

Influence of Nutrient Application on Quality of Strawberry (*Fragaria × Ananassa* Duch.) Cv Camarosa in Central India

ABSTRACT

The experiment was carried out according to completely randomized block design. It comprises of eleven treatments and three replications involving soil and foliar application of nutrients and their combinations. The main aim of this experiment was to find out the effect on the biochemical quality of strawberry fruit with the use of nutrient application methods. The 50 % RDF (Recommended Dose of Fertilizer) application in soil and foliar spray of NPK nutrient had a positive effect on the quality parameter. The maximum TSS (8.6 °Brix), minimum acidity percentage (0.78 %) and pH (3.41), highest TSS: Acid ratio (11.03), maximum total sugars (7.90 %), non-reducing sugars (4.92 %) and reducing sugar (2.98 %), ascorbic acid content (37.81 mg/100g) was recorded in treatment T₄ (NPK 50% (Soil application) + 1st Spray of 19:19:19 at 45 DAT, 2nd Spray of 0:52:34 at 60 DAT, 3rd Spray of 0:0:50 at 75 DAT). Another quality attribute maximum (650.75ppm) anthocyanin and Lab value (L- 23.56, a-28.16, and b-5.84) found in T₂ (NPK 50% (Soil application) + 1st, 2nd & 3rd Spray of 19:19:19 at 45, 60 & 75 DAT).

Keyword: Strawberry, Quality, NPK nutrients, Soil and Foliar Application, Central India.

1. INTRODUCTION

Strawberry (*Fragaria x ananassa* Duch.) is one of the most important delicious soft fruits and high-value cash crops around the world. It is an herbaceous perennial plant with a shallow adventitious root system that belongs to the family Rosaceae (Yadav *et al.*, 2010). It is the most important fruit of the temperate zone, but it can also be cultivated in subtropical and tropical climates with the introduction of

day-neutral cultivars (Andrew, 2000). It requires an optimum day temperature of 24°C and a night temperature of <10°C. During blossom development, they need a photoperiod of 8 to 12 hours for around 10 days (Samad *et al.*, 2021). The fruit is rich in active ingredients that are beneficial to human health, including amino acids, carotenoids, phenols, flavonoids, vitamins, proteins, and other minerals. The fruit contains 90.95 % moisture, 0.67 g protein, 7.68 g carbohydrate, 32 kcal energy, 4.89 g sugar, 0.5 g fat, and 58.8 mg vitamin C per 100 g of fresh weight of fruit (Giampieri *et al.*, 2012). It is eaten fresh and used to make jams, squash, ice cream, syrups, ready-to-serve (RTS) products, cosmetics and confectionery, etc. (Sharma and Sharma, 2003).

Nutritional status plays an important role in strawberry growth, yield, and quality because strawberries are very sensitive to balance nutrient. NPK are crucial macronutrients in the growth and development of plants. They play a significant role in various physiological and morphological aspects, serving as essential molecules involved in fundamental metabolic processes (Ali *et al.*, 2023). Fertilizer plays an important role in maintaining soil fertility as well as enhancing nutrient response efficiency, maintaining an ideal C:N ratio, and maximizing crop productivity to the desired quality. (Barooah and Datta 2020). Nowadays, there is a growing interest in the application of water-soluble fertilizers as a means to enhance nutrient absorption through foliar feeding. Water-soluble fertilizers have the advantage of being readily soluble in water, allowing for easy absorption by plants. By utilizing foliar feeding, we can minimize environmental pollution and improve nutrient utilization by reducing the dose of fertilizers that need to be added to the soil (Iguvenc and Badem, 2002). The efficacy of foliar application of nutrients can be up to 20 times greater than that of soil application (Lodhi, 2022).

Nitrogen is the most important macronutrient in crop production because it plays an essential role in cell division, photosynthesis, and high nutrient uptake. It is present in amino acids, nucleoproteins, amines, amino sugars, and various other organic compounds within the plant system (Bai *et al.*, 2023). Phosphorus is an essential component of nucleoproteins, enzymes, and lipids, contributing significantly to cell formation, photosynthesis, carbohydrate synthesis, and distribution within plants. It is commonly known as a source of energy due to its role in storing and transferring energy in plants during photosynthesis (Busman *et al.*, 1998). It helps in several growth factors like root development, increased stem length and stalk development, improved flower production, increased fruit size and yield, and producing firm berries. Potassium is an essential mineral for strawberries, which require large amounts. It plays an important role in plants in the production and transport of proteins

and sugars, increases phenolic composition and antioxidant capacity, enzymatic activation, protein synthesis, and photosynthesis, regulates the movement of water in the plant, and improves plant resistance against diseases and pests (Preciado-Rangel *et al.*, 2020). The high potassium content of the nutrient solution improves the growth, production, and quality of strawberry fruits (Nakro *et al.*, 2022). This study is undertaken to optimize NPK fertilizers and evaluate the effect of nutrients on various growth stages for better quality of strawberry cv “Camarosa” at a lower cost in central part of India.

