**Enhancing Crop Quality and Food Security Through Fertigation and Foliar Feeding Strategies**

**Abstract**

Chilli (*Capsicum annuum* L.), a commercially important crop, plays a key role in domestic and international markets. In India, chilli is cultivated on 4.18 lakh hectares, with an annual production of 44.17 lakh tonnes. However, productivity remains low at 10.60 t ha⁻¹, primarily due to water stress, insufficient nutrient supply, and vulnerability to pests and diseases. Fertigation and foliar feeding offer effective solutions for balanced nutrition in crops, with fertigation delivering nutrients directly to the root zone, while foliar spraying facilitates rapid nutrient absorption without nutrient fixation. This study assessed the impact of fertigation and multinutrient foliar spray on chilli (variety Sierra) at a farmer's field in Kanjikuzhi (90 66/ N latitude and 76031/ E longitude) from November to April 2023–2024, using a Split Plot Design with 20 treatments and 3 replications. Main plot treatment involves comparison of varying fertilizer doses involving adhoc precision farming practices and nutrient recommendation followed for soil application given as fertigation (100 per cent of 75:40:25 NPK/ha) indicated as F4. The adhoc recommendation for precision farming is 210:48:276 NPK kg/ha which is given in varying doses as 75% of RDF(F1),100% of RDF(F2),125% of RDF(F3). The subplot treatment includes soil application of secondary and micronutrient based on soil test(S1), foliar feeding of Sampoorna KAU multimix for vegetables at 0.5% (S2), foliar feeding of multinutrient mixtures prepared based on the soil test given at 0.25(S3) and 0.5(S4) per cent concentration. Fertigation done in 3 days intervals and foliar spray at 15,30 and 45 days after transplanting. The optimal result was obtained with 100% of 210:48:276 NPK kg/ha combined with Sampoorna foliar spray for ascorbic acid (86 mg/100 g), while 125% RDF with Sampoorna foliar spray recorded the highest TSS (3.03°Brix) and oleoresin content (25.7%). Balanced nutrient application unlocks access to nutrient-rich foods, playing a key role in combating malnutrition and strengthening food security for healthier, more resilient communities.

Key words: Fertigation, foliar spray, chilli, malnutrition, multi nutrient

**INTRODUCTION**

A major spice crop in India is the chilli (*Capsicum annuum* L.), which belongs to the Solanaceae family. Grown on 4.05 lakh hectares, 42.72 lakh tonnes of green chilli are produced annually in India.in India productivity of green chilli is 10.54 t ha-1 which is very low Anonymous (2022). Vitamin A, C, and minerals abound in chilli fruit. To prepare pickles, sauces, and paste, use ripe, green chillies. In the food and beverage sectors, oleoresin is an essential oil, which can be extracted from chilli.

Despite being an important crop, its production is quite modest. Increasing the area under cultivation of chillies or using better varieties and cultural methods are the different ways to increase yield. Proper application of fertiliser is one of the quickest and easiest way to increase the yield per unit area among many cultural practices (Natsheh and Mousa, 2014). One of the key elements influencing the development and yield of the crops is a balanced diet. It is equally crucial to consider the optimal levels at which nutrients should be administered and the source from which they originate. The application of nutrients to a crop increases agricultural output and improves crop quality.

Fertigation is an efficient method for controlling the timing and placement of fertilizers, enhancing fertilizer use efficiency by minimizing losses due to leaching, volatilization, and fixation into less available forms in the soil (Papadopoulos, 1994). Additionally, foliar application of micronutrients plays a crucial role in improving crop yield and quality, as these nutrients participate in various enzymatic and metabolic processes without undergoing fixation in the soil. This study focuses on the interactive effects of fertigation and foliar spray on the quality of chilli.

