Response of nutrient management on growth, yield and quality of strawberry: A review

Dr. Aradhana Barooah and Himadri Shekhar Datta

Abstract
Strawberry is a small fruit but for quality higher production large amount of nutrients are required for which efficient nutrient management is essential. Though inorganic fertilizers are major source of nutrients, imbalanced application of only chemical fertilizers may cause deleterious effect on soil health and environment. Organic manures can be used to supply nutrients for sustainable growth, yield and quality of strawberry. But sole application of organic manure has some problems like imbalanced supply of nutrients, not cost effective and less production as compared to inorganic fertilization. Biofertilizers are natural fertilizers with living microbial inoculants and can make unavailable nutrients available to plants. Integrated nutrient management can play important role for sustainable strawberry growth, yield and quality by maintaining long term soil fertility. Keeping in view of proper nutrient management for better growth, yield and quality of strawberry, different nutrient management in strawberry is reviewed.

Keywords: Strawberry, vermicompost, biofertilizer, integrated nutrient management

Introduction
Breeding between two American species, Fragaria chiloensis and Fragaria virginiana resulted in a hybrid plant which is the cultivated Strawberry (Fragaria × ananassa Duch.) (Trejo-Téllez and Gomez-Merino, 2014) [65]. It is a small fruit belonging to family Rosaceae which have acquired significant prominence among fruits and is now classified as a functional food offering multiple health benefits beyond basic nutrition with antioxidant and antihypertensive properties (Basu et al., 2014) [9]. Strawberry fruit is greatly appreciated by all irrespective of age group for its characteristic flavour, attractive red colour, juicy texture, and sweetness and the fruit is rich in vitamin C (40-120 mg/100 g fruit), protein and different minerals viz., phosphorus, potassium, calcium and iron (Kanupriya, 2002) [30], phenolics and flavonoids (Hakkinen and Torronen, 2000) [23]. Strawberries have got economic importance and are consumed either fresh or in prepared products like jams, juices, and jellies. This has led to the development of great interest in the study of Strawberry from the agronomic, genomic, and nutritional points of view (Giampieri et al., 2012) [18]. Strawberry is a permanent herbaceous plant with adventitious root system and most of the roots (50 to 90%) confined on the top surface soil and the plant is very sensitive to nutrient fluctuation (Yadav et al., 2010) [74]. Strawberry can be cultivated in a wide range of soil varying from light sand to heavy clay but grows best in humus rich light porous soil (Sharma and Singh, 1999 [52]; Sharma, 2002 [81]). Proper nutrient management is inevitable as it affects vegetative growth as well as yield of crop (Sharma et al., 2006) [50]. Nutrient management as well as maintenance of soil fertility is crucial for increased yield and fruit quality of strawberry and both macro and micro nutrients have positive effect on strawberry crop production (Trejo-Téllez and Gómez-Merino, 2014) [65]. Though application of chemical fertilizers is essential for significant enhancement of growth, development, yield and quality of strawberry, but continuous indiscriminate use of exclusive application of inorganic fertilizers only may cause deficiency of micronutrients and create hazardous effect on soil fertility and ecosystem, and ultimately poor crop yield (Singh and Singh, 2009) [53]. Okwuagwu et al., (2003) [44] reported that increasing soil enzyme activity, available nitrates, carbon to total organic carbon ratio of organic manures enhance the soil fertility. Organic farming plays an important role by improving soil health as well as enzymatic activity of fruit plants (Kumar et al, 2018) [37]. But organic manure has some disadvantages as compared to chemical fertilizers like lower fertilizer efficiency, imbalance of nitrogen, phosphorus, potassium leading to lower yield of crop (Song et al., 2017) [58] and organic manures are less available, expensive and production cost may increase up to 30% (Hamlet, 2001) [24]. Therefore, cost-effective increased yield with better quality fruits cannot be obtained by application of organic manures only. Being the carrier-based micro-organisms, biofertilizers help in increase of production by nitrogen fixation, phosphate solubilization and
releasing hormones, vitamins and growth promoting substances (Bamboriya et al., 2018) leading to enhancement of yield and quality of fruits. Therefore, a judicious integrated application of organic and inorganic nutrients along with biofertilizers may help in enhancing crop growth, yield and quality of strawberry (Subraya et al., 2017) as well as sustaining soil health (Meena et al., 2019).

