Water conservation • Can be grown year-round. • No traces of human activity. • Produces healthier crops with fewer pesticides. • Use of nutrient solution that can be reused.	• Precision monitoring & expensive start-up costs limit this technology to low profile crops. • Requires a higher level of energy. • There is a lower rate of pollination.
Opportunities	Threats

• There are no seasonal restrictions. • Using artificial lights. • Nutrient required by the crop. • Highly regulated environment.	• When a component of the vertical irrigation system fails, that may lead to early plant death.
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Conclusion

Food sustainable development in urban areas could benefit greatly from the use of vertical farms. Vertical farming is surely a solution to critical issues in Indian farming like an absence of providing or oversupply of farm produce, too much use of pesticides, fertilizers, weaken soils and even the unemployment. It ensures high level of food safety with a year round production. The state and central governments can support farmers initially by providing a rebate on initial investment costs at lower prices for increasing the area on vertical farming and to protect farmer's interest.

References

1. Al-Chalabi, M. (2015). Vertical farming: Skyscraper sustainability. *Sustainable Cities and Society*, 18, 74-77.
2. AlShrouf, A. (2017). Hydroponics, aeroponic and aquaponic as compared with conventional farming. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, 27(1), 247-255.
3. Arancon, N. Q., & Edwards, C. A. (2005). Effects of vermicomposts on plant growth. *Soil Ecology Laboratory, The Ohio State University, Columbus, 43210*, 16-18.
4. Beacham, V., Vickers, L. H., & Monaghan, J. M. (2019). Vertical farming: A summary of approaches to growing skywards. *The Journal of Horticultural Science and Biotechnology*, 94(3), 277-283.
5. Bhangaonkar, A. B., Joshi, M. P., & Huseni, S. S. (2017). Exploring economical & environmental benefits of vertical farming using multistory panels. *International Journal of Advance Engineering and Research Development*.
6. Bridgewood, L. (2002). *Hydroponics: Soilless gardening explained*. Crowood Press.
7. Cicekli, M., & Barlas, N. T. (2014). Transformation of today green house into high technology vertical farming systems for metropolitan regions. *Journal of Environmental Protection and Ecology*, 15(4), 1779-1785.
8. Dunn, B., & Singh, H. (2017). OSU extension fact sheets: Building a vertical hydroponic tower. Oklahoma Cooperative Extension Service.
9. FAOSTAT. (2012). *Food and agricultural organization of United States; Rome, Italy: FAO*

Statistical yearbook, 2012. World food and agriculture, www.fao.org.

10. **Kumar, A.** (2019). Integration of vertical farming and hydroponics: A recent agricultural trend to feed the Indian urban population in 21st century. *Acta Scientific Agriculture* 3(2): 54-59.
11. **Manoj, K.G., & Sreedhar, G.** (2015). Vertical farming using information and communication technologies. Researchgate.
12. **Markham, D.** (2015). Farm in a box produces an acre's worth pf crops in a shipping container.
13. **Pascual, M. P., Lorenzo, G. A., & Gabriel, A. G.** (2018). Vertical farming using hydroponic system: Toward a sustainable onion production in Nueva Ecija, Philippines. *Open Journal of Ecology*, 8, 25-41.
14. **Sonawane, M. S.** (2018). Status of vertical farming in India. *International Archive of Applied Sciences and Technology*, 9, 122-125.
15. **Yeang, K.** (2002). Reinventing the skyscraper- A vertical theory of urban design. *Wiley academy*.

Received : November 2023; Revised : December 2023; Accepted : January 2024



HYDROPONICS FARMING: CHALLENGES AND POSSIBILITIES

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ABSTRACT

Hydroponics is a innovative agricultural method of plant growing without soil using mineral nutrient solutions. It is also called “Controlled Environmental Agriculture” (CEA). Hydroponics, a water culture, is now used in both research and commercial fields. Some countries successfully implemented this technique for fast-growing horticulture crops such as strawberries, lettuce, tomatoes and carnations. In this technique water culture scientists discovered that as compared to soil-based growth, hydroponic plant system needs only a small number of inorganic elements in addition to water, oxygen, and sunlight to grow the plant. Hydroponics farming can be a major advantage for Indian agriculture; it has the potential to produce crops in every season without soil. This system has become increasingly popular in recent years due to its numerous benefits, including increased water and nutrient efficiency, reduced land use, and increased crop yield and quality. Such practices can help Indian farmers increase their crop productivity even in small fragmented lands. This review paper focuses on the challenges and possibilities of bringing soil-less farming in India to ensure its stability so that it may prove more beneficial for Indian farmers to grow crops which are 100% organic, toxic-free and of better quality.

Keywords: hydroponics, nutriculture, soilless culture.

Introduction

All of the essential elements needed for plant growth are found in soil. It offers water, nutrients, and other things necessary for plants to flourish successfully. The existence of soil enables all significant beneficial processes, including the fixation of nitrogen, the provision of moisture, and the development of entire plants. However, in urban settings, space is one of the limiting elements for any form of agricultural production; in contrast, plants require broad spaces and open fields to develop. Plant scientists recently created hydroponics to get around this restriction. The Greek words “hydro,” which means water, and “ponos,” which implies labour, are the origin of the phrase hydroponics.

This system is most effective to help face the challenges of climate change and also helps in the production of crops and vegetables which is 100% safer to eat. For hydroponics technology, no soil is required to grow some selected demanded crops. It is also termed as (soil-less culture) technique where crops are grown in liquid-based nutrient-rich solutions under a green greenhouse. As it is well known hydroponics does not require any soil, where the root system is supported using inert medium such as clay pellets, perlite, gravels etc. The purpose behind this is to allow the plant roots to come in direct contact with nutrient solutions while having access to oxygen, which is essential for proper growth.

The global demand for food grains and other

vegetables are increasing every year. Our country India is no exception to this. This technique can be an alternative to Indian agriculture system, which still depends upon age old techniques. Indian farmer are not much aware of hydroponics systems, as it require some skills to operate this system. The main challenge is low literacy rate among farmers, which is low and in order to prepare them, we need to guide maximum number of farmers so that those farmers could guide and teach another one. For the farmers those have less fragmented land can perform hydroponic culture in greenhouse to increase crop productivity. In cases of crop loss by natural disaster, they must have another option of farming to survive and grow organic, pesticides free vegetables which would further enhance economic growth of our country.

Market size and trends

In 2020, the hydroponics industry had a value of USD 2.1 billion and is predicted to grow at a CAGR of 20.7% from 2021 to 2028. The rapid growth of the industry can be attributed to the increasing acceptance of hydroponic systems for indoor vegetable cultivation. Moreover, countries such as Canada, the Czech Republic, and South Africa have legalized marijuana, resulting in unconventional agricultural methods being used for marijuana production. As consumers become more aware of the harmful effects of pesticides and artificial ripening agents, the use of hydroponics is expected to increase since it eliminates the need for these substances and produces healthier vegetables.