**MATERIALS AND METHODS**

The experiment was conducted in 2023–24 during November to April, at farmer's field in Kanjikuzhi, Alappuzha, Kerala, India (90.66/ N latitude and 76.31/ E longitude at an elevation of 612m above mean sea level having sandy soils. The observed maximum and minimum temperature ranged from 27.1-39.1 0C and 16.1-29.9 0C, respectively the variations in the evaporation ranged from 0.8 to 8.5 mm during the growing months. The experiment was laid out in a Split Plot Design with twenty treatments and three replications. The main plots consisted of two types of fertilizer recommendations: the adhoc precision farming practice of 210:48:276 NPK kg/ha (KAU adhoc 2013) and the normal fertilization practice of 75:40:25 NPK kg/ha (KAU 2016). The four main plot treatments were as follows: F1 – 75% of the recommended dose of fertilizer (RDF) through fertigation (157.5:36:207 NPK kg/ha), F2 – 100% RDF through fertigation (210:48:276 NPK kg/ha), F3 – 125% RDF through fertigation (262.5:60:345 NPK kg/ha), and F4 – 100% RDF through fertigation (75:40:25 NPK kg/ha) and sub plot treatments: S1- Soil test-based recommendation of secondary and micronutrients as soil application, S2- 0.5 per cent Sampoorna KAU multimix vegetables having composition of Zn-3.5-4.5%, B-2.5-3.5%, Cu-0.3-0.5%, Fe- < 0.2%, Mg- < 0.2%, Mo- < 0.02%), S3 and S4 are 0.25% and 0.5% multinutrient mixtures, respectively, containing 5% MgSO₄.7H₂O, 0.1% ZnSO₄.7H₂O, and 0.1% borax, S5- Water spray. The land was thoroughly ploughed and brought to a fine tilth. Raised beds measuring 12 meters in length and 1.2 meters in width were prepared. Chilli seedlings were transplanted 30 days after sowing onto the raised beds, following a triangular planting pattern with a spacing of 60 x 60 cm. A bi-color polyethylene mulch, featuring a black surface underneath and a silver surface on top, with a thickness of 40 microns, was spread over the beds. Two drip laterals with a discharge rate of 4 LPH (liters per hour) were laid on the beds for irrigation. Fertigation was carried out as per the experimental plan. Half dose of phosphorus was applied as a basal dose in soil using rock phosphate, full dose of nitrogen, potassium, and remaining half dose of phosphorus was supplied through fertigation using water-soluble fertilizers such as urea, muriate of potash, and monoammonium phosphate. Fertigation was carried out at 3 days intervals. Fertilizers were applied by pressure differential method by using venturi system. Eight plants were tagged from each plot. Observations on growth parameters were recorded from these tagged plants at 30,90 and 120 days after transplanting. Analysis of variance was performed following the statistical method described by Gopinath *et al*., 2020 and the significance difference among the treatment means were calculated at 5 per cent level of significance

Table 1. Different fertilizer dose applied per split

|  |  |  |  |
| --- | --- | --- | --- |
| **Different plots** | **Total**  **(Kg ha-1)** | **Basal as soil**  **application for P (kg/ha)** | **Per split (g /cent)** |
| Plot 1 75% RDF |  |  |  |
| N | 157.5 |  | 33.87 |
| P | 36 | 18 | 2.98 |
| K | 207 |  | 34.91 |
| Plot 2 100% RDF |  |  |  |
| N | 210 |  | 45.16 |
| P | 48 | 24 | 3.98 |
| K | 276 |  | 46.56 |
| Plot 3 125% RDF |  |  |  |
| N | 262.5 |  | 56.46 |
| P | 60 | 30 | 4.97 |
| K | 345 |  | 58.19 |
| Plot 4 100% RDF KAU |  |  |  |
| N | 75 |  | 15.63 |
| P | 40 | 20 | 3.31 |
| K | 25 |  | 4.21 |

**RESULT AND DISCUSSION**

Quality parameters in chilli, such as ascorbic acid, total soluble solids (TSS), and oleoresin, are essential indicators of its nutritional, flavour, and industrial value. Ascorbic acid, a naturally occurring compound with antioxidant properties crucial for human health, was significantly influenced by varying levels of fertigation and foliar application, as shown in Fig 1. The highest ascorbic acid content in green chili at 120 days after transplanting was recorded in the treatment of F2S2 (86.00 mg 100 g-1) while the lowest value was observed in the treatment of F4S5(32.66 mg 100 g-1). The increase in vitamin C content under higher fertilizer doses may be attributed to greater nitrogen uptake, which enhances enzyme activity for amino acid synthesis. These findings are consistent with those of Vasu (2011) in cabbage and Jaspreet (2019) in chili. Additionally, foliar spraying significantly boosted ascorbic acid levels, with crops treated with Sampoorna showing the highest content, likely due to the zinc in Sampoorna, which functions as a metal activator for enzymes in the D-galacturonate pathway which provides an alternative route ascorbic acid synthesis in plants by utilizing D-galacturonic acid from pectin degradation, enhancing antioxidant production and contributing to stress tolerance and nutritional quality. These results align with the findings of Singh *et al*. (2018) in broccoli and Barche *et al*. (2011) in tomato.