A. Influence of organic nutrients on growth, yield and quality of strawberry

a. Effect of FYM (farm yard manure) on growth, yield and quality of strawberry: Being the most important and commonly used bulky organic manure, FYM, plays an important role in enhancement of strawberry yield by improving physico-chemical properties of soil along with release of macro and micro nutrients (Lakkineni and Abrol, 1994) (38), Rashid (2018) made a study on growth, yield and quality of strawberry cultivars viz., Festival and AOG, by using different organic manures (cowdung, mustard oilcake and poultry manure) in single and in combined treatments and observed that combined application of cowdung + mustard oilcake + poultry manure is the best treatment in terms of yield (19.14 t/ha). Application of 40 tonnes of organic fertilizer (FYM) + 60 kg/ha NPK fertilizers in strawberry cultivation resulted higher fruit yield (27.62 t/ha) (Mahadeen, 2009) (40). Maximum residual available major soil nutrient content like N (375.66 kg/ha), P (24.36 kg/ha) and K (164.52 kg/ha) was observed in the combined treatment of 100% NPK through FYM (Ahmadi et al., 2018) (4). Organic fertilization enhances early onset of reproductive stage of strawberry (Herenica et al., 2011) (28). Total sugars, TSS and juice percentage increased at organic manure treated strawberry plants (El-Hamid et al., 2006) (17).

b. Effect of compost on growth, yield and quality of strawberry: Application of compost in soil with proper management can add array of nutrients to soil (Tejada et al., 2001) (62), enhances soil organic matter, improves water holding capacity and other physical properties of soil (Wells et al., 2000) (23), increases population of beneficial soil microbes, reduces plant pathogens (Abawi and Widmer, 2000) (1) and has positive effect on growth and yield of many plants (Sarwar et al., 2008) (49). Direct application of rice straw compost in soil and foliar application enhances yield and quality of strawberry. Application of 80% rice straw compost along with 20% soil resulted in highest yield (185.3 g/plant) and sweetness (total sugar 5.19%) of strawberry (Ashrafi et al., 2019) (7). In dryland conditions, application of sawdust, compost and manure to strawberry plantings, significantly increased organic matter content of the soil as compared to control (Webster, 1961) (71). Better crop growth, higher yield and good quality fruits of strawberry can be derived by applying kitchen waste based liquid manure (Tiwari et al., 2016) (63). Recycled food waste based liquid compost can also increase strawberry production (Dara, 2017) (15). Liquid organic fertilizer of vegetable waste @ 750 ml and 1:2 (soil rice husk charcoal) media revealed maximum leaf area (835.42 cm²) and better quality of strawberry (Ginandjar et al., 2019) (19). Foliar application of aerobically prepared compost tea increased strawberry yield by 20% in comparison to control and water sprays (Welke, 2004) (72).