2. Material and Methods

The experiment was conducted during the 2023-2024 winter season in a subtropical climate at the new nursery, Jawaharlal Nehru Krishi Vishwavidyalaya, Adhartal, Jabalpur, to study the influence of nutrient application on the quality of strawberry (*Fragaria x ananassa* Duch.) cv Camarosa in Central India. The experiment was conducted using a completely randomized block design comprising eleven treatments and three replications. The treatments details were:

Table1 Description of treatments involving soil and foliar application of NPK fertilizers in strawberry

Treatments	Treatments details
T ₁	Control [100% RDF - Soil application (NPK- 80:40:40 kg/ha)]
T ₂	NPK 50% (Soil application) + 1 st , 2 nd and 3 rd Spray of 19:19:19 at 45,60 and 75 DAT
T ₃	NPK 50% (Soil application) + 1 st and 2 nd Spray of 19:19:19 at 45 and 60 DAT, 3 rd Spray of 0:0:50 at 75 DAT
T ₄	NPK 50% (Soil application) + 1 st Spray of 19:19:19 at 45 DAT, 2 nd Spray of 0:52:34 at 60 DAT and 3 rd Spray of 0:0:50 at 75 DAT
T ₅	NPK 50% (Soil application) + 1 st Spray of 19:19:19 at 45 DAT, 2 nd Spray of 0:52:34 at 60 DAT and 3 rd Spray of 13:0:45 at 75 DAT
T ₆	NPK 50% (Soil application) + 1 st and 2 nd Spray of 19:19:19 at 45 and 60 DAT, 3 rd Spray of 13:0:45 at 75 DAT
T ₇	1 st , 2 nd and 3 rd Spray of 19:19:19 at 45,60 and 75 DAT
T ₈	1 st and 2 nd Spray of 19:19:19 at 45 and 60 DAT, 3 rd Spray of 0:0:50 at 75 DAT
T ₉	1 st Spray of 19:19:19 at 45 DAT, 2 nd Spray of 0:52:34 at 60 DAT and 3 rd Spray of 0:0:50 at 75 DAT
T ₁₀	1 st Spray of 19:19:19 at 45 DAT, 2 nd Spray of 0:52:34 at 60 DAT and 3 rd Spray of 13:0:45 at 75 DAT
T ₁₁	1 st and 2 nd Spray of 19:19:19 at 45 and 60 DAT, 3 rd Spray of 13:0:45 at 75 DAT

DAT- Day after transplanting

Tissue cultured plants were transplanted into each hole of polythene mulch at a 60 cm × 30 cm distance. Fertilizers were applied in the field through soil (RDF – NPK @80:40:40 kg/ha) and foliar applications as per the combination of treatments. All water-soluble fertilizers were applied at the rate of 0.5% in three intervals for all treatments. The strawberry field was drip-irrigated every 2–3 days. Leaf

miner infestation was observed, identified by U-shaped grooves on the lower leaf surface and inward curling of leaf edges due to tissue desiccation. Spraying chlorpyrifos 50% and cypermethrin 5% EC with a hand sprayer effectively controlled the pest. During early growth, the crop was alternately sprayed with carbendazim 12% + mancozeb 63% WP to protect against fungal diseases. The observations with regards to the yield and quality was recorded from the randomly selected tagged plants and statistical analysis was carried out using the OPSTAT software package. ANOVA was used to assess treatment effects and significant differences among means were determined using the least significant difference test at a 5% significance level.

2.1 TSS- Total Soluble Solid (°Brix)

The TSS in ripe fruit juice were measured using a hand refractometer (0–32 °B). A small amount of juice was placed on the prism to obtain the TSS reading.

2.2 Acidity (%)

To analyse the titratable acidity (TA), a volume of five millilitres of juice was extracted from the fruit sample and then diluted to a total volume of 100 millilitres. It was titrated against 0.1 N NaOH using phenolphthalein as an indicator. The acidity level was determined by applying the formula provided, which calculates the percentage of mallic acid present in the juice (Ranganna, 1986).

$$\text{Total acidity \%} = \frac{\text{Titre value} \times \text{Normality of NaOH} \times \text{Vol. made up} \times \text{eq. weight of acid} \times 100}{\text{Vol. of sample taken for estimation} \times \text{wt. or vol. of sample taken} \times 100}$$

2.3 pH

A pH meter that is digital was utilized to measure the pH level of a strawberry. Following the calibration of the pH meter using standard buffers of pH 4.0 and 7.0, 25ml of strawberry juice was poured into a beaker and the pH level was measured, ensuring enough time for the pH to stabilize before recording the readings

