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# Micronutrient and Metabolic Profiling of Strawberry Cultivars Grown in Subtropical Conditions: A Review

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## ABSTRACT

Strawberry is most economically important fresh and processed fruits, consumed both for its pleasant flavor and its nutrient content. Due to the fruit's high concentration of antioxidants and phytochemicals, eating strawberries has been linked to maintain good health and preventing the development of chronic diseases. The following information has been compiled from previous year research papers, which contain valuable insights into the health benefits, nutritional status and effects of strawberries. Balanced nutrition is needed by delicate strawberry plants so it's important to maintain the nutritional status for better growth, yield and quality of strawberry fruits. Although strawberries are a highly perishable fruit and cannot be kept for an extended amount of time, several wrapping techniques have preserved the fruit's quality when kept at ambient temperature. Disorder like albinism can be corrected with proper spacing and spray of borax and GA3. One step toward helping farmers maximize their profits is the notion of waste utilization in horticultural crops. Therefore, the goal of doubling farmer's income by minimizing their after-harvest losses and enhancing the demand of perishable cultivable fruit crops is achieved. This review paper showing different practices related to strawberry like its propagation, metabolites and health benefits, biochemistry of fruit ripening, effect of micro and macronutrients on strawberry's growth, yield and quality.


**Key words:** Growth, Health, Metabolites, Micronutrient, Strawberry.

Strawberry the *Rosaceae* family's fruit is one of the most attractive soft fruit of the world. It is an aggregate fruit 'achenes' and its edible part is fleshy thalamus. Runners used to propagate but nowadays tissue culture is also adopted. Optimum moisture and temperature conditions in upper layer of soil are essential for strawberry plant because these conditions affect growth and yield performance of the crop. Because the roots are shallow in nature, plants require regular watering in less quantity (Vishal *et al.,* 2016). The plant thrives in all climates, whether they are typically temperate, subtropical plains, or even high-altitude tropical regions (Pramanick *et al.,* 2019).

Strawberry is covering 1000 ha total area with production of 8000 MT in India (NHB, 2019-20). Here, Maharashtra is leading state in production of this fruits. It is grown in Uttarakhand, Uttar Pradesh, Himachal Pradesh, Madhya Pradesh, Maharashtra, Karnataka, Punjab and Haryana in India. This fruit is a good source of vitamin A (60 IU/100 g of edible portion) (Panigrahi *et al.,* 2019), vitamin C (58.8 mg/100 g), carbohydrates (8.4 g), fats (0.5 g), protein (0.07 g) (Tariq *et al.,* 2018; Hossain *et al.,* (2016), minerals like potassium (164 mg), calcium (21 mg) and phosphorus (21 mg) and other dietary. Strawberry has a delightful flavor and taste and is a great source of potassium, secondary metabolites, sugar and fibre (Farid *et al.,* 2020). It contains relatively high amount of ellagic acid, quercetin, fisetin and ellagitannins (Giampieri *et al.,* 2015). Additionally, strawberry fruit has been shown to be helpful in reducing inflammation, obesity- related problems, and the risk of developing a number of malignancies and heart ailments (Afrin *et al.,* 2016). Strawberry fruit have great demand in fresh market or in the form of preserve as well as in processing industries. Strawberry is heavy feeder which requires micro and macronutrient for more production. For a better yield of high quality fruits, strawberries need more nutrients. Increasing growth, flowering, fruit yield and quality of strawberry plant by the use of micronutrients like copper sulphate, zinc sulphate *etc.* Deficiency of these micronutrients causes chlorosis in strawberry by Zn and stunted growth habit by deficiency of Cu (Zewail *et al.,* 2020). The Zn treatment has a positive impact on several biological mechanisms by enhancing nutrient uptake and stabilizing phytohormone, antioxidant, and amino acid levels in plant parts (Leite *et al.,* 2020). Zinc plays a significant role in many different enzymes, whether as metal elements in the catalysts themselves, or as a functional or controlling element