Advantages of hydroponics:

1. The use of hydroponic techniques results in high-yield, healthy crops free from soil-borne pests, illnesses, and weed infestation.
2. Organic food is produced by soilless cultures, which also avoid the use of hazardous chemicals and pesticides.
3. Small-root plants can be grown closer to one another, using less area than a traditional dirt garden.
4. In hydroponics, crops grow twice as quickly and yield doubles, resulting in more production from the same amount of area.
5. No water waste because, in comparison to traditional farming, this technique uses just one-twentieth of the water for crops. Evolution of

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6. Less labour is needed.
7. Crops may be grown year-round, so there's no need to worry about changing seasons.
8. One farming method that reduces abiotic stress is hydroponics.
9. Eco-friendly methods that do not damage the environment.

Possibilities:

1. Offering farmers more training opportunities.
2. Offering them a hydroponic system at a reasonable cost.
3. The goal of hydroponics is to create a hydroponic food park in every city.
4. In order for farmers to benefit from this technique, agricultural universities and research institutions should collaborate with the Indian government to conduct surveys and attempt to implement it on a large scale.
5. The most prestigious job in the country should be farming, allowing young farmers to envision themselves working in the industry and utilising cutting-edge farming methods.

Types of Hydroponic Systems

Although there are many other hydroponic farming techniques, there are six fundamental varieties that can be divided into active and passive systems:-

1. **Wick System-** The Wick System, which is frequently thought of as the most straightforward kind of hydroponics, is referred to as a passive system, which simply means that it has no moving parts. Instead, wicks are utilized to draw nutrient solution into the growing media. These wicks hang down into a water reservoir. Perlite, Vermiculite, Rockwool, and Coconut Fiber are among the most widely used growing mediums that can be utilized with this technique. Although it is the most straightforward approach, it is not recommended for growing large plants or plants that require a lot of water since these plants may use the nutrient solution more quickly than the wicks can replenish it.
2. **Water Culture** This system is active since it contains moving pieces. Water Cultures are still regarded as the most basic type of active system, nevertheless. With this technique, the plant roots are fully submerged in the water reservoir containing the nutritional solution. The water is usually oxygenated with the aid of a pump, allowing the roots to breathe. Although this technique is sometimes regarded as the most

straightforward active system, few plants are suitable for it. Similar to the Wick System, big plants are not a good fit for this technique.

3. **Ebb & Flow System** With these methods, the water-based fertilizer solution temporarily floods the grow tray. The solution is then used to encircle the plant roots before being drained back into the reservoir using a pump that is submerged in the liquid. Usually, a timer is used to automate this operation. These adaptable systems work with a range of growing media.
4. **Drip System** The most common kind of hydroponic system in use today. A network of raised misting jets that spray the plants from above are controlled by a submerged pump that pumps water and fertilizer solution from a reservoir. This system comes in two main forms: one with a recovery system that collects nutritional solution and returns it to the reservoir, and the other without. Non-recovery systems require less upkeep since they keep the reservoir's pH level from fluctuating, even though recovery systems can use the nutrient solution more efficiently.
5. **N.F.T. System** Most people probably envision a system like this when they think of hydroponics. The nutrient Film Technique, also known as NFT, is a technique that uses a continuous flow of nutrient solution that is pumped from the reservoir into the growing tray. This system has the significant benefit of not requiring a growing medium because the plants are supported by tiny plastic baskets, allowing the roots to hang down and absorb nutrients directly from the solution. In order to avoid technical problems, this type of system can be rather high maintenance; however, once the flow of nutrients stops, plant roots can quickly dry out.
6. **Aeroponic System** This hydroponic technique is frequently thought of as high-tech. Similar to the NFT system, there is no growing medium; instead, the nutrient solution is misted onto the roots every few minutes. This method, like the NFT system, necessitates considerable attention because if the misting cycle is broken, the roots quickly dry out.

Constraints:

Hydroponics has certain restrictions in addition to its many advantages. Setting up a large-scale application requires technical expertise. Additional setup costs are expensive and necessitate ongoing oversight. Poor handling during hydroponics techniques can easily lead to the introduction of water-based diseases. Not all

crops can be cultivated using these methods, which is another significant constraint. Carrots and potatoes are two such examples. pH, humidity, and temperature are further restrictions.

Challenges:

Because hydroponic systems are expensive, poor Indian farmers cannot afford them. Crop-growing involves significant skills and practical understanding. Reduced awareness leads to an unfocused agriculture sector in India. Giving knowledge and instruction to all farmers, from average to impoverished, is not an easy task. Another motive is to support the farmer in generating interest and to ensure better results and high harvests. Farmers that are willing to work in this field but lack system understanding should hire a horticulture or other qualified staff. Hiring employees at a reasonable salary is a significant challenge.

Table- List of crops that can be grown in Hydroponics

Type of Crop	Name of the Crop
Vegetables	Tomato, chilli, beet, cauliflower, melons, cucumber, cabbage
Fruits	Strawberry
Condiments	Mint, parsley
Flower	Marigold
Medicinal	Aloe vera
Fodder	Barley, sorghum
Leafy	Lettuce

Hydroponics Prospects in India:

In certain nations, such as Israel, where the environment is dry and arid, hydroponics has been effectively implemented. The fastest-growing area of agriculture is hydroponics, which has great potential for future food production. People are focusing more on innovative technologies like hydroponics and aeroponics to feed the country as a result of the country's declining land and growing population. Climate change and natural disasters like droughts and floods are some of the causes for the transition to new technology that offers safe food production.

Conclusion

Hydroponic systems are very successful methods that are applied in a variety of

agricultural fields as well as in the event of a natural disaster. Although this system employs fewer personnel, it is nonetheless costly and complex despite having a high level of output. The farmer or other concerned party can change this notion to a more cost-effective one or design some equipment. Since the hydroponics system needs to have its PH and nutrient levels checked, understanding these things is essential. Any country can focus on implementing such a system, either in villages or by establishing food parks or urban farms under government control. When utilised properly, this method can result in self-sufficiency.