2.4 TSS: Acid ratio

TSS: acid ratio was calculated by using this formula.

$$\text{TSS: Acid ratio} = \frac{\text{TSS (° Brix)}}{\text{Acid (\%)}}$$

2.5 Ascorbic acid (mg/100g)

10 ml of strawberry juice were measured and then diluted to 100 ml with a three percent metaphosphoric acid solution. The solution was filtered using Whatman's No. 42 discs. To prevent

interference from sulphur dioxide, a mixture of 40% formaldehyde and 0.1 ml of HCl was added to the samples. Subsequently, a 10ml aliquot of the metaphosphoric extract was titrated with the standard 2,6-dichlorophenol-indophenol dye until a pink end point was reached, which should last for 15 seconds. The following formula was used to calculate the ascorbic acid content (Ranganna, 1986).

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre} \times \text{dye factor} \times \text{Volume made up} \times 100}{\text{Aliquot taken (ml)} \times \text{Weight of sample (g)}}$$

2.6 Sugar estimation

Sugars were estimated as suggested by Lane and Eynon (1923) and modified by Ranganna (1986). The method is briefly explained as follow:

A) Sample preparation

A 25 ml juice sample was extracted and combined with 100 ml of distilled water, followed by neutralization using 1 N NaOH. 2 ml of lead acetate solution was added and allowed to stand for 10 minutes. Afterward, 1 to 2 ml of potassium oxalate solution was added to neutralize the lead, and the final volume was adjusted to 250 ml.

B) Standardization of the Fehling's solution

A mixture of 50 ml of Fehling's solution A and 50 ml of Fehling's solution B was prepared. Then, 10 ml of this mixed solution was transferred using a pipette into a 250-ml conical flask, which already contained 50 ml of distilled water. Titration was done using a 50-ml burette filled with a standard invert sugar solution. The invert sugar solution (18 to 19 ml) was added gradually until the titration was completed, ensuring that no more than one ml of the invert sugar solution was used. The flask was then heated on a hot plate. To indicate the end point, three drops of methylene blue indicator were added, and the titration was completed within one minute. The decolorization of the solution indicated the end point.

$$\text{Factor of Fehling's solution} = \frac{\text{Titre value}}{1000} \times 2.5$$

2.6.1 Reducing sugar (%)

The 10 ml sample was diluted with distilled water to a volume of 100 ml. The solution was then transferred into a burette. In a conical flask, 5 ml of Fehling A and 5 ml of Fehling solution B were combined, followed by the addition of 10 ml of distilled water. Using the methylene blue indicator, the

solution was heated and then titrated again with this burette solution until the red precipitate was observed. The end point is noted for each sample.

$$\text{Reducing sugar}(\%) = \frac{\text{Dilution} \times \text{Factor of Fehling}(\text{gm})}{\text{Weight of sample} \times \text{Titre}} \times 100$$

2.6.2 Total sugar (%)

Transfer 50 ml of the clarified solution into a 250-ml conical flask using a pipette. Then, add 5 g of citric acid and 50 ml of water to the flask. Gently boil the mixture for 10 minutes to ensure the complete inversion of sucrose, and then allow it to cool. Next, transfer the cooled solution to a 250-ml volumetric flask and neutralize it with 1 N NaOH, using phenolphthalein as an indicator. Finally, add enough additional solution to reach the desired volume in the flask. To achieve inversion at room temperature, take a 50-ml aliquot of the clarified and delead solution and transfer it to a 250-ml flask. Add 10 ml of HCl (1+1) to the flask and let it stand at room temperature (20° C or above) for 24 hours. Afterward, neutralize the solution with a concentrated NaOH solution and adjust the volume to the desired level. Take an aliquot and determine the total sugars as invert sugars.

$$\text{Total sugar}(\%) = \frac{\text{Dilution} \times \text{Factor of Fehling}(\text{gm})}{\text{Weight of sample} \times \text{Titre}} \times 100$$

2.6.3 Non-Reducing sugar (%)

The non-reducing sugar percentage was calculated by deducting the reducing sugar percentage from the total sugar content and then presented as a percentage.

$$\text{Non – Reducing sugar}(\%) = \text{Total sugar}(\%) - \text{Reducing sugar}(\%)$$

2.7 Anthocyanin (ppm)

Total anthocyanins were determined according to the pH differential spectroscopic method (Cheng and Breen 1991). 3 ml of extracts were diluted in 5 ml of two different buffers; 0.025 M potassium chloride pH = 1.0 and 0.4 M sodium acetate pH = 4.5, respectively. After 30 minutes of incubation at room temperature, absorption (A) was measured at $\lambda = 510$ and $\lambda = 700$ nm (Thermo Scientific Helios β , UK). All extracts were analyzed in duplicate.