Fig 1. Effect of fertigation on ascorbic acid content of chilli

Total soluble solids (TSS) are a key quality parameter that directly influences the flavour of chili. Table 2 highlights the significant differences in TSS observed under various fertigation levels and foliar sprays. The highest TSS value was recorded in the treatment F3S2(3.030 brix), while the lowest was recorded with F4S5(0.860 brix). The increase in TSS with higher fertilizer doses may be due to improved nitrogen and phosphorus uptake, which are essential for starch formation. During ripening, starch converts into sugars, enhancing sweetness (Aguyoh *et al*., 2010). Foliar application of macro- and micronutrients significantly influenced TSS content in chili, with Sampoorna Multimix producing the highest TSS due to its micronutrient content, which promotes growth by accelerating the synthesis of carbohydrates, vitamins, and other quality attributes. These findings are consistent with those of Dixit *et al*. (2017) and Ejaz *et al*. (2011) in tomato.

Oleoresin is a viscous, semi-solid, gel-like extract or essential volatile oil derived from spices, free from bacteria, spores, and mold. It contains the key quality attributes found in chilies. In this study, the highest oleoresin content was observed in the treatment F3S2(25.70%) from Table 2 it can be inferred. In contrast, the lowest content was recorded for the treatment F4S5(13.00 %). The higher oleoresin content might be attributed to enhanced synthesis and translocation of photosynthates in the fruits, facilitated by improved nutrient uptake under optimal soil moisture conditions. These findings are consistent with earlier research by Supekar (2020), Bidari and Hebsur (2011), who reported a positive correlation between colour value and oleoresin content with the concentration of nitrogen (N), potassium (K), and sulphur (S) in whole red chilli fruits. The study also revealed that oleoresin content significantly increased when secondary and micronutrients were applied in combination with NPK. Macro and micronutrients play a critical role in boosting oleoresin levels by supporting enzyme activity, enhancing nutrient absorption, and promoting the synthesis of essential oils and resins in plants. Similar trends were noted by Malawadi (2003) and Mahaveappa (2017).

**Table 2**. Fruit quality enhancement by balanced fertilization

|  |  |  |
| --- | --- | --- |
| **Treatments** | **Quality characteristics** | |
| **Levels of primary nutrients(F)** |  | |
|  | **Oleoresin (%)** | **TSS (0 brix)** |
| F1-75% KAU adhoc N P K | 19.50 | 1.39 |
| F2-100% KAU adhoc N P K | 20.33 | 1.70 |
| F3-125 % KAU adhoc N P K | 22.71 | 2.10 |
| F4 -100 % KAU POP N P K | 15.94 | 1.22 |
| SEm (±) | 0.22 | 0.03 |
| CD | 0.63 | 0.10 |
| **Levels of multi nutrients(S)** |
| S1- soil test-based recommendation multi nutrient application | 22.76 | 1.28 |
| S2-0.25 % Sampoorna KAU multimix | 21.57 | 2.22 |
| S3-0.25% multimix nutrient mixture | 17.96 | 1.53 |
| S4-0.5% multimix nutrient mixture | 20.72 | 1.90 |
| S5-water spray | 15.08 | 1.08 |
| SEm (±) | 0.55 | 0.05 |
| CD | 1.63 | 0.17 |
| **Interactions (FxS)** |
| F1 S1 | 22.60 | 1.13 |
| F1 S2 | 22.20 | 1.70 |
| F1 S3 | 17.86 | 1.33 |
| F1 S4 | 20.53 | 1.83 |
| F1 S5 | 14.33 | 0.96 |
| F2 S1 | 22.80 | 1.50 |
| F2S2 | 23.58 | 2.40 |
| F2 S3 | 18.16 | 1.56 |
| F2 S4 | 21.10 | 1.93 |
| F2 S5 | 16.00 | 1.13 |
| F3 S1 | 24.36 | 1.40 |
| F3 S2 | 25.70 | 3.03 |
| F3 S3 | 22.50 | 2.16 |
| F3S4 | 24.00 | 2.53 |
| F3S5 | 17.00 | 1.36 |
| F4S1 | 21.30 | 1.10 |
| F4S2 | 14.80 | 1.76 |
| F4S3 | 13.33 | 1.06 |
| F4S4 | 17.26 | 1.33 |
| F4 S5 | 13.00 | 0.86 |
| SEm (±) | 1.11 | 0.11 |
| CD | NS | 0.34 |