References

1. Britto, D.T. & Kronzucker, H.J. (2002): NH_4^+ toxicity in higher plants: a critical review. *Journal of Plant Physiology* 159 (6): 567-584.
2. Cramer, G.R. (2002) Sodium-calcium interactions under salinity stress. In: *Salinity: Environment-Plants Molecules*, A. Lauchli & U. Lüttge: 205-227, Kluwer Academic Publishers, Dordrecht, Netherlands
3. Dreccer, M.F., Ogonnaya, F.C. & Borgognone, M.G. (2004): Sodium exclusion in primary synthetic wheats. *Proceedings of 54th Australian Cereal Chemistry Conference and 11th Wheat Breeding Assembly*, C.K. Black, J.F. Panozzo & G.J. Rebetzke: 118-121, Royal Australian Chemical Institute, Melbourne, Australia
4. Drihem, K. & Pilbeam, D.J. (2002): Effects of salinity on accumulation of mineral nutrients in wheat growth with nitrate-nitrogen or mixed ammonium: nitrate-nitrogen. *Journal of Plant Nutrition*, 25 (10): 2091-2113
5. Wangwilbulkit, M., Vajrodaya S., (2016): *Ex-situ propagation of Pogostemon helferi* (Hook. f.) Press using tissue culture and a hydroponics system. *Agriculture and natural resources* 50: (20-25).
6. Farnoosh, A., Asghar, G., Golabi, H.M., (2016): Interaction effects of water salinity and hydroponic growth medium on eggplant yield, water-use efficiency, and evapotranspiration. *Journal International soil and water conservation research*, 99-106
7. Saha, S., Monroe, A., Day, M.R., (2016): yield, plant quality and nutrition of basil (*Ocimum basilicum* L.) under soilless agricultural systems. *Journal- annals of agriculture science*, 61: 181-186.
8. Sardare M.D., Shraddha V., Admane A review on plant without soil – Hydroponics. *Journal International Journal of Research in Engineering and Technology* (02): 03 Mar-2013. 299-304.
9. Anuragputra, P., Yuliando, H., (2015): Soil less culture system to support water use efficiency and product quality: A review *Agriculture and Agriculture science Procedia*, 3: (283-288)
10. Sonneveld, C., (2000): Effects of salinity on substrate grown vegetables and ornamentals in greenhouse horticulture. *PhD Thesis*, University of Wageningen, The Netherlands
11. Savvas, D., (2002): Nutrient solution recycling in hydroponics. In: *Hydroponic Production of Vegetables and Ornamentals* (Savvas D; Passam H C, 299–343. Embryo Publications, Athens, Greece
12. Samreen, T.H., Shah, H.U., Ullah, S., Javid, M., (2013): Zinc effect on growth rate, chlorophyll, protein and mineral contents of hydroponically grown mungbeans plant (*Vigna radiata*). *Arabian journal of Chemistry*
13. Van Os E A; Gieling T. H., Ruijs M. N. A., (2002): Equipment for hydroponic installations. In: *Hydroponic Production of Vegetables and Ornamentals* (Savvas D; Passam H C, 103–141. Embryo Publications, Athens, Greece
14. Shavruk, Y., Genc, Y., Hayes, J., (2012): The use of hydroponics in abiotic stress tolerance research. *Journal-A standard methodology for plant biological research*. 3(39-66).

Received : September 2023; Revised : October 2023; Accepted : January 2024



PRECISION APPLICATION OF NITROGEN BY ROOT DIPPING APPLICATION AS STARTER SOLUTION IN CHILLI (*CAPSICUM ANNUUM* L.)

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ABSTRACT

To meet the nutritional demand of the vegetable crops, it is essential to supply nutrients throughout their growth period. Supply of nutrients at initial growth stages of plant leads to improved root development thus ultimately enhances nutrient uptake. Application of fertilisers near the plant root zone had been found more beneficial in liquid form as compared to solid applications. Therefore, an experiment was conducted that comprised one control N₁ (water dip only) and three concentrations of urea solution *viz.*, N₂ (1% urea solution), N₃ (2% urea solution) and N₄ (3% urea solution) applied as root dip to chilli hybrid *i.e.*, G₁ (Arka Gagan) and variety namely G₂ (Kashi Anmol). All the treatments were laid out in Factorial Randomized Block Design (FRBD) with three replications. The data observed for all the parameters was found significantly affected with the use of varying concentration of urea solution. All the growth and yield parameters were statistically improved with increased concentration of urea solution from 0 to 3 per cent, while the least days to first flowering (87.50) and days to 50% flowering (94.83) and days to first harvest (112.83) were observed under control treatment. Performance of the hybrid (Arka Gagan-962.1 g/plant) and variety (Kashi Anmol-879.7 g/plant) in terms of yield was improved by 24 % and 19.4% respectively, with the application of 3% urea solution as root dipping as compared to control treatment (water dip).

Keywords: Root primming, Liquid fertilizers, Nitrogen, Starter solution, Urea

Introduction

Chilli or Hot pepper (*Capsicum annuum* L.) is the third most important vegetable and spice crop of family Solanaceae, following tomato and potato (29). It is a warm season crop that requires humid temperature to grow and a dry climate to mature. It is semi-perennial in nature, but commonly grown as an annual crop. Chilli exhibits several important minerals and bioactive compounds that have antioxidant, antibacterial, antiviral, anti-inflammatory and anticancer properties (24). Fresh green chillies have more vitamin C (242 mg/100 gm) than citrus fruits (70 mg/100 gm) (27). Besides adding flavour, chilli also have important nutraceutical value (33). Capsaicin is

currently used for the treatment of diabetic neuropathy, osteoarthritis, post-herpetic neuralgia, and psoriasis (22).

Being a largest consumer, producer and exporter of chilli, India produced 4.7 million tonnes from an area of 4.3 lakh ha with productivity of 8.4 tonne/ha (28). The productivity of crops depends upon various biotic and abiotic factors among which fertilization is considered as most important (15), (14), (26). Nitrogen is an important nutrient that affects growth and photosynthetic rates, thus productivity (9), (31), (45). Only a small amount (10% to 40%) of nitrogenous fertilizer is taken up by plants (8) most of it is lost due to hydrolysis, leaching and microbial immobilisation or

degradation (17), (19). Therefore, the precision of amount, duration and method of nitrogenous fertilizer application is of utmost importance.

Application of fertilizers in liquid form found to be more beneficial if placed near the plant root zone at early growth stages of plant (12), (32). It makes the nutrients more readily available thus significantly increases the nutrient uptake by plant roots. The increased efficiency with liquid applications decreases the fertilizer requirement up to 50% less than conventional solid applications (25). Providing nutrition at early stage in liquid form can also help to reduce the transplanting shock. Applications of phosphate fertilizer as starter solution at three days after transplanting observed the higher survival rate of tomato seedlings (13). Urea containing starter solutions have also been found to improve plant growth of different vegetables like chilli, cabbage, cauliflower and tomato (12), (32), (39). In this context, the research was aimed at finding the correct dose of urea solution application as starter solution for quality production of chilli with higher productivity.

Materials and Methods

Experimental site

The present investigation entitled “Precision application of nitrogen by root dipping application as starter solution in chilli (*Capsicum annuum* L.)” was conducted at experimental Vegetable Research Farm, P.G. Department of Agriculture, Khalsa College, Amritsar during 2022-2023.

Planting materials

The seeds of hybrid Arka Gagan were procured from IIHR, Bangalore, Karnataka and variety Kashi Anmol from IIVR, Varanasi, Uttar Pradesh, India. The seeds were sown in plug trays filled with a soilless mixture of cocopeat, perlite and vermiculite (3:1:1) during the second fortnight of October in the year, 2022.