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(Bairwa *et al.,* 2022). During vegetative growth of strawberry, spray of Ca helps to delay ripening and mold development. It also helps in maintaining fruit persistency, enhancing vitamin C content, physiological disorder of apple. An increase in apoplastic Ca concentration is typically caused by calcium administration, which may change the structure and function of cell walls, membranes and fruit ripening (Kazemi *et al.,* 2015). Major elements including nitrogen, potassium and phosphorus are crucial for strawberry growth, development and production. It is impossible to dispute the significance of secondary elements like iron, boron, zinc, copper, *etc.* because they acted as a catalyst to keep the growth and production going (Sabahat *et al.,* 2021). Micronutrient foliar feeding has a significant impact on strawberry characteristics relating to plant growth, yield, factors influencing yield and qualities. Foliar feeding of micronutrients boosts the usage efficiency of micronutrients by trying to minimize nutrient losses (Sangeeta *et al.,* 2019). With the use of Zn and Fe, improvement in production and quality has been noted in a number of fruit crops (Shanker *et al.,* 2019). Beside these nutrients, environment factor also impact the growth and development (Patil and Chetan, 2018).

**Health benefits of strawberry fruits**

Any form of strawberry consumption is linked with better lipid profiles, micro vascular function and platelet reactivity, among other indicators of cardiovascular health. Increased consumption of polyphenols has been linked to lowered CVD risk and decreased platelet reactivity. In addition to being a good source of dietary nitrate, strawberries are loaded in polyphenolic components such anthocyanin, flavanols, ellagic acid (EA) and ellagitannins (ET) are known to have beneficial effect on vascular system. Dietary nitrate can improve vascular health by converting to nitrite and nitric oxide, which can then cause ischemia and prevent platelet aggregation (Holt *et al.,* 2020). The primary strawberry phytochemical bioavailability and metabolism, as well as how they work to fight a variety of diseases developed in human body (Afrin *et al.,* 2016). Strawberry fermented beverages may have antioxidant, antibacterial and anti-bio film formation properties. This suggests that they may be good natural candidates for antioxidants, antibacterial and anti-bio film agents (Zhao *et al.,* 2021).

**Presence of secondary metabolites**

Phenolic compounds, the most prevalent class of secondary metabolites, are found in strawberry fruits and have at least one aromatic organic ring in their chemical compositions. Coumarins, flavanoids, phenolic acid and tannin are comes under Phenolic compound (Delgado *et al.,* 2019). Pelarogonidin 3-glucoside is major anthocyanin which has anti-inflammatory effect (Amini *et al.,* 2017). Flavonoids including anthocyanins are secondary metabolites in which flavonoids protect plant from UV radiation while anthocyanins guard plant from blue and green light (Landi *et al.,* 2021; Agati *et al.,* 2020). The two main flavonols found in farmed strawberries are one is quercetin and is other kaempferol (Labadie *et al.,* 2020). Regarding the dietary effects of flavanols, they may enhance nitric oxide availability and vascular function as well as control metabolism and respiration (Al-Dashti *et al.,* 2018).

**Benefits of strawberry on corona virus (COVID-19) pandemic**

The immune system is significantly modulated by the vitamins and minerals found in diets high in fruits and vegetables, particularly the vitamins A, C, D, E and B complex as well as zinc and selenium (De Faria Coelho-Ravagnani *et al.,* 2021). Berries are one of those foods that have anti-inflammatory and antioxidant properties that help to maintain a robust immune system and lower the risk of corona virus infection. The immune system is improved by strawberries because they include antioxidants like vitamin C and bioactive chemicals found in plants. It is used to cure the flu and a cold. By defending cells, strawberries have the capacity to combat free radicals in the body (Batta, 2020).

**Biochemistry of fruit ripening**

Additionally, sucrose has been cited as a crucial indicator of strawberry fruit ripeness. It has been demonstrated that a variety of fruit transcriptional regulators control the ripening of strawberry fruit (Hossain *et al.,* 2018). In strawberry, the flavonoid chain genes FaPAL, FaCHS, FaCHI and FaDFR appeared to be universally regulated by FaMYB1, 5 and 10. The FaSUT1 sucrose transporter gene plays a key role in the buildup of sucrose throughout fruit development (Zhao *et al.,* 2017). They interact with other proteins like FabHLH to improve the manufacture of anthocyanin and to accelerate fruit ripening (Xu *et al.,* 2017). A strawberry transcription element TCP family's role in strawberry fruit ripening was confirmed and FvTCP9 was discovered and isolated. Notably, strawberry fruit ripening was either hindered by temporary RNAi or accelerated by over-expression of FvTCP9. According to transcript analysis, ABA and anthocyanin are crucial components of this physiological process (Xie *et al*., 2020).