2.8 Lab Value (L, a, b)

The L, a, b scales rise above language barriers enabling companies to easily communicate colour and colour differences. Hunter L, a, b colour scales based on the Opponent-Colour Theory. This theory assumes that the receptors in the human eye perceive colour as the following pairs of opposites.

L scale: Light vs. dark where a low number (0-50) indicates dark, and a high number (51-100) indicates light.

a scale: Red vs. green where a positive number indicates red, and a negative number indicates green.

b scale: Yellow vs. blue where a positive number indicates yellow, and a negative number indicates blue.

3. Results and Discussion

Application of RDF and foliar sprays of NPK showed significant difference between treatments in total soluble solid and sugar (Table 2). The maximum TSS (8.6°Brix), maximum total sugars (7.90 %), non-reducing sugars (4.92%) and reducing sugar (2.98 %) was recorded with NPK 50% (soil application) + 1st spray of 19:19:19 at 45 DAT, 2nd spray of 0:52:34 at 60 DAT, and 3rd spray of 0:0:50 at 75 DAT (T₄). The rise TSS and sugar levels in fruits could potentially be attributed to the increased absorption of NPK nutrients through foliar application, which is facilitated by the movement of plant assimilates into the developing fruits. The higher amounts of sugars can be linked to the presence of potassium, which enhances carbohydrate metabolism, and potash acts as a catalyst. The increase in sugar content may also be a result of the foliar application of potassium which play a significant role in the synthesis and breakdown of carbohydrates, as well as the translocation and synthesis of proteins. Additionally, they aid in the neutralization of physiologically important organic acids and assist in the conversion of starch into simple sugars. Furthermore, these substances are involved in the loading and unloading of sucrose and amino acids in the phloem. These results were correspondence with Awad *et al.* (2010), Tohidloo *et al.* (2018), Maurya *et al.* (2017) and Ali *et al.* (2023) in strawberry.

Table 2 Influence of Nutrient Application on Total soluble solid, Total Sugar (%), Reducing Sugar (%) and Non-reducing Sugar (%) and of Strawberry

Treatments	TSS (°Brix)	Total sugar (%)	Non- Reducing Sugar (%)	Reducing Sugar (%)
T ₁ : Control 100% RDF - Soil application (NPK- 80:40:40 kg / ha)	6.60	5.37	2.92	2.45
T ₂ : NPK 50% (Soil application) + 1 st , 2 nd & 3 rd Spray of 19:19:19 at 45, 60 & 75 DAT	7.80	6.53	3.99	2.55

T ₃ : NPK 50% (Soil application) + 1 st & 2 nd Spray of 19:19:19 at 45 & 60 DAT, 3 rd Spray of 0:0:50 at 75 DAT	7.63	6.13	3.62	2.51
T ₄ : NPK 50% (Soil application) + 1 st Spray of 19:19:19 at 45 DAT, 2 nd Spray of 0:52:34 at 60 DAT, 3 rd Spray of 0:0:50 at 75 DAT	8.60	7.90	4.92	2.98
T ₅ : NPK 50% (Soil application) + 1 st Spray of 19:19:19 at 45 DAT, 2 nd Spray of 0:52:34 at 60 DAT, 3 rd Spray of 13:0:45 at 75 DAT	7.90	7.54	4.74	2.80
T ₆ : NPK 50% (Soil application) + 1 st & 2 nd Spray of 19:19:19 at 45 & 60 DAT, 3 rd Spray of 13:0:45 at 75 DAT	7.63	6.00	3.32	2.75
T ₇ : 1 st , 2 nd & 3 rd Spray of 19:19:19 at 45, 60 & 75 DAT	7.13	5.61	3.12	2.49
T ₈ : 1 st & 2 nd Spray of 19:19:19 at 45 & 60 DAT, 3 rd Spray of 0:0:50 at 75 DAT	7.10	5.59	3.16	2.43
T ₉ : 1 st Spray of 19:19:19 at 45 DAT, 2 nd Spray of 0:52:34 at 60 DAT, 3 rd Spray of 0:0:50 at 75 DAT	7.40	5.64	3.05	2.59
T ₁₀ : 1 st Spray of 19:19:19 at 45 DAT, 2 nd Spray of 0:52:34 at 60 DAT, 3 rd Spray of 13:0:45 at 75 DAT	7.53	5.97	3.40	2.57
T ₁₁ : 1 st & 2 nd Spray of 19:19:19 at 45 & 60 DAT, 3 rd Spray of 13:0:45 at 75 DAT	6.70	5.65	3.27	2.38
SEm±	0.30	0.25	0.14	0.09
C.D. @ 5%	0.91	0.74	0.43	0.28

The data recorded for acidity in strawberry fruit's juice is mentioned in Table 3. The minimum acidity percentage (0.78%) was recorded in T₄ which received NPK 50% (Soil application) + 1st Spray of 19:19:19 at 45 DAT, 2nd Spray of 0:52:34 at 60 DAT, 3rd Spray of 0:0:50 at 75 DAT. Whereas, the

maximum acidity percentage (0.96%) was recorded in T₁ (Control 100% RDF - Soil application (NPK- 80:40:40 kg / ha)). The acidity of the strawberry fruit decreased when NPK fertilizers were applied, as these nutrients enhanced the conversion of organic acids into sugars (Ali *et al.*, 2023). These findings correlate with the findings obtained by Maurya *et al.*, (2017).