Experimental methodology

The urea solutions of different concentration i.e., 1%, 2 % and 3 % were prepared by dissolving the required amount of urea fertilizer (46% N) per litre of water. The control treatment was kept as water dip only (0% urea solution). Before transplanting the seedlings at the age of thirty-five days, the seedlings were uprooted from the plug trays and growing medium was removed by shaking or slightly hitting to ground. The seedling roots of both Arka Gagan and Kashi Anmol

were dipped into urea containing solutions. The treated seedlings were planted on one side of the ridges at a spacing of 75 cm × 45 cm. The field was slightly irrigated just after transplanting. The experiment consisted of eight treatments replicated thrice that were laid out in factorial randomised block design. There were fifteen plants transplanted in each treatment per replication. The whole experiment was performed under low tunnel technology to save the seedlings from frost till the middle of February. All the package and practices were followed for raising a good crop as per given in the book prepared by Punjab Agricultural University, Ludhiana (3).

Observations recorded

The data for different plant parameters were determined from six randomly selected plants in each replication per treatment and the average was calculated. The data was collected as follows;

Growth parameters

The plant height (cm) at fifteen days interval was measured from base to tip of the last leaf with the help of measuring tape. The number of primary and secondary branches in plant was counted at final harvest and their sum was used as number of total branches per plant. The length of longest root was measured with the help of measuring scale from stem base to the end point of root after final harvest by uprooting the plants.

Flowering parameters

The number of days taken from the date of transplanting to the appearance of first flower was counted and expressed as number of days to first flowering. The number of days taken from transplanting to the opening of flowers on 50% plants in each treatment per replication were noted down and expressed as days to 50% flowering. The number of days taken from transplanting to harvest of at least one ripe fruit in each treatment per replication were counted and expressed as days to first harvest.

Fruit and yield parameters

The data for fruit parameters was taken from randomly selected six fruits in each treatment per replication in the middle of harvesting and the average was computed. The fruit length was measured from the apex to base of fruit leaving peduncle. Average fruit weight (g) was worked out by weighing randomly selected five fruits in each treatment per replication and average was worked out. The total number of fruits harvested in each picking was counted, adding the

number over all pickings and average of six plants was worked out to express number of fruits per plant. Fruit yield per plant was calculated by adding marketable yield of randomly selected six plants in each picking and their averaged was calculated. The total yield per hectare (q/ha) was calculated by multiplying the yield per plant with the number of plants in a hectare.

Statistical analysis

The data pertaining to the present investigation were statistically analysed at the 5% level of significance using OPSTAT software (36).

Results

Growth parameters

Plant height

Significant variation was recorded in plant height of chilli due to different concentrations of urea solution at all (15, 30, 45, 60 and 90) days after transplanting (DAT) (Table 1). The plant growth is represented with their respective treatments in the Fig. 1. At 15 DAT, the tallest plant height (14.13 cm) was recorded from N₄ (3% urea solution) followed by 12.03 cm under N₃ (2% urea solution), which was statistically at par with 11.10 cm under N₂ (1% urea solution) treatment. While, the shortest plant height (9.48 cm) was recorded from control, where no urea solution as root dipping was applied. Similarly at 30 DAT, the tallest plant height (18.59 cm) was recorded in N₄ (3% urea solution) followed by N₃ (2% urea solution) and N₂ (1% urea solution) 17.38 cm and 15.02 cm, respectively. The shortest plant height of 12.35 cm was recorded from N₁ (0% urea solution) treatment at 30DAT. Same trends of growth in plant height was observed as tallest plant height of 26.48, 30.75 and 34.11 cm under N₄ (3% urea solution) treatment at 45, 60 and 90 DAT, respectively. The shortest plant height of 20.18, 24.21 and 29.00 cm at 45, 60 and 90 DAT, respectively was observed under N₁ (0% urea solution) treatment.

Among genotypes, Arka Gagan achieved maximum height of 15.25 cm, 20.54 cm, 28.82 cm, 33.64 cm and 37.85 cm than Kashi Anmol genotype as 8.11 cm, 11.12 cm, 17.76 cm, 21.27 cm and 25.04 cm at all 15, 30, 45, 60 and 90 DAT respectively. Combined effect of different concentrations of urea solution and the genotypes showed significant differences for plant height only at 15 and 30 DAT. The difference in plant height as combined effect of urea solution and genotypes at 45, 60 and 90 DAT was found statistically non-significant. However, at 15 DAT

the tallest plant (18.73 cm) was recorded from G₁N₄ (Arka Gagan and 3% urea solution) the shortest plant height (6.93 cm) was recorded from G₂N₂ (Kashi Anmol and 1% urea solution). At 30 DAT the tallest plant (24.58 cm) was recorded from G₁N₄ (Arka Gagan and 3% urea solution) which was statistically at par with G₁N₃ (Arka Gagan and 2% urea solution) (22.87 cm) while the shortest plant was recorded from G₂N₁ (Kashi Anmol and 0% urea solution) (9.50 cm).

Number of branches per plant

The highest number of branches (30.07) was recorded under N₄ (3% urea solution) followed by N₂ with 26.35 and N₃ with 25.46 while the lowest number of branches (25.00) was recorded under N₁ (1% urea solution). It was evident from the results, that number of branches per plant increased with the application of urea solution at higher concentration *i.e.*, 3% urea solution. While, the concentration lower than 3% urea solution did not influenced the number of branches per plant. Genotype Arka Gagan observed statistically higher number of branches (27.74) than the genotype Kashi Anmol (25.70). Similarly, the significant interaction effect was observed where the highest number of branches (31.67) per plant was recorded from G₁N₄ (Arka Gagan and 3% urea solution) followed by 28.47 under G₂N₄ (Kashi Anmol and 3% urea solution).

Root length (cm)

The longest root (22.58 cm) was measured from the treatment N₄ (3% urea solution) followed by 17.91 cm under N₃ (2% urea solution) which was statistically at par with 16.36 cm under N₂ (1% urea solution), while the shortest root length (13.10 cm) was measured from N₁ (0% urea solution) that is presented in table 1. The length of plant roots with their respective treatments is presented in Fig. 2. Among genotypes, the longest (19.12 cm) root length was measured from the genotype Arka Gagan than in the genotype Kashi Anmol (15.85 cm).

The interaction effect of urea solution and genotypes showed significant variation where the longest root (26.66 cm) was measured under G₁N₄ (Arka Gagan and 3% urea solution) treatment combination followed by 19.50 cm under G₁N₃ (Arka Gagan and 2% urea solution), while the shortest root length (13.03 cm) was measured in the treatment combination G₂N₁ (Kashi Anmol and 0% urea solution) statistically at par with 13.16 cm under G₁N₁ (Arka Gagan and 0% urea solution).

Flowering parameters

Data presented in the Table no. 2 revealed that the minimum days to first flowering (87.50), 50% flowering (94.83) and first harvesting (112.83) observed under control whereas maximum days to first flowering (92.50), 50% flowering (100.33) and first harvesting (117.83) was recorded under 3% starter solution. Among genotypes, Arka Gagan took the minimum days to first flowering (95.50), 50% flowering (99.41) and first harvesting (119.16) as compared to the genotype Kashi Anmol. Interaction effect of starter solution and genotypes observed non-significant for the days to first flowering, 50% flowering and for the first harvesting.