**Propagation of strawberry**

Now a day, strawberry is propagated with runners or with in vitro micro propagation in tissue culture. Among the different combinations of growth regulators for *in vitro* propagation of strawberry, nodal segments cultured on MS media supplemented with $BA^+$ $NAA^+$ adenine sulphate took less time for sprouting (92.59%) and also produced maximum shoot length due to the explants physiological state, genetic makeup and adequate auxin and cytokinin levels (Jhajhra *et al.,* 2018). The paper concluded the effect of temperature, GA3 and BA concentrations and photoperiod on strawberry runner induction and discovered that photoperiod length had greatest impact on runner induction

with 16 hours photoperiod, 25/15°C day and night temperature and 50 mg/L BA. Protein involved with photosynthesis and carbohydrate metabolism was generating for runner induction (Li *et al.,* 2020).

**Flower bud initiation in strawberry**

In order to trigger floral initiation, innovative forcing approach required depriving nursery plants of nitrogen. To encourage an early floral start, the following artificially low temperature practices have been developed: short days with solar irradiance and low temperatures in cooling infrastructure; constant dark-low temperatures with refrigeration facilities, including industrial warehouses and intermittent low temperature storage (Yoshida *et al.,* 2020). In this work, the stamen and axillary bud initiation deficits of the *F. vesca* ethyl methanesulfonate (EMS) induced loss of axillary meristems (*lam*) mutant. LAM is necessary for the beginning of axillary buds, which is necessary for the development of runners and branch crowns. The strawberry axillary bud initiation process has been shown to be regulated by the functionally characterized gene LAM. GA is more important for axillary buds destiny transition than for bud initiation (Feng *et al.,* 2021). In the short-day variety "Benihoppe", over expression of FaHAN deferred blooming and encouraged the development of runners during reproductive growth (Liang *et al.,* 2022).

**Effect of controlled environment on strawberry growth**

Strawberries are frequently grown in controlled environments with regulated lighting and temperature because the influence of open environment on strawberry (Samtani *et al.,* 2019). Strawberry fruit output and quality are significantly influenced by artificial light's wavelength and intensity and compared to other light sources, blue light alone increases strawberry (*F. ananassa cv. Elsanta*) fruit yield by around 25% (Nadalini *et al.,* 2017). In "Elan" but not in "Yotsuboshi" flower bud initiation after transplanting may be sped up by extending the photoperiod. In order to produce high-quality transplants, strawberry plugs might be grown under artificial illumination with a tailored photoperiod, albeit the success of this strategy seems to depend on the cultivar (Tsuruyama *et al.,* 2018).

**Plastic mulch effect on strawberry plant**

Different color polythene mulches and spacing are important in strawberry production because they conserve moisture, manage weeds, regulate hydrothermal cycles and protect the delicate strawberries from direct soil contact (Das *et al.,* 2022). Several types of mulches most importantly black polythene assisted in modifying the hydrothermal favorable soil conditions and soil management growing conditions for plants (Ngente *et al.,* 2021). Black plastic mulch has warming properties and is primarily used for winter season strawberries growing in Florida. However, growers stretch planting dates to boost earliness, black plastic mulch might exacerbate heat stress during establishment (Daschamps *et al.,* (2019). In comparison to other coloured mulches, red and black color plastic mulches yielded more strawberries. The type of mulch had no impact on the vegetative growth of plants or the quality of the berries (Lalk *et al.,* 2020). Plastic mulch and low tunnel strawberry plant production gradually improved strawberry cv. festival's vegetative growth characteristics, fruit yield and its components and fruit quality parameter (Soliman *et al*., 2015).