The effect nutrient application significantly influenced TSS: acid ratio clearly shows in Table 3. Highest TSS: Acid ratio (11.03) was recorded in T₄ (NPK 50% (Soil application) + 1st Spray of 19:19:19 at 45 DAT, 2nd Spray of 0:52:34 at 60 DAT, 3rd Spray of 0:0:50 at 75 DAT), while the minimum (6.88) was recorded in T₁ which received Control 100% RDF - Soil application (NPK- 80:40:40 kg / ha). The TSS and TSS: acidity ratio decreased in the fruits of plants that were not provided with additional potassium nutrition during the fruit development. Conversely, the total soluble solids and total soluble solids to acidity ratio increased in the fruits of treatments that included potassium, aligning with the findings of Khalil and Hammoodi in 2020 and Preciado-Rangel *et al.*, (2020) in strawberry.

Data pertaining to pH value of strawberry juice as influenced by nutrient application showed significant differences (Table 3). The minimum acidity percentage (3.41) was recorded in T₄ which received NPK 50% (Soil application) + 1st Spray of 19:19:19 at 45 DAT, 2nd Spray of 0:52:34 at 60 DAT, 3rd Spray of 0:0:50 at 75 DAT. Whereas, the maximum acidity percentage (3.55) was recorded in T₁ (Control 100% RDF - Soil application (NPK- 80:40:40 kg / ha)). The relationship between percent acidity and pH levels is interconnected. A decrease in percent acidity will result in a lower pH, and conversely, an increase in percent acidity will lead to a higher pH. These findings align with previous studies conducted by Wani *et al.*, 2013.

Data pertaining Ascorbic acid of strawberry fruit juice is mentioned in Table 3. Ascorbic acid content was significantly influenced by nutrient application. Maximum ascorbic acid content (37.81 mg/100g) was recorded in T₄ (NPK 50% (Soil application) + 1st Spray of 19:19:19 at 45 DAT, 2nd Spray of 0:52:34 at 60 DAT, 3rd Spray of 0:0:50 at 75 DAT). The enhancement of NPK nutrients and with foliar spray of potash during fruit development has been shown to boost the synthetic and catalytic functions of various enzymes and co-enzymes crucial to produce ascorbic acid. These results are in accordance with the findings of Ali *et al.*, (2023), Maurya *et al.*, (2017), Tohidloo *et al.*, (2018) and Awad *et al.*, (2010).

Anthocyanin content was significantly influenced by different nutrient application clearly show in Table 3. Maximum anthocyanin content (650.75ppm) was recorded in T₂ (NPK 50% (Soil application)

+ 1st, 2nd & 3rd Spray of 19:19:19 at 45, 60 & 75 DAT) which was on par with T₆ (641.07), T₄ (636.07), T₅ (617.21) and T₃ (607.46), while the minimum Anthocyanin (454.75) was recorded T₁ Control 100% RDF - Soil application (NPK- 80:40:40 kg / ha). Strawberry plants that received more nutrients produced fruits with the highest phenolic content, including a higher content of pelargonidin-3-glucoside, the main component of anthocyanins (Wang and Lin, 2003). Similarly, anthocyanin levels decreased in strawberries when they suffered from nitrogen deficiency (Jezek *et al.*, 2018). These results are in accordance with the findings of Yoshida *et al.*, (2002) in strawberry.

Table 3 Influence of Nutrient Application on Acidity, TSS: acid ratio, pH, Ascorbic acid and Anthocyanin of Strawberry fruit

Treatments	Acidity (%)	TSS: Acidity ratio	pH	Ascorbic acid (mg/100g)	Anthocyanin (ppm)
T ₁ : Control 100% RDF - Soil application (NPK- 80:40:40 kg / ha)	0.96	6.88	3.55	29.92	578.99
T ₂ : NPK 50% (Soil application) + 1 st , 2 nd & 3 rd Spray of 19:19:19 at 45, 60 & 75 DAT	0.83	9.40	3.42	33.78	650.75
T ₃ : NPK 50% (Soil application) + 1 st & 2 nd Spray of 19:19:19 at 45 & 60 DAT, 3 rd Spray of 0:0:50 at 75 DAT	0.84	9.08	3.42	33.14	607.46
T ₄ : NPK 50% (Soil application) + 1 st Spray of 19:19:19 at 45 DAT, 2 nd Spray of 0:52:34 at 60 DAT, 3 rd Spray of 0:0:50 at 75 DAT	0.78	11.03	3.41	37.81	636.07
T ₅ : NPK 50% (Soil application) + 1 st Spray of 19:19:19 at 45 DAT, 2 nd Spray of 0:52:34 at 60 DAT, 3 rd Spray of 13:0:45 at 75 DAT	0.80	9.88	3.42	36.54	617.21