Fruit and yield parameters

All the fruit parameters were statistically influenced with use of different concentrations of urea solution (Table 3). The maximum average fruit length (7.89 cm), fruit diameter (9.50 mm) and fruit weight (2.87 g), number of fruits per plant (382.57), yield per plant (1019.74 g) and yield per hectare (302.14 q/ha) were measured under the 3% starter solution treatment and the minimum average fruit length (7.06 cm), fruit diameter (7.10 mm) and fruit weight (2.64 g), number of fruits per plant (337.72), yield per plant (836.96 g) and yield per hectare (247.98 q/ha) were measured under control treatment (0% urea solution). Among different chilli genotypes, significantly maximum number of fruits per plant (465.14), yield per plant (962.13 g) and yield per hectare (285.07 q/ha) was found in genotype Arka Gagan whereas maximum fruit diameter (8.60 mm) and fruit weight (3.44 g) was observed in Kashi Anmol. While, the variation in fruit length between different chilli genotypes was observed non-significant. The interaction effect of starter solution and genotypes, the maximum fruit diameter (10.0 mm) and fruit weight (3.62 g) was observed under 3% urea solution applied to Arka Komal (G_2N_4). While, the maximum number of fruits per plant (505.84) were observed under the treatment combination of Arka Gagan at 3% urea solution (G_1N_4). Whereas, the interaction effect of genotypes and urea solution was found non-significant for yield per plant (g) and yield (q/ha) in chilli.

Discussion

All the growth parameters like plant height, total number of branches per plant and root length were significantly improved with the increasing concentration of urea as starter solution. Moreover, the

maximum plant height at all days, total number of branches (27.74) and root length (19.12 cm) was measured under 3% starter solution whereas, the minimum plant height, total number of branches per plant (25.00) and root length (25.00cm) was recorded under control. The increased plant height with increased concentration of nitrogen was also observed by (38) and (23). The application of nitrogen enhances the vegetative growth that ultimately improved the number of branches per plant (5). Root length increased with increasing levels of nitrogen was also observed by (41) in chilli and in cabbage by (30). At initial growth period up to 30 DAT, the interaction of cultivars with higher concentration of urea solution (3%) application produced maximum plant height. The results are in line with study conducted by (10) who also observed the significantly highest plant height (cm) from interaction of cultivars and nitrogen applications as compare to control treatment. While, at later growth stage from 45 to 90 DAT, the interaction effect of chilli genotypes and concentration of urea solution was not significant. Similar results of non-significant interaction between cultivars and nitrogen level was observed by (43).

The delay in flowering with increased application of nitrogen fertilization may be due to the diversion of photosynthates for vegetative growth instead of reproductive phase (18). Similar results were reported in capsicum by (40) and in potato by (34). The delayed flowering leads to increased days in first fruit harvest that was also observed by (42) and (7) in chilli. The different responses of the genotypes for the flowering time might be related to genetic variation (43). Similar results of late first harvest in Calabrese type broccoli (55.81 days to) than the sprouting green (81.19 days) type broccoli were observed under the different level of nitrogen application by (16).

The availability of important nutrient supplement *i.e.* nitrogen at early growth stage may helped to boost fruit length (cm), fruit diameter (mm) and fruit weight (g) that was also reported in studies conducted by (41), (32), (20), (1). Moreover, the nitrogen improves vegetative growth that produce more number of branches thus more number of fruits (41) The similar results of increased number of fruits with increased nitrogen applications were reported by (32). The response of additional nitrogen may be due to the fact that plant produce more leaves would have increased photosynthetic and hence better performance in terms of yield (35). (37) and (2) founds similar result of

significantly increase in yield per plant with the increased nitrogen in broccoli and pepper. The higher average fruit weight and higher number of fruits per plant could be another reason for high yield (21), (44), (6) and (11).

Conclusion

Application of urea solution as root dipping improved the growth and yield parameters of chilli. All the parameters were found to be improved with increased concentration of urea solution except for flowering that was delayed. Both the hybrid Arka Gagan and variety Arka Komal performed positively to applied urea solution as root dipping that recorded higher yield of 24 % and 19.4% per plant respectively compared to control (water dip).

Acknowledgement

Authors are thankful to the authorities of Khalsa College, Amritsar for providing the required resources and support to conduct this research experiment. Authors are also thankful to the PG Department of Khalsa College for providing all facilities to conduct the experiment. The first author is the student of Gagandeep Singh, for his M.Sc. thesis submitted to Guru Nanak Dev University, Amritsar.

References

1. Akanbi, W.B., Togun, A.O., Akinfasoye, J.O. & Tairum, F.M. (2007). Physio-chemical properties of eggplant (*Solanum melongena* L.) fruit in response to nitrogen fertilizer and fruit size. *Agricultural Journal*, 2(1), 140-148.
2. Aliyu, L. (2002). Growth and yield of pepper (*Capsicum annum* L.) as affected by nitrogen and phosphorus application and plant density. *Crop Research Hisar*, 23(3), 467-475.
3. Anonymous (2021). *Package of Practices for Cultivation of Vegetables*. Punjab Agricultural University, Ludhiana.
4. Anonymous (2023). Area and production of chilli in India. *Ministry of Agriculture and Farmer welfare, Government of India*. Retrieved 13 September, 2023, from <https://www.indiastat.com>. Gade
5. Ayodele, O.J., Alabi, E.O. & Aluko, M. (2015). Nitrogen fertilizer effects on growth, yield and chemical composition of hot pepper (Rodo). *International Journal of Agriculture and Crop Sciences*, 8(5), 666-673.
6. Bahuguna, A., Singh, B. & Bahuguna, S. (2014). Consequence of optimum levels of fertilizer on enlargement and yield of vegetable pea cv. VI ageti matar 7 under Uttarakhand hills condition, *Journal of Agronomy*, 13(3), 153-157.
7. Baloch, P.A., Abro, B.A., Solangi, A.H. & Siddiqui, A.A. (2013). Growth and yield characteristics of chilli as affected by nitrogen in presence and absence of phosphorus and potassium: nitrogen for growth and yield of chilli. *Biological Sciences*, 56(2), 70-75. <https://doi.org/10.52763/PJSIR.BIOL.SCI.56.2.2013.70.75>.
8. Bhardwaj, D., Ansari, M., Sahoo, R. & Tuteja, N. (2014). Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microbial Cell Factories*, 13, 1-10. <https://doi.org/10.1186/1475-2859-13-66>.
9. Biswas, M., Sarkar, D.R., Asif, M.I., Sikder, R.K., Mehraj, H. & Jamal Uddin, A.F.M., (2015). Effect of nitrogen levels on morphological and yield response of BARI tomato-9. *Journal of Science, Technology and Environment Informatics*, 1(2), 68-74. <http://dx.doi.org/10.18801/jstei.010215.08?>
10. Boroujerdnia, M. & Ansari, N.A. (2007). Effect of different levels of nitrogen fertilizer and cultivars on growth, yield and yield components of romaine lettuce (*Lactuca sativa* L.). *Middle Eastern and Russian Journal of Plant Science and Biotechnology*, 1(2), 47-53.
11. Chakrabarty, S. & Islam, A. K. M. (2017). Selection criteria for improving yield in chili (*Capsicum annum* L.). *Advances in Agriculture*, 1-9. <https://doi.org/10.1155/2017/5437870>.
12. Chhonkar, V.S. & Jha, R.N. (1963). The use of starters and plant growth regulators in transplanting of cabbage (*Brassica Oleracea* var. *capitata* L.) and their response on growth and yield. *Indian Journal of Horticulture*, 20(2), 123-128.
13. Desher, M.A. (2017). The effect of phosphate fertilizer starter solution on growth of two tomato (*Lycopersicon Esculentum* Mill) Varieties in Sandy Soil. *Al-Qadisiyah Journal of Agriculture Sciences*, 7(1), 1-15. <https://doi:10.33794/QJAS.2017.124332>.
14. El-Afifi, S.T., Zaghloul, M.M., El-Sawy, M.B.I. & Hashim, A.M.A. (2014). Effect of starter solutions in soil and foliar spray with some stimulants on growth and productivity of Chinese cabbage. *Journal of Plant Production*, 5(1), 21-40. <https://doi:10.21608/JPP.2014.53311>.

