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

**ABSTRACT**

The experiment comprised 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 changes in the biochemical quality of strawberry fruit with the use of low-cost nutrient application methods while reducing nutrient wastage and environmental impact through precision nutrient application. The 50 % RDF (Recommended Dose of Fertilizer) application in soil and foliar spray of Nitrogen, Phosphorus and Potassium (NPK) nutrient had a positive effect on the quality parameter such as total soluble solids (TSS), acidity, pH, TSS:acid ratio, total sugar, reducing and non-reducing sugars, and ascorbic acid content. 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 days after transplanting (DAT), 2nd Spray of 0:52:34 at 60 DAT, 3rd Spray of 0:0:50 at 75 DAT). Another quality attribute with maximum anthocyanin (650.75ppm) and Lab value (L- 23.56, a-28.16, and b-5.84) was found in T2 (NPK 50% (Soil application) + 1st, 2nd & 3rd Spray of 19:19:19 at 45, 60 & 75 DAT). Therefore, 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, for enhanced fruit quality.

**Keyword:** Biochemical parameters, NPK nutrients, Soil Application, Foliar Application, Multispray, 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 is also cultivated in subtropical and tropical climates with the introduction of day-neutral cultivars (Andrew, 2000). Strawberry requires an optimum day temperature of 24°C and a night temperature of <10°C. During bud 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 and 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 consumed fresh and used to make jams, squash, ice cream, syrups, ready-to-serve products, cosmetics and confectionery, etc (Sharma and Sharma, 2003).

Nutrient status plays an important role in strawberry growth, yield, and quality because strawberries are very sensitive to nutrient balance. 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 nutrient availability to plants as well as enhancing the 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 plant uptake in foliar application of nutrients can be up to 20 times greater than that of soil application (Lodhi, 2022).

Nitrogen (N) is the most important macronutrient in crop production because it plays an essential role in cell division, photosynthesis, and is required for plants throughout the growth cycle. It is present in amino acids, nucleoproteins, amines, amino sugars, and various other organic compounds within the plant system (Bai *et al.,* 2023). Phosphorus (P) 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 (Khan *et al*., 2023). 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 (K) 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 in the nutrient solution improves the growth, production, and quality of strawberry fruits (Nakro *et al.,* 2022). Therefore, 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.

1. **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 (23°12’09 North Latitude, and 79°57’29 East longitude), to study the influence of nutrient application on the quality of strawberry (Fragaria × ananassa Duch.) cv Camarosa in Central India. The soil in the experimental field was medium to black with good drainage and uniform textured with medium NPK status. The climate of the region was typically sub-tropical, with extreme winters and summers. It receives an average annual rainfall of 1350 mm, during the south-west monsoon from June to October. The maximum temperature averaged 46 °C, while the minimum temperature is 6.80 °C. The average annual relative humidity stood at 74%. Meteorological data for the crop season was monitored at the Meteorological Observatory Krishi Nagar, JNKVV, Jabalpur. The experiment was conducted using a completely randomized block design comprising eleven treatments and three replications. The treatment details are presented in Table 1.:

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

|  |  |
| --- | --- |
| **Treatments** | **Treatments details** |
| T1 | Control [100% RDF - Soil application (NPK- 80:40:40 kg/ha)] |
| T2 | NPK 50% (Soil application) + 1st, 2nd and 3rd Spray of 19:19:19 at 45,60 and 75 DAT |
| T3 | NPK 50% (Soil application) + 1st and 2nd Spray of 19:19:19 at 45 and 60 DAT, 3rd Spray of 0:0:50 at 75 DAT |
| T4 | NPK 50% (Soil application) + 1st Spray of 19:19:19 at 45 DAT, 2ndSpray of 0:52:34 at 60 DAT and 3rd Spray of 0:0:50 at 75 DAT |
| T5 | 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 13:0:45 at 75 DAT |
| T6 | NPK 50% (Soil application) + 1st and 2nd Spray of 19:19:19 at 45 and 60 DAT, 3rd Spray of 13:0:45 at 75 DAT |
| T7 | 1st, 2nd and 3rd Spray of 19:19:19 at 45,60 and 75 DAT |
| T8 | 1st and 2nd Spray of 19:19:19 at 45 and 60 DAT, 3rd Spray of 0:0:50 at 75 DAT |
| T9 | 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 |
| T10 | 1st Spray of 19:19:19 at 45 DAT, 2nd Spray of 0:52:34 at 60 DAT and 3rd Spray of 13:0:45 at 75 DAT |
| T11 | 1st and 2nd Spray of 19:19:19 at 45 and 60 DAT, 3rd Spray of 13:0:45 at 75 DAT |

*DAT- Day After Transplanting*

Tissue cultured strawberry 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 chlorpyriphos 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. Prior to ANOVA, data were tested for normality using the Shapiro-Wilk test and for homogeneity of variances using Levene’s test. The assumptions were met, justifying the use of parametric analysis. Two-way 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 ⁰B). 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).

**2.3 pH**

A digital pH meter 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.

**2.5 Ascorbic acid (mg/100g)**

Strawberry juice (10 ml) was measured and then diluted to 100 ml with a 3% 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):

**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:

1. **Sample preparation**

A 25 ml juice sample was extracted and combined with 100 ml of distilled water, followed by neutralization using 1 N NaOH. Lead acetate solution (2ml) 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.

1. **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.