c. Effect of vermicompost on growth, yield and quality of strawberry: Vermicompost is an accelerated product of organic wastes, which is produced by interaction between earthworms and microorganisms, contains plant growth hormones and plant growth regulators (Kumar et al., 2018) (57). Vermicompost as well as vermiwash play an important role as growth promoter and protector of crop plants (Adhiakary, 2012) which help in increasing production. For transitional and organic production of strawberry, vermicompost can be applied as sustainable soil management strategy (Beck et al., 2016) (10). A study was conducted to evaluate the effect of vermicompost on growth and yield of ‘Chandler’ variety of strawberry under field condition. Significant enhancement in strawberry growth parameters and yield; including 37% increase in leaf areas, 37% in plant shoot biomass, 40% in numbers of flowers, 36% in numbers of plant runners and 35% in marketable fruit weights was found in vermicompost treated plants (Arancon et al., 2004) (6), Arancon et al. (2003) (5) also reported significant increase of leaf areas, number of strawberry suckers, number of flowers, shoot weights and total marketable strawberry yield in vermicompost added plots as compared to the inorganic fertilizer treated plots. Another study on foliar use of vermicompost and mustard oilcake as alternative source of nutrients for strawberry production revealed that maximum plant height (17.3 cm/plant), highest number of leaves (19.9/plant), highest number of runners (5.9/plant), highest number of fruits (26.9/plant), single fruit weight (14.3 g), fruit weight (383.7 g/plant), brix (7.8%) and highest yield (11.0 t/ha) was found in vermicompost treated plants (Rahman et al., 2018) (46). In 18 weeks old greenhouse grown strawberry, maximum above ground vegetative biomass (15.3 g) was found when vermicompost at 25% is added with synthetic fertilizer as compared to synthetic fertilizer addition only (5.3 g) (Broz et al., 2017) (12). Enhanced vegetative growth as well as improved quality of strawberry fruits can be achieved by farm yard manure and vermicompost based organic amendments (Khalid et al., 2013) (32). Application of vermicompost @ 2.5 to 10 t/ha with inorganic fertilizer significantly increased plant spread, leaf area, dry matter and the marketable fruit yield of strawberry up to 58.6% with better quality parameters (Singh et al, 2008) (96). Hasan (2013) made a study on strawberry germplasm and organic matter response and reported that vermicompost was an excellent organic nutrient for growth, development and quality attributes including sweetness of strawberry. Changotra et al., (2017) (13) also reported positive effect of vermicompost on growth and yield quality of strawberry. Singh et al., (2010) (55) made a study on the effect of vermicompost on plant growth, fruit yield and quality of Chandler cultivar of strawberry and found that vermicompost application @ 10 t/ha increased plant spread (16.1%), leaf area (31.4%), dry matter (17.7%) and increased fruit yield (29.1%) over chemical fertilizer. Vermicompost treated plants produce healthy fruits with better quality (higher TSS, ascorbic acid content, lower acidity). Mehraj et al., (2014) (50) made an experiment to study the response of different organic manures viz., cowdung, vermicompost and poultry litter on strawberry and found that vermicompost gave maximum number of fruits (19.2/plant), maximum above ground vegetative biomass (15.3 g), single fruit weight (14.4 g), total fruit weight (282.8 g/plant) and brix percentage (10.2%). Study also suggested vermicompost as a potential source of plant nutrients for organic strawberry production. For soilless production of strawberry, vermicompost + sand (20:80) and 15.85 v/v% can be used as it has a high potentiality to enhance highest growth, yield (585 g/plant), quality and chemical contents (Abul-Soud et al., 2015) (2). Arancon et al., (2004) (6) reported that application of food and paper waste vermicompost profusely...
increase growth, flowering and yield of strawberry cv. Chandler.