15. Gade, P.A., More, S.S., Shelke, R.D. & Nalegaonkar, A.R. (2020). Growth and instability in area, production and yield of chilli in India. *International Journal of Current Microbiology and Applied Sciences*, 9(11), 2647-2654. <https://doi.org/10.20546/ijcmas.2020.911.321>.
16. Giri, R.K., Sharma, M.D., Shakya, S.M., Yubak Dhoj, G.C. & Kandel, T.P. (2013). Growth and yield responses of broccoli cultivars to different rates of nitrogen in western Chitwan, Nepal. *Agricultural Sciences* 4, 8-12. <https://doi.org/10.4236/as.2013.47A002>.
17. Green, J.M. & Beestman, G.B. (2007). Recently patented and commercialized formulation and adjuvant technology. *Crop Protection*, 26, 320-327. <https://doi.org/10.1016/j.cropro.2005.04.018>.
18. Guohua, X.U., Wilif, S, & Kolkafi, U. (2001). Interaction effect of nutrient concentration and container volume on flowering, fruiting and nutrient uptake of sweet pepper. *Journal of Plant and Nutrient*, 24(3), 479-501. <http://dx.doi.org/10.1081/PLN-100104974>.
19. Hirel, B., Tétu, T., Lea, P. J. & Dubois, F. (2011). Improving Nitrogen Use Efficiency in Crops for Sustainable Agriculture. *Sustainability*, 3(9), 1452-1485. <https://doi.org/10.3390/su3091452>.
20. Islam M.R., Sultana T., Haque M.A., Hossain M.I., Sabrin N. & Islam R. (2018). Growth and yield of chilli influenced by nitrogen and phosphorus. *Journal of Agriculture and Veterinary Science*, 11(5), 54-68. <https://doi.org/10.9790/2380-1105025468>.
21. Jilani M.S., Afzal M.F. & Waseem K. (2008). Effect of different nitrogen levels on growth and yield of brinjal (*Solanum melongena* L.). *Journal of Agricultural Research (Pakistan)*, 46(3), 245-251.
22. Jin R, Pan J, Xie H, Zhou B and Xia X (2009) Separation and Quantitative Analysis of Capsaicinoids in Chili Peppers by Reversed-Phase Argentionation LC. *Chromatographia* 70:1011-13
23. Katuwal, S., Ashworth, A.J., Moore Jr, P.A. & Owens, P.R. (2023). Characterization of nutrient runoff from perennial and annual forages following broiler litter application. *Journal of Environmental Quality*, 52(1), 88-99. <https://doi.org/10.1002/jeq2.20425>.
24. Khan M A, Asghar M A, Iqbal J, Ahmed A and Shamsuddin Z A (2014) Aflatoxins contamination and prevention in red chillies (*Capsicum annuum* L.) in Pakistan. *Food Addit Contam* 7:1-6
25. Latifah, E., Dewi, H.A., Daroini, P.B., Korlina, E., Hasyim, A., Andri, K. B., Zakariya, A. Z., Kuntariningsih, A., Negoro, A. A., Hakim, A. & Luther, G. C. (2019) Impact of starter solution technology on the use of fertilizers in production of chilli (*Capsicum annuum* L). *Earth and Environmental Science*, 230, 1-7. <https://doi.org/10.1088/1755-1315/230/1/012063>.
26. Mahmud, K., Hossain, T., Haque Mou, T., Ali, A. & Islam, M. (2020). Effect of nitrogen on growth and yield of chili (*Capsicum annuum* L.) in Roof Top Garden. *Turkish Journal of Agriculture - Food Science and Technology*, 8(1), 246-251. <https://doi.org/10.24925/turjaf.v8i1.246-251.2763>.
27. Marin A, Ferreres F, Tomas B F A and Gil M (2004) Characterization and quantization of antioxidant constituents of sweet pepper (*Capsicum annuum* L.). *J Agric Food Chem* 52:3861- 69.
28. Natarajan, A., Sahu, M., Srivastava, S.C. & Jaulkar, A.M. (2023). Study on cost of cultivation and economic returns from chilli crop growing districts of Telangana, India. *International Journal of Environment and Climate Change*, 13(9), 1592-1601. <https://doi.org/10.9734/ijec/2023/v13i92391>.
29. Naz S, Anjum M A and Ahmad I (2006) Growth of Chilli (*Capsicum annuum* L.) F1 hybrid sky line-2 in response to different ages of transplants. *J Res (Sci)* 17:91-95.
30. Pramanik, S. (2007). Effect of nitrogen and phosphorus on the growth and yield of cabbage. M.Sc. Thesis, Sher-e-Bangla Agricultural University, Dhaka, 21-42.
31. Rehman, M., Yang, M., Fahad, S., Saleem, M.H., Liu, L., Liu, F. & Deng, G. (2020). Morpho-physiological traits, antioxidant capacity, and nitrogen metabolism in ramie under nitrogen fertilizer. *Agronomy Journal*, 112(4), 2988-2997. <https://doi.org/10.1002/agj2.20212>.
32. Roy, R., Rahim, M.A. & Alam, M.S. (2010). Effect of starter solution and GA₃ on growth and yield of cabbage. *Journal of Agroforestry and Environment*, 3(2), 187-192. <https://doi.org/10.3329/jesnr.v4i2.10138>.
33. Ruanma K, Shank L and Chairote G (2010) Phenolic content and antioxidant properties of green chilli paste and its ingredients. *Maejo Int J Sci Technol* 4:193-200.
34. Sanli, A., Karadoğan, T., Erba?, S. & Tosun, B. (2015). The effects of plant density and eye number per seed piece on potato (*Solanum tuberosum* L.) tuber yield. *Scientific Papers-Series A, Agronomy*, 58, 325-331.