**Role of strawberry in income generation**

The goal of doubling farmer's income by minimizing their after-harvest losses and enhancing the demand of perishable cultivable fruit crops is achieved. Because it is a seasonal fruit and is nutrient-dense, it may be consumed outside of the growing season. It can also give rural farm women work and help farmers quadruple their income (Mehta *et al.,* 2019). Resource usage efficiency looks into each input's effectiveness and shows if it is being used too much or too little (Qamar *et al.,* 2017). Since the goal of every productive farm is to maximizing profit by reducing expense, it is crucial to assess the level of efficiency of the farmers when it comes to input utilization (Khatun *et al.,* 2019).

**Packaging material for strawberry storage**

Freshly picked fruits is packed in plastic punnets and wrapped in a variety of packaging materials, including cellophane paper, cling film, low-density polyethylene 25, 50 and 75μ and polypropylene 25μ. Modified atmospheric packaging using different films may be shown to be one of the best and most economical ways to have a longer lifespan with proper quality for a soft fruit like strawberries (Panda *et al.,* 2016). MSN (mesoporous silica nanoparticle) prepared films had a positive effect on fruit weight reduction and antioxidant activity, but they didn't seem to differ much in texture, pH, or citric and ascorbic acid levels from unwrapped samples. Based on these findings, PEC (pectin) based films made with MSN (mesoporous silica nanoparticle) and glycerol can be recommended as suitable options for increasing the life span of various fruits (Al-Asmar *et al.,* 2019).

**Influence on physiological disorder of strawberry**

The 5.5/7.0 ratio of $K^+/Ca^{2+}$ ratios remarkably accelerated or lowest the tip burn physiological disorder of Albion cultivar of strawberries in soilless and high amount of k can limit the availability of Ca and Mg and cause growing leaves and flowers to burn at the tips (Adak *et al.,* 2019). With excess application of nitrogen in the soil, low pH causes malformed fruits which are distorted and resemble a cat's face while fruits with albinism which are swollen and have white or pink spots on their surface and lower the yield by 20-25%. This disorder can be corrected with proper spacing and spray of borax and GA3 during Feb and Nov (Chaudhary *et al.,* 2022). *Trichoderma* like bio agents have many advantages, including the prevention and treatment of diseases as well as enhance the yield, improved nutrient absorption and improved crop quality (Marra *et al.,* 2019). It is possible to

suggest applying calcium and boron together to lower the prevalence of albinism, fruit deformity and grey mould in strawberries as well as to increase yield (Kumar *et al.,* 2022).

**Coating maintains strawberries quality during storage**

Prior to storage, strawberries coated with chitosan (0.5%) may help to maintain the fruit's characteristics and strawberries coated with chitosan (0.1%) retain their biochemical characteristics. Chitosan fruit coating improved acceptance of strawberries by consumers under extended cold storage and a 0.5% chitosan coating, strawberry sweetness was preserved (Hassan *et al.,* 2020). Because edible coating allows for less water vapour transfer, aloe vera gel (AV gel) addition can substantially reduce fungal decay, extending strawberries' life span up to 15 days of storage at the highest AV gel concentration (20%) while maintaining their physical and chemical properties, such as colour and hardness. Compound films produced from banana starch, chitosan and AV gel serves as examples (Pinzon *et al.,* 2020). Strawberries' shelf life would be increased by *Prosopis juliflora* leaf Ethanolic extract coating (water soluble) while maintaining their storage quality standards and act against spoiling agents including *B. cinerea* (Saleh *et al.,* 2022). The edible coating of calcium chloride and sodium alginate worked well to slow the rise of pH and soluble solid content while reducing metabolism and transpiration rates. Additionally, the coating stopped the growth of surface mould for up to 15 days and preserved the cut fruits' sensory attributes, such as colour and texture (Alharaty *et al.,* 2020).

## Micronutrient effect on strawberry

**Effect of micronutrient on growth, flowering**

The growth parameter of strawberry cv. Winter Dawn at 60 DAP showed notable increase by different micronutrient application at all growth stages (Saha *et al.,* 2019). Combined treatment spray of $FeSO_4$ and $ZnSO_4$ increases vegetative growth in strawberry cv. Chandler due to chlorophyll synthesis and electron transfer in oxidation (Singh *et al.,* 2015). Effect of micronutrients with treatment $ZnSO_4$ + $H_3BO_4$ + $FeSO_4$ @ 0.4% shows minimum days after transplanting to first flower (64.30 days) and no. of flower per plant also increased in strawberry cv. Chandler (Verma *et al.,* 2018). Earliest flowering, maximum no. of flower/plant increased with the application of $GA_3$ 75 ppm+ $ZnSO_4$ 0.4%+ Boric acid 0.4% in cv. Chandler (Bairwa *et al.,* 2022).