**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 was noted for each sample.

**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 (25°C), take a 50-ml aliquot of the clarified and deleaded solution and transfer it to a 250-ml flask. Add 10 ml of HCI (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.

**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.

**2.7 Anthocyanin (ppm)**

Total anthocyanins were determined according to the pH differential spectroscopic method (Cheng and Breen 1991). Extracts (3 ml) 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 (25°C), absorption (A) was measured at λ = 510 and λ = 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 (8.6ºBrix), 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 (Hasanuzzaman et al., 2018). 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, potassium aids in the neutralization of physiologically important organic acids and assist in the conversion of starch into simple sugars. Furthermore, these nutrients are involved in the loading and unloading of sucrose and amino acids in the phloem. These results are in line 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 TSS, Total Sugar, Reducing Sugar and Non-reducing Sugar of Strawberry**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **TSS**  **(˚Brix)** | **Total sugar (%)** | **Non-Reducing Sugar (%)** | **Reducing Sugar (%)** |
| T1: Control 100% RDF - Soil application (NPK- 80:40:40 kg / ha) | 6.60 | 5.37 | 2.92 | 2.45 |
| T2: NPK 50% (Soil application) + 1st, 2nd & 3rd Spray of 19:19:19 at 45, 60 & 75 DAT | 7.80 | 6.53 | 3.99 | 2.55 |
| T3: NPK 50% (Soil application) + 1st & 2nd Spray of 19:19:19 at 45 & 60 DAT, 3rd Spray of 0:0:50 at 75 DAT | 7.63 | 6.13 | 3.62 | 2.51 |
| 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 | 8.60 | 7.90 | 4.92 | 2.98 |
| T5: 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 13:0:45 at 75 DAT | 7.90 | 7.54 | 4.74 | 2.80 |
| T6: NPK 50% (Soil application) + 1st & 2nd Spray of 19:19:19 at 45 & 60 DAT, 3rd Spray of 13:0:45 at 75 DAT | 7.63 | 6.00 | 3.32 | 2.75 |
| T7: 1st, 2nd & 3rd Spray of 19:19:19 at 45, 60 & 75 DAT | 7.13 | 5.61 | 3.12 | 2.49 |
| T8: 1st & 2nd Spray of 19:19:19 at 45 & 60 DAT, 3rd Spray of 0:0:50 at 75 DAT | 7.10 | 5.59 | 3.16 | 2.43 |
| T9: 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 | 7.40 | 5.64 | 3.05 | 2.59 |
| T10: 1st Spray of 19:19:19 at 45 DAT, 2nd Spray of 0:52:34 at 60 DAT, 3rd Spray of 13:0:45 at 75 DAT | 7.53 | 5.97 | 3.40 | 2.57 |
| T11: 1st & 2nd Spray of 19:19:19 at 45 & 60 DAT, 3rd 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. (*P* = .05)** | **0.91** | **0.74** | **0.43** | **0.28** |

The data recorded for acidity in strawberry fruit’s juice is shown 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 with NPK fertilization, 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 as clearly shown 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). 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 as shown 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)** |
| T1: Control 100% RDF - Soil application (NPK- 80:40:40 kg / ha) | 0.96 | 6.88 | 3.55 | 29.92 | 578.99 |
| T2: NPK 50% (Soil application) + 1st, 2nd & 3rd Spray of 19:19:19 at 45, 60 & 75 DAT | 0.83 | 9.40 | 3.42 | 33.78 | 650.75 |
| T3: NPK 50% (Soil application) + 1st & 2nd Spray of 19:19:19 at 45 & 60 DAT, 3rd Spray of 0:0:50 at 75 DAT | 0.84 | 9.08 | 3.42 | 33.14 | 607.46 |
| 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 | 0.78 | 11.03 | 3.41 | 37.81 | 636.07 |
| T5: 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 13:0:45 at 75 DAT | 0.80 | 9.88 | 3.42 | 36.54 | 617.21 |
| T6: NPK 50% (Soil application) + 1st & 2nd Spray of 19:19:19 at 45 & 60 DAT, 3rd Spray of 13:0:45 at 75 DAT | 0.84 | 9.08 | 3.43 | 32.49 | 641.07 |
| T7: 1st, 2nd & 3rd Spray of 19:19:19 at 45, 60 & 75 DAT | 0.94 | 7.59 | 3.48 | 30.49 | 465.36 |
| T8: 1st & 2nd Spray of 19:19:19 at 45 & 60 DAT, 3rd Spray of 0:0:50 at 75 DAT | 0.89 | 7.98 | 3.49 | 30.40 | 516.62 |
| T9: 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 | 0.93 | 7.96 | 3.43 | .31.46 | 546.12 |
| T10: 1st Spray of 19:19:19 at 45 DAT, 2nd Spray of 0:52:34 at 60 DAT, 3rd Spray of 13:0:45 at 75 DAT | 0.92 | 8.19 | 3.47 | 31.06 | 576.23 |
| T11: 1st & 2nd Spray of 19:19:19 at 45 & 60 DAT, 3rd 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. (*P* = .05)** | **0.09** | **1.10** | **0.03** | **4.00** | **61.13** |



**Fig. 1 Visual comparison of strawberry fruit quality under different nutrient applications (T1 to T11 are treatments as described in Table 1)**

The data noted for Lab value of strawberry fruit is shown 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.

Fig.2 Influence of nutrient application on LAB value of strawberry

1. **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.

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