35. Sharmin, S. and Rahman, L. (2019). Optimization of nitrogen requirement for better growth and yield of brinjal (*Solanum melongena* L.). *Archives of Agriculture and Environmental Science*, 4(1), 33-38. <http://dx.doi.org/10.26832/24566632.2019.040105>.
36. Sheoran, O.P., Tonk, D.S., Kaushik, L.S., Hasija, R.C. & Pannu, R.S. (1998). Statistical software package for agricultural research workers. Department of Mathematics Statistics, CCS HAU, Hisar, 8(12), 139-143.
37. Shuvo, M. F., Khatun, K., Mostarin, T., Das, S.K., Bappy, S.H., Hossain, J., Akter, M. & Hossain, M. Md. (2021) Influence of starter solution and mulching on growth and yield of broccoli. *Asian Journal of Research in Botany*, 5(1), 33-45.
38. Singegol, H.Y., Patil, H.B. & Patil, D.R. (2007). Growth and yield of green chilli (*Capsicum annuum* L.) cv. Pusa Jwala as influenced by nitrogen and phosphorus. *Asian Journal of Horticulture*, 2(2), 184-187.
39. Soniya, I. A., Mostarin, T. Khatun, K., Haq, Md. E., Akhter, S., Sharmin, I., Monira, S. & Parvin, A. (2019). Effect of starter solution and age of seedling on growth and yield of broccoli (*Brassica oleracea* var. *italica*). *Asian Journal of Research in Crop Science*, 4(4), 1-11. <https://doi.org/10.9734/ajrcs/2019/v4i430081>.
40. Srivastava, B.K., Singh, M.P. & Joshi, K. (2003). Standardization of nitrogen and phosphorus requirement for *capsicum* hybrid. *Progressive Horticulture*, 35(2), 202-204.
41. Subedi, P., Bhattarai, P., Lamichhane, B., Khanal, A. & Shrestha, J. (2023). Effect of different levels of nitrogen and charcoal on growth and yield traits of chilli (*Capsicum annuum* L.). *Heliyon*, 9(2), 1-8. <https://doi.org/10.1016/j.heliyon.2023.e13353>.
42. Sutagundi, R.B. (2000). Effect of mulches and nutrient management on growth and yield of chilli (*Capsicum annuum* L.). M.Sc. Thesis, University of Agricultural Sciences, Dharwad, Karnataka, India
43. Wahocho, N.A., Zeshan Ahmed, S., Jogi, Q., Talpur, K.H. & Leghari, S.J. (2016). growth and productivity of chilli (*Capsicum annuum* L.) under various nitrogen levels. *Science International*, 28(2), 1321-1326.
44. Yatung T., Dubey R. K., Singh V., Upadhyay G., & Pandey A. (2014). Selection parameters for fruit yield and related traits in chilli (*Capsicum annuum* L.). *Bangladesh Journal of Botany*, 43(3), 283-291. <http://dx.doi.org/10.3329/bjb.v43i3.21600>.
45. Zhang, H., Zhao, Q., Wang, Z., Wang, L., Li, X., Fan, Z., Zhang, Y., Li, J., Gao, X., Shi, J. & Chen, F. (2021). Effects of nitrogen fertilizer on photosynthetic characteristics, biomass, and yield of wheat under different shading conditions. *Agronomy*, 11(10), 1989. <https://doi.org/10.3390/agronomy11101989>.

Table 1 Effect of root dipping application as starter solution on growth parameters of chilli

		Plant height (cm) at different days					Number of branches per plant	Root length (cm)
Treatments		15 Days	30 Days	45 Days	60 Days	90 Days		
Genotypes	G ₁ (Arka Gagan)	15.25 ^a	20.54 ^a	28.82 ^a	33.64 ^a	37.85 ^a	27.74 ^a	19.12 ^a
	G ₂ (Kashi Anmol)	8.11 ^b	11.12 ^b	17.76 ^b	21.27 ^b	25.04 ^b	25.70 ^b	15.85 ^b
	CD (p= 0.05)	0.93	1.24	2.06	2.27	2.22	0.67	1.34
	SE(m)	0.30	0.40	0.67	0.74	0.72	0.21	0.43
Urea solution	N ₁ (0% urea solution)	9.48 ^c	12.35 ^d	20.18 ^b	24.21 ^b	29.00 ^b	25.00 ^c	13.10 ^c
	N ₂ (1% urea solution)	11.10 ^b	15.02 ^c	22.57 ^b	27.38 ^b	30.80 ^b	26.35 ^b	16.36 ^b
	N ₃ (2% urea solution)	12.03 ^b	17.38 ^b	23.95 ^b	27.48 ^b	31.86 ^b	25.46 ^b	17.91 ^b
	N ₄ (3% urea solution)	14.13 ^a	18.59 ^a	26.48 ^a	30.75 ^a	34.11 ^a	30.07 ^a	22.58 ^a
	CD (p= 0.05)	1.32	1.76	2.91	3.22	3.15	0.95	1.89
	SE(m)	0.43	0.57	0.95	1.05	1.02	0.31	0.62
Interaction	Genotype × Urea solution							
	G ₁ N ₁	11.30 ^c	15.2 ^c	23.93	28.86	33.23	25.80 ^c	13.16 ^{ef}
	G ₁ N ₂	15.26 ^{bc}	19.54 ^b	27.91	32.97	37.36	28.21 ^b	17.16 ^{bcd}
	G ₁ N ₃	15.73 ^b	22.87 ^{ab}	29.86	34.56	39.10	25.27 ^c	19.50 ^b
	G ₁ N ₄	18.73 ^a	24.58 ^a	33.60	38.16	41.70	31.67 ^a	26.66 ^a
	G ₂ N ₁	7.66 ^e	9.50 ^g	16.43	19.56	24.76	24.20 ^e	13.03 ^f
	G ₂ N ₂	6.93 ^f	10.50 ^f	17.23	21.80	24.23	24.50 ^{de}	15.56 ^{de}
	G ₂ N ₃	8.33 ^{de}	11.90 ^e	18.03	20.40	24.63	25.46 ^{de}	16.33 ^{cd}
	G ₂ N ₄	9.53 ^d	12.60 ^d	19.36	23.33	26.53	28.47 ^b	18.50 ^{bc}
	CD (p= 0.05)	1.87	2.49	N/S	N/S	N/S	1.34	2.68
	SE(m)	0.61	0.81	1.34	1.48	1.45	0.43	0.87

Table 2 Effect of root dipping application of starter solution on flowering parameters of chilli