T ₆ : NPK 50% (Soil application) + 1 st & 2 nd Spray of 19:19:19 at 45 & 60 DAT, 3 rd Spray of 13:0:45 at 75 DAT	0.84	9.08	3.43	32.49	641.07
T ₇ : 1 st , 2 nd & 3 rd Spray of 19:19:19 at 45, 60 & 75 DAT	0.94	7.59	3.48	30.49	465.36
T ₈ : 1 st & 2 nd Spray of 19:19:19 at 45 & 60 DAT, 3 rd Spray of 0:0:50 at 75 DAT	0.89	7.98	3.49	30.40	516.62
T ₉ : 1 st Spray of 19:19:19 at 45 DAT, 2 nd Spray of 0:52:34 at 60 DAT, 3 rd Spray of 0:0:50 at 75 DAT	0.93	7.96	3.43	31.46	546.12
T ₁₀ : 1 st Spray of 19:19:19 at 45 DAT, 2 nd Spray of 0:52:34 at 60 DAT, 3 rd Spray of 13:0:45 at 75 DAT	0.92	8.19	3.47	31.06	576.23
T ₁₁ : 1 st & 2 nd Spray of 19:19:19 at 45 & 60 DAT, 3 rd Spray of 13:0:45 at 75 DAT	0.96	6.98	3.53	30.07	454.76
SEm±	0.03	0.37	0.17	1.35	20.72
C.D. @ 5%	0.09	1.10	0.03	4.00	61.13

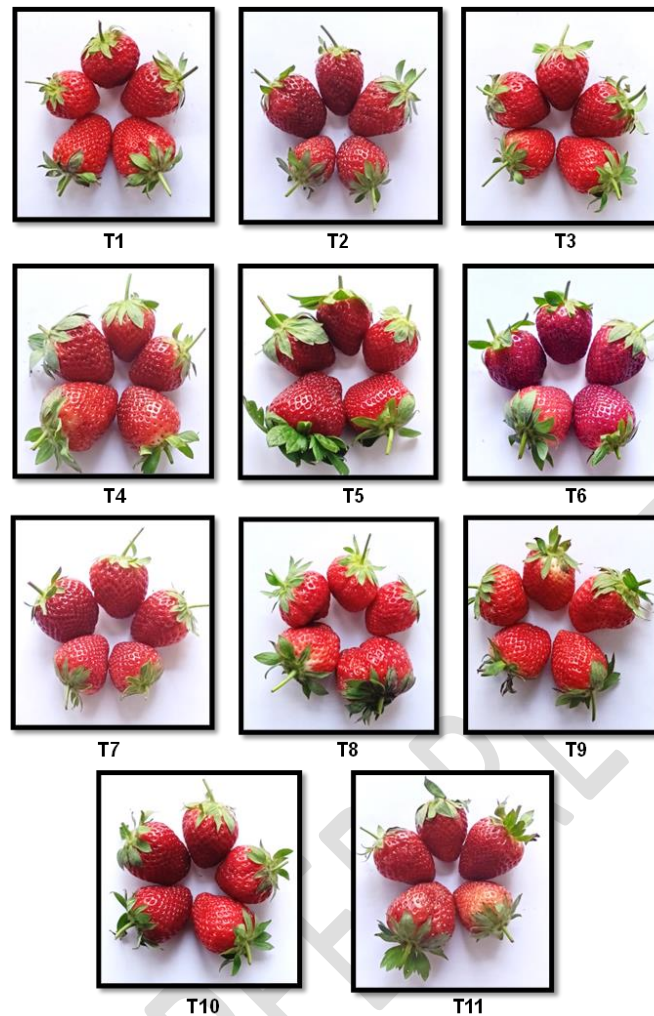
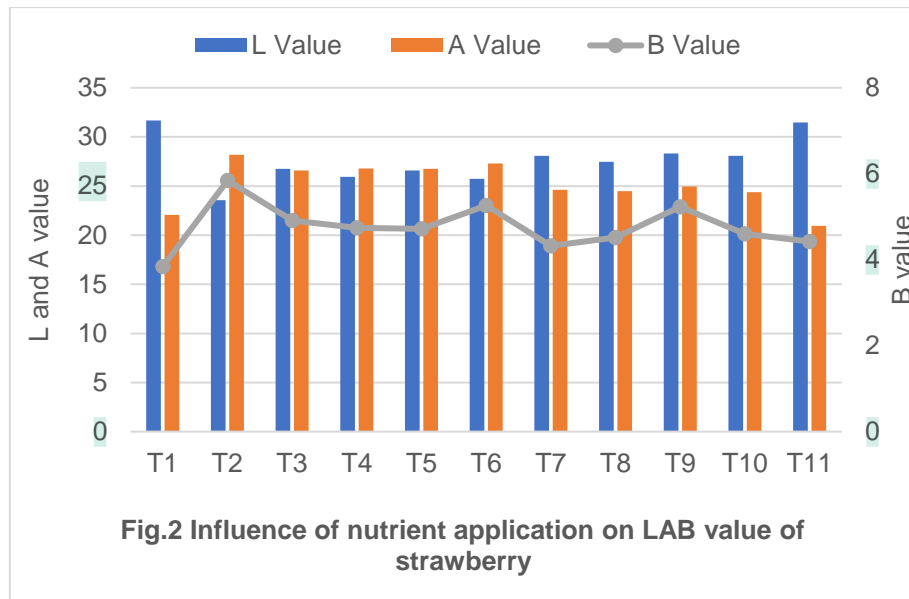