d. Effect of biofertilizer on growth, yield and quality of strawberry: Biofertilizers are microbial inoculants help in increasing crop production by maintaining soil health. Organic manure use efficiency (Hassan, 2015) [26] and strawberry growth and yield was stimulated by application of plant growth promoting biofertilizers (Karldag et al., 2009) [31]. Plant growth, fruit quality and yield of strawberry can be significantly improved by appropriate combined application of bio-fertilizers with plant growth regulators (Sood et al., 2018) [60]. A study on application of effective microorganisms (2%) and nitrogen treatment of 100 kg/ha through foliar application and fertigation in ‘Paros’ variety of strawberry in field condition showed maximum fresh (10.82 g) and dry weight (1.6 g) of berries (Einizadeh and Shokouhian, 2018) [16]. Application of NPK fertilizers with single microbial inoculation in strawberry plants can reveal positive effect on strawberry plant growth (Glinicki et al., 2011) [29]. Mishra and Tripathi (2011) [43] made a study and found that combined application of Azotobacter and PSB significantly increased growth parameters like plant height, number of leaves, crowns, runners, number of flowers, fruit set per plant, fruit quality of berries (length, width, weight, volume, TSS, total sugars, ascorbic acid, titratable acidity). Highest fruit set yield and optimum fruit quality of strawberry cv. Sweet Charlie was found when the crop was inoculated with Azotobacter and Azospirillum @ 2kg/ha each, with 60 kg N/ha and 100 ppm GA3 (Singh and Singh, 2009) [53]. Significant effect on number of primary flowers per plant (8.0), number of secondary flowers per plant (10.0), total number of flowers per plant (7.0), number of primary fruit per plant (7.0), number of secondary fruit per plant (10.0) and total number of fruit per plant (17.0) was observed by combined application of PSB + nitrogen (225 kg/ha) and phosphorus (150 kg/ha) (Zargar et al., 2008) [77]. A study on application of biofertilizer and nitrogen to strawberry cv ‘Chandler’ revealed that Azotobacter inoculated plants resulted in maximum plant height (24.92 cm), more number of leaves per plant (26.29 cm), more leaf area (96.12 cm²), number of runners (18.70/plant), heavier fruit (10.02 g), more fruit length (35.9 mm) and more fruit breadth (22.91 mm) (Rana and Chandel, 2003) [45]. Tripathi et al (2017) [66] made an experiment to study the efficacy of bio fertilizers and mulching on growth, yield and quality of strawberry cv. Chandler and found that Azotobacter (7kg/ha) + black polythene produced higher yield (108.06 g/plant), maximum berry length (2.91 cm), width (1.81 cm), weight (7.13 g), volume (4.38 cc), TSS (7.18 °Brix), total sugars (5.62%), ascorbic acid (56.07 mg/100 g pulp) with minimum acidity (0.25%). In hydroponic system, the effect of Azospirillum and Azotobacter species on the growth and development of strawberry was studied and found Azotobacter and nitrogen treatments better than Azospirillum species (Rueda et al., 2016) [48]. Todeschini et al. (2018) [46] made an experiment and found that co-inoculation of different strains of arbuscular mycorrhizal fungi (AMF) with plant growth promoting bacteria (PGPB) (strains of Pseudomonas sp.) can enhance strawberry yield and quality as well as can help in maintenance of soil fertility. Use of fungal bacterial biofilm as a biofertilizer in strawberry cultivation reduces the use of chemical fertilizer (Singhalge et al., 2019) [57].

e. Combined effect of organic manure and biofertilizer on growth, yield and quality of strawberry: A study on effect of organic manure and biofertilizers on growth, yield and quality of strawberry cv. Sweet Charlie revealed that integrated application of vermicompost (50%), poultry manure (50%) and Azotobacter showed maximum plant height (19.61 cm), number of leaves (21.11), number of fruits (30.41/plant), number of fruits (20.41/plant), fruit length (3.70 cm), fruit width (3.20 cm), fruit weight (11.83 g) and fruit yield (144.77 g/plant, 2.32 kg/plot, 7.72 t/ha) (Soni et al., 2018) [39]. Kumar et al., (2015) [36] revealed that vegetative growth parameter like fruit setting and Total Soluble Solids in strawberry plants increased when organic matter is applied in combination with biofertilizer. Influence of combined nutrient management on yield, quality, shelf life and economics of strawberry revealed that application of poultry manure, vermicompost, Azotobacter and PSB gave highest yield (112.63 g/plot), quality (TSS 7.05 °B, ascorbic acid 53.42 mg/100 g of pulp) and shelf life (5.69 days) while highest B:C ratio (1:3.64) was found in FYM, vermicompost, Azotobacter and PSB treated strawberry crops (Jain et al., 2017) [29]. In another study Kumar et al (2016) [37] revealed that integrated application of vermicompost @ 2.5 t/ha + half dose of recommended dose of NPK fertilizer resulted maximum plant height, number of leaves per plant, days taken to first flowering, number of flowers per plant, number of fruits per plant, duration of harvesting and yield per plant. A study on the effect of different organic combinations on yield and quality of strawberry cv. Kurdistan reported that combined application of manure + Azotobacter + wood ash + phosphorus solubilising bacteria + oil cake significantly enhanced fruit diameter (3.11 cm), length (3.95 cm), volume (20,397 cm³), weight (11.11 g), total sugar (7.95%), TSS (9.01 °B), acidity (0.857), TSS: acidity ratio (11.12) and yield (238.95 g/plant) (Dashapour and Jouki, 2012) [14]. Gupta and Tripathi (2012) [21] reported that combined application of Azotobacter (7kg/ha) + vermicompost (30 t/ha) significantly increased the plant height (19.45 cm), number of leaves (63.60), number of runners per plant (5.34) and maximum number of flowers (67.48) and fruit set (39.21) in strawberry cv. Chandler. Combined application of vermicompost + Azotobacter + PSB + Arbuscular mycorrhiza recorded maximum plant height, plant spread, number of leaves, leaf area and yield of strawberry (Singh et al., 2015) [54].