**CONCLUSION**

The study highlights the significant impact of fertigation and foliar spray on the quality parameters of chilli (*Capsicum annuum* L.), such as ascorbic acid, total soluble solids (TSS), and oleoresin content. Fertigation, combined with foliar application of secondary and micronutrients, proved to be an effective method to enhance nutrient uptake and improve both yield and quality. The optimal results for ascorbic acid (86 mg/100 g) were observed in the treatment with 100% RDF (210:48:276 NPK kg/ha) combined with 0.5% Sampoorna foliar spray, indicating a marked improvement in antioxidant content. For TSS (3.03 °Brix) and oleoresin content (25.7%), the 125% RDF dose combined with Sampoorna foliar spray gave the best results, suggesting a positive correlation between increased fertilization and the enhancement of flavour and industrial quality attributes of chilli. These findings demonstrate the importance of balanced nutrient management in boosting the nutritional quality of crops, thereby improving food security. The application of fertigation with the right combination of foliar sprays plays a crucial role in unlocking nutrient-rich produce, which contributes to combating malnutrition and strengthening agricultural sustainability.

**References**

Aguyoh JN, Audi W, Saidi M, Gao-Qiong L.2010. Growth, yield and quality response of watermelon (Citrullus lanatus CV. Crimson Sweet) subjected to different levels of tithonia manure. International Journal of Science and Nature 1(1):7-11.

Anonymous. 2022. Third advance estimate of area and production of horticultural crops. India Stat Agriculture, New Delhi.

Barche, S., Singh, P., Mahasagar, H. and Singh, D.B. 2011. Response of foliar application of micronutrients on tomato variety Rashmi. *Indian Journal of Horticulture*, *68*(2), pp.278-279.

Bidari, B. I. and Hebsur, N. S. 2011. Potassium in relation to yield and quality of selected vegetable crops Karnataka Journal Agricultural Sciences. 24 (1): 55-59.

Dixit, A., Sharma, D., Sharma, T.K. and Bairwa, P.L. 2017. To study the effect of calcium and different micronutrients on fruit quality attributes of tomato CV â€˜ Arka Rakshakâ€™. *Journal of Pharmacognosy and Phytochemistry*, *6*(6S), pp.400-403.

Ejaz, M., Waqas, R., Butt, M., Rehman, S.U. and Manan, A. 2011. Role of macro-nutrients and micro-nutrients in enhancing the quality of tomato. *Int. J. Agron. Vet. Med. Sci*, *5*, pp.401-404.

Gopinath, P. P, Parsad, R, Joseph, B, Adarsh, V. S. (2020). GRAPES: General Rshiny Based Analysis Platform Empowered by Statistics. https://www.kaugrapes.com/home. version 1.0.0. DOI: 10.5281/zenodo.4923220

Jaspreet, K. 2019. *Response of muskmelon (Cucumis melo L.) to drip irrigation and fertigation under mulch conditions* (Doctoral dissertation, Punjab Agricultural University, Ludhiana).

Mahadevappa, P. 2017. *Effect of foliar application of potassium nitrate, ferrous sulphate and magnesium sulphate on growth, yield and quality of chilli (capsicum annuum l.) cv* (Doctoral dissertation, UASD).

Malawadi, M.N. 2003. *Effect of secondary and micronutrients on yield and quality of chilli (Capsicum annuum L.)* (Doctoral dissertation, University of Agricultural Sciences, Dharwad).

Natsheh, B. & Mousa, S. (2014). Effect of organic and inorganic fertilizers application on soil and cucumber (*Cucumis sativa* L.) plant productivity. International Journal of Agriculture and Forestry, 4(3), 166-170.

Papadopoulous, I. (1994). Use of labled fertilizers in fertigation research. In: proc. nucl. technique in soil pl studies for sustainable agric and dev. Vienna, Austria, October 1994

Singh V, Singh AK, Singh S, Kumar A, Mohrana DP.2018. Impact of foliar spray of micronutrients on growth, yield and quality of broccoli (*Brassica oleracea* var. italica) cv. Pusa KTS-1. The Pharma Innov. J. 7(8):99-101.

Supekar, S.J. 2020. *Impact of irrigation and fertigation levels on growth, yield and quality of summer chilli (capsicum annuum L.)* (Doctoral dissertation, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani).

Vasu, D. 2011. *Effect of fertigation on yield, quality and fertilizer use efficiency in cabbage (Brassica oleracia var. Capitata)* (Doctoral dissertation, ACHARYA NG RANGA AGRICULTURAL UNIVERSITY).