Fig. 1 Visual comparison of strawberry fruit quality under different nutrient applications

The data noted for Lab value of strawberry fruit is ~~clearly show~~ in Fig2. Lab Value was significantly influenced by different nutrient application. L scale (Light vs. dark where a low number (0-50) shows dark, and a high number (51-100) shows light), a scale (Red vs. green where a positive number shows red, and a negative number shows green) b scale (Yellow vs. blue where a positive number shows yellow, and a negative number shows blue). The minimum (23.56) L value and maximum a and b value (28.16 and 5.84) was recorded in T₂ (NPK 50% (Soil application) + 1st, 2nd & 3rd Spray of 19:19:19 at 45, 60 & 75 DAT). In this study, fruits with high N supply showed higher anthocyanin concentrations. Hunter values also showed the same trend. The lowest L value (darkness) and highest a value (redness) and b values (yellowness) were found in fruits with the highest N supply, ultimately the LAB value of strawberries also started improving as the concentration of N increased. But excessive use of N reduces the hue of the fruit. Similar findings were reported by Wang and Cheng (2011) in apple and Yoshida *et al.* (2002) in strawberry.



4. Conclusion

The 50% RDF application in soil and foliar spray of NPK nutrient had the significantly positive effect on quality parameter on strawberry fruit. The minimum acidity, pH and maximum TSS, TSS: Acid ratio, sugars and ascorbic acid was best performance in treatment T4 (NPK 50% (Soil application) + 1st Spray of 19:19:19 at 45 DAT, 2nd Spray of 0:52:34 at 60 DAT, 3rd Spray of 0:0:50 at 75 DAT). Another quality trait anthocyanin and Lab value found in T2 (NPK 50% (Soil application) + 1st, 2nd & 3rd Spray of 19:19:19 at 45, 60 & 75 DAT).

Based on the findings, it is recommended that strawberry farmers adopt a nutrient management strategy involving 50% RDF soil application combined with targeted foliar sprays: 19:19:19 at 45 DAT, 0:52:34 at 60 DAT and 0:0:50 at 75 DAT. This approach enhances fruit quality significantly by improving sweetness, acidity balance, color and nutritional value, ultimately leading to better marketability and higher profits.

Disclaimer (Artificial intelligence)

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

REFERENCES

1. Ali, B., Babar, M., Fatima, R.N., Mahmood, A., Sher, A., Siddique, T., Aslam, M.S. *et al.* (2023). Effect of Different Doses of NPK at Different Time Intervals on Growth, Yield and Quality of Strawberry CV. Chandler (*Fragaria x ananassa*). *Journal of Survey in Fisheries Sciences*, 10(2S),

4095-4108.