B. Influence of Integrated Nutrient Management on growth, yield and quality of strawberry
Integrated application of organic manure and biofertilizer with chemical fertilizer is an important step in sustainable strawberry production, reduction of environmental contamination and can enhance the qualitative and quantitative characteristics of strawberry (Habibzadeh et al., 2019) [22]. A study on the effect of organic, inorganic and biofertilizer based integrated nutrient management for nitrogen supply on growth of strawberry variety Chandler revealed that biofertilizer (Azospirillum) along with half of the Nitrogen through organic manuring viz., vermicompost and remaining half Nitrogen through inorganic fertilization significantly increased sustainable growth and yield of strawberry in field condition (Yadav et al., 2016) [76]. Maximum marketable strawberries (101.99 kg/ha) and TSS (total soluble solid) in berries (12.2° Brix) was also found in integrated application of biofertilizer, vermicompost and inorganic fertilizer. Combined application of mineral, organic and biofertilizer significantly increased leaf area (529.66 cm²)/plant, number of leaves (28.56), number of fruits (33.73) and total production (367.24 g/plant) (Khalil and Agah, 2017)
Yadav et al. (2010) [75] made a field study on application of various sources of nutrients without effecting the growth and yield of strawberry crop at lower cost and found that number of crown (4.33/plant), number of runners (11.33/plant), length of runners (45.67 cm), number of plantlets (12.53 lakh/ha), fruit characteristics like number of flowers (29.60/plant), number of berries (22.27/plant), and fruit yield (101.99 q/ha) were highest in integrated treatment of Azotobacter with 50% N substituted by vermicompost and remaining 50% through chemical fertilizer in two equal splits at establishment and before flowering stage. However due to lower cost of FYM than vermicompost, N substituted by FYM provided highest B:C ratio than vermicompost. Ahmad et al. (2017) [4] made a polyhouse experiment to study the effect of integrated nutrient management on yield and quality of strawberry variety Sabrina and found that the strawberry plants treated with 100% RDF + VAM @ 10 kg/ha + 0.4% Boron + 0.5% ZnSO₄ spray resulted in significantly maximum number of fruits/plant (19.07), fruit weight (16.23 g), fruit length (4.28 cm), fruit diameter (2.56 cm), fruit volume (18.83 ml), yield/plant (309.70 g), yield/ha (17.20 tons), Benefit: Cost ratio (2.37), TSS (10.13 0 Brix), total sugar (6.01%), reducing sugar (5.17%), TSS: Acid ratio (16.78) and lowest titrable acidity (0.61%). Significantly maximum leaf nutrient content like N (2.74%), P (0.51%), K (2.99%), Zn (29.00 ppm) and B (76.67 ppm) was also found in the strawberry plants treated with 100% RDF, VAM @ 10 kg/ha, 0.4% Boron, 0.5% ZnSO₄ spray. Kirad et al. (2009) [34] made an integrated approach of application of chemical fertilizer, organic manures viz., farmyard manure, vermicompost, poultry manure and rhizosphere bacteria culture, alone and in combination with different reducing level of chemical fertilizer and highest plant spread (32.37 cm), fruits per plant (8.77), fruit yield per hectare (8.07 t), shelf life (3.95 days) were found at 75% recommended fertilizer rate + 25% vermicompost + rhizosphere bacteria culture treatment but maximum plant height (20.35 cm) and acidity (0.83%) were observed in 75% recommended fertilizer rate + 25% vermicompost. Application of 25 per cent nitrogen through FYM + 75 per cent nitrogen as urea + Azotobacter in strawberry plant Cv. Chandler revealed highest amount of fruit quality parameters like total soluble solids, total sugars, ascorbic acid and anthocyanin content (Umar et al., 2009) [67]. The impact of integrated nutrient management on yield and quality of strawberry (Fragaria x ananassa Duch.