Treatments		Number of days to first flowering	Number of days to 50% flowering	Number of days to first harvesting
Genotypes	G ₁ (Arka Gagan)	95.50 ^a	99.41 ^a	119.16 ^a
	G ₂ (Kashi Anmol)	84.58 ^b	95.58 ^b	111.50 ^b
	CD (p= 0.05)	0.96	0.92	0.86
	SE(m)	0.31	0.30	0.28
Urea solution	N ₁ (0% urea solution)	87.50 ^d	94.83 ^d	112.83 ^d
	N ₂ (1% urea solution)	89.50 ^c	96.50 ^c	114.66 ^c
	N ₃ (2% urea solution)	90.66 ^b	98.33 ^b	116.00 ^b
	N ₄ (3% urea solution)	92.50 ^a	100.33 ^a	117.83 ^a
	CD (p= 0.05)	1.36	1.31	1.21
adjustright	SE(m)	0.44	0.42	0.39
Interaction	Genotype × Urea solution			
	G ₁ N ₁	93.00	96.33	116.66

	G ₁ N ₂	95.00	98.00	118.33
	G ₁ N ₃	96.00	100.66	119.66
	G ₁ N ₄	98.00	102.66	122.00
	G ₂ N ₁	82.00	93.33	109.00
	G ₂ N ₂	84.00	95.00	111.00
	G ₂ N ₃	85.33	96.00	112.33
	G ₂ N ₄	87.00	98.00	113.66
	CD (p= 0.05)	N/S	N/S	N/S
	SE(m)	0.62	0.60	0.56

Table 3 Effect of root dipping application of starter solution on fruit and yield parameters of chilli

Treatments		Fruit length (cm)	Fruit diameter (mm)	Fruit weight (g)	Number of fruits per plant	Yield per plant (g)	Yield per hectare (q/ha)
Genotypes	G ₁ (Arka Gagan)	7.49	8.33 ^b	2.06 ^b	465.14 ^a	962.13 ^a	285.07 ^a
	G ₂ (Kashi Anmol)	7.40	8.60 ^a	3.44 ^a	253.57 ^b	879.70 ^b	260.64 ^b
	CD (p= 0.05)	N/S	0.19	0.06	10.79	22.31	6.61
	SE(m)	0.06	0.06	0.02	3.52	7.28	2.15
Urea solution	N ₁ (0% urea solution)	7.06 ^c	7.1 ^d	2.64 ^d	337.72 ^b	836.96 ^d	247.98 ^d
	N ₂ (1% urea solution)	7.29 ^{bc}	8.35 ^c	2.74 ^c	348.30 ^b	889.18 ^c	263.45 ^c
	N ₃ (2% urea solution)	7.53 ^b	8.93 ^b	2.76 ^b	368.84 ^{ab}	937.78 ^b	277.85 ^b
	N ₄ (3% urea solution)	7.89 ^a	9.5 ^a	2.87 ^a	382.57 ^a	1019.74 ^a	302.14 ^a
	CD (p= 0.05)	0.27	0.27	0.08	15.27	31.55	9.34
	SE(m)	0.09	0.09	0.02	4.98	10.30	3.05
Interaction	Genotype × Urea solution						
	G ₁ N ₁	7.04	7.9 ^f	2.02 ^d	428.53 ^d	868.48	257.32
	G ₁ N ₂	7.39	8.1 ^{ef}	2.07 ^d	445.00 ^c	920.97	272.87
	G ₁ N ₃	7.68	8.3 ^{de}	2.04 ^d	481.19 ^b	981.57	290.83
	G ₁ N ₄	7.84	8.9 ^c	2.13 ^d	505.84 ^a	1077.49	319.25
	G ₂ N ₁	7.08	6.3 ^g	3.26 ^c	246.90 ^e	805.45	238.64
	G ₂ N ₂	7.19	8.6 ^{cd}	3.41 ^b	251.59 ^e	857.39	254.03
	G ₂ N ₃	7.38	9.5 ^b	3.49 ^b	256.49 ^e	894.00	264.88
	G ₂ N ₄	7.94	10.0 ^a	3.62 ^a	259.31 ^e	961.99	285.03
	CD (p= 0.05)	N/S	0.38	0.12	21.59	N/S	N/S
	SE(m)	0.12	0.12	0.04	7.05	14.56	4.31



Fig 1. Effect of root dipping on plant growth of chilli where fig i, ii, iii and iv represents plant growth of hybrid Arka Gagan and fig a, b, c and d represents the plant growth of variety Kashi Anmol

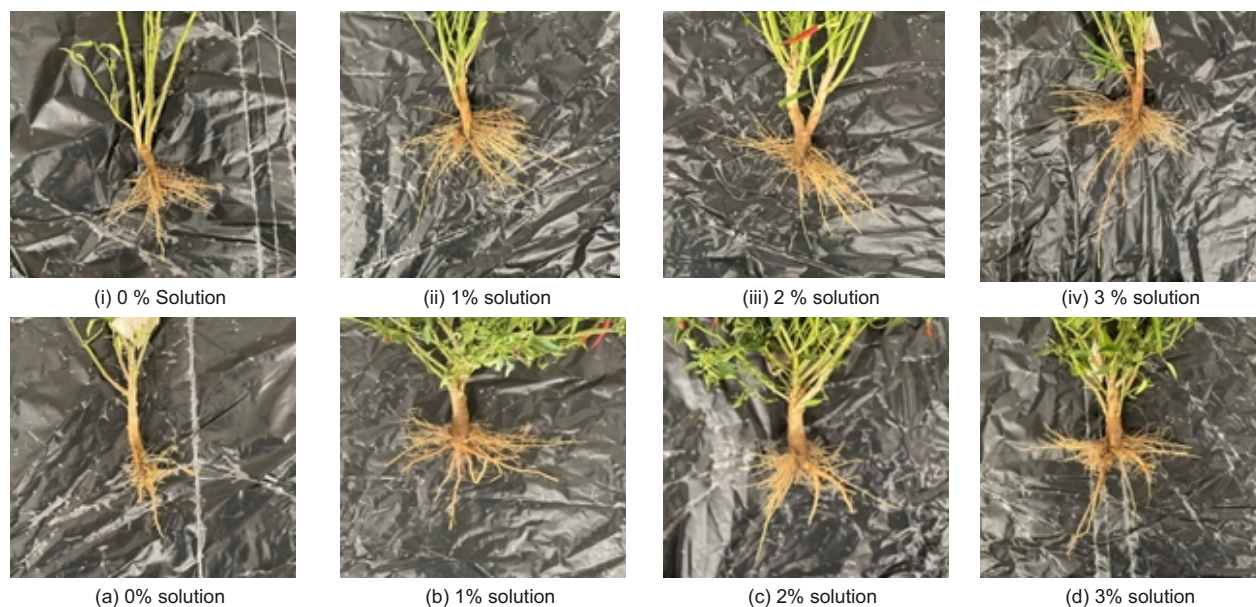


Fig 2. Effect of root dipping application of starter solution on root growth of chilli where fig i, ii, iii and iv represents root growth of hybrid Arka Gagan and fig a, b, c and d represents the fruits of variety Kashi Anmol