2. Andrew, M.F. (2000). Book of temperate fruit crops. Master publication. Argentina.
3. Awad, E.M., Mohamed, R.A., & Asfour, H.E. (2010). Effect of compost, foliar spraying with potassium and boron on growth, yield and fruit quality of strawberry. *Journal of Plant Production*, 1(8), 1101-1112.
4. Bai, X., Liu, K., Ning, T., Deng, C., Wang, L., Li, D., Wang, T., & Li, J. (2023). Effects of multiple N, P, and K fertilizer combinations on strawberry growth and the microbial community. *PLoS ONE*, 18(11).
5. Barooah, A., & Datta, H.S. (2020). Response of nutrient management on growth, yield, and quality of strawberry: A review. *Journal of Pharmacognosy and Phytochemistry*, 9(5), 3222-3228.
6. Busman, L., Lamb, J., Randall, Rehm, G. & Schmit. (1998). The nature of phosphorus in soils. Document FO-06795-GO, University of Minneapolis, MN.
7. Cheng, G.W. & Breen, P.J. (1991). Activity of phenylalanine ammonia-lyase (PAL) and concentrations of anthocyanins and phenolics in developing strawberry fruit. *Journal of the American Society for Horticultural Science*, 116(5), 865-869.
8. Giampieri, F., Tulipani, S., Suarez, J.M.A., Quiles, J.L., Mezzetti, B. & Battino, M. (2012). The strawberry: composition, nutritional Quality and impact on human health. *International journal of applied and basic nutritional sciences*, 28, 9-19.
9. Iguvenc, I. & Badem, H. (2002). Effect of foliar application of different source and levels of nitrogen on growth and yield of tomato. *The Indian journal of agriculture sciences*, 72(2), 104-105.
10. Jezek, M., Zörb, C., Merkt, N. & Geilfus, C.M. (2018). Anthocyanin management in fruits by fertilization. *Journal of agricultural and food chemistry*, 66(4), 753-764.
11. Khalil, N.H. & Hammoodi, J.K. (2020). Effect of nitrogen, potassium and calcium in strawberry fruit quality. *International Journal of Agricultural and Statistical Sciences*, 16(1), 1967-1972.
12. Lane, J.H. & Eynon, L. (1923). Determination of reducing sugar by means of Fehling's solution with methylene blue as internal indicator. *Journal of the Society of Chemical Industry*, 17, 32-37.
13. Lodhi R. (2022). Effect of foliar application of nutrient sources on growth, yield & quality of watermelon. M.Sc. Theses, JNKVV, Jabalpur. 117p.
14. Maurya, J.K., Singh, J.P., Tomar, S. & Kumar, R. (2017). Optimization of NPK Fertilizers for Higher Yield and Quality of Strawberry (*Fragaria x ananassa* Duch.) Fruits. *International Journal of Current*

Microbiology and Applied Sciences, 6(9), 1534-1538.

15. Nakro, A., Bamouh, A., Khatib, Q.E. & Ghaouti, L. (2022). Effect of potassium source and dose on yield and quality of strawberry fruit. *American Journal of Plant Sciences*, 13, 1196-1208.
16. Preciado-Rangel, P., Troyo-Dieguez, E., Valdez-Aguilar, L.A., Gaecia-hernandez, J.L. & Luna-ortega, J.G. (2020). Interactive effects of the potassium and nitrogen relationship on yields and quality of strawberry grown under soilless conditions. *Plants*, 9(4), 441.
17. Ranganna, S. (1986). Manual of analysis of Fruit and Vegetable products, Tata MC Graw Hill Publishing Company Ltd. New Delhi.
18. Samad, S., Butare, D., Marttila, S., Sønsteby, A. & Khalil, S. (2021). Effects of temperature and photoperiod on the flower potential in everbearing strawberry as evaluated by meristem dissection. *Horticulturae*, 7(11), 484.
19. Sharma, V.P., & Sharma, R.R. (2003). The Strawberry. *Indian Council of Agricultural Research*, New Delhi, pp. 166.
20. Tohidloo, G., Souri, M.K., & Eskandarpour, S. (2018). Growth and fruit biochemical characteristics of three strawberry genotypes under different potassium concentrations of nutrient solution. *Open Agriculture*, 3(1), 356-362.
21. Wang, H., & Cheng, L. (2011). Differential effects of nitrogen supply on skin pigmentation and flesh starch breakdown of 'Gala' apple. *Hort Science*, 46(8), 1116-1120.
22. Wang, S.Y. & Lin, H.S. (2003). Compost as a soil supplement increases the level of antioxidant compounds and oxygen radical absorbance capacity in strawberries. *Journal of Agricultural and Food Chemistry*, 51(23), 6844-6850.
23. Wani, R.A., Sheema, S., Malik, T.H., Geelani, S., Bashir, S., Dar, N.A. & Prasad, V.M. (2013). Impact of integrated nutrient management on growth, yield and quality of strawberry (*Fragaria x annanassa* Duch.) cultivation in India. *Advances in Horticultural Science*, 27(4), 147-151.
24. Yadav, S.K., Khokhar, U.U. & Yadav, R.P. (2010). Integrated nutrient management for strawberry cultivation. *Indian journal of horticulture*, 64(4), 445-449.
25. Yoshida, Y., Goto, T., Hirai, M. & Masuda, M. (2002). Anthocyanin accumulation in strawberry fruits as affected by nitrogen nutrition. *In Proceedings of the Fourth International Strawberry Symposium*, Vols. 1 and 2, 357-360.