**Effect of micronutrient on fruit quality, yield**

Before harvesting, the application of micronutrients like zinc sulphate, Boron and iron sulphate helps in enhancing the quality of strawberry fruits. Foliar application of Zn, Fe and B treatment at three time interval *i.e.* 30 DAT, 60 DAT and 90 DAT increases quality characters of strawberry fruit (Sudha *et al.,* 2018). TSS: acid ratio, total sugar and reducing sugar, ascorbic acid and anthocyanin content increased with the application of $ZnSO_4$ and minimum acidity is recorded with this treatment (Saha *et al.,* 2019). Average fruit weight of strawberry is improved by the foliar application of Zn Parmar *et al.* (2021). Combination of micronutrients like $ZnSO_4$ + $H3BO_4$ + $FeSO_4$@ 0.4% increase fruit per plant. This may be done by increase leaves chlorophyll content, translocation of metabolites, photosynthetic efficiency (Verma *et al.,* 2018). Strawberry plant treated with RDF + $ZnSO_4$ @ 0.6% significantly increase the yield 1.17 kg/plant. This treatment significantly influenced yield and yield attributes parameters of strawberry (Chandrakar *et al.,* 2019). Improvement of yield characters might be a result of the additional positive effects of Fe on yield. It is possible that plants getting Zn + Fe created more photo synthates and translocated to the growing fruits (Parmar *et al.,* 2021). 0.4% Zn foliar spray performs best in term of growth and yield in strawberry plants (Mishra *et al.,* 2016). Growth and yield of strawberry is increased with the application of $ZnSO_4$ 150 mg/l (Kazemi *et al.,* 2015). Growth regulators and micronutrient have a great potential which influence the vegetative growth and yield of strawberry (Yadav *et al.,* 2017). 99 mg/l Zn application enhanced growth, yield in strawberry cultivation and increase Zn concentration in fruits (Bhatti *et al.,* 2021). Boron deficiency worsens fruit quality by raising titratable acidity, but its application enhances fruit quality (Haider *et al.,* 2019).

**Macronutrient effect on growth, yield and flowering**

Early blooming, vegetative growth and other reproductive, vegetative and qualitative characteristics of the strawberry plant were all significantly influenced by potassium (Ijaz *et al.,* 2016). All growth characters like maximum plant height with 120% dose of P per plant and maximum plant spread, number of leaves per plant and minimum no. of days taken to first initiation of flower observed with RDP 100%, but with increased P rates (120%), these growth characters decreased (Reddy *et al.,* 2021). The continual application of water soluble phosphatic fertilizer together with the prescribed doses of nitrogen and potassium may have contributed to these findings by enhancing nutritional absorption in strawberry fruits (Ahmad *et al.,* 2018; Singh *et al.,* 2019).

## CONCLUSION

In addition to providing critical nutrients and dietary advantages including essential vitamins and minerals, strawberries are also a substantial source of phytochemical that is good for human health. Because strawberries are a "functional food," their anti-oxidant, anti-diabetic, anti-hypertensive, anti-carcinogenic and anti-hyperglycemic qualities give customers additional health advantages. Treating strawberries with edible coating increase the life span at ambient temperature, reduce the decay of fruits and act against many spoiling agents. Different macro and micronutrient and plastic mulch plays crucial role in growth, yield and quality of this fruit plant. Black polyethylene mulch improved soil moisture regime and significantly decreased irrigation and weed development. It also concluded that the

main building blocks for all biochemical and metabolic activities are called macronutrients and micronutrients are crucial for plant growth from seed to fruit set, berry size, crop physiology, generation of amino acids and more effective absorption of macronutrients. Physiological disorders can also be improved with Ca and B application.

**Conflict of interest**

All authors declared that there is no conflict of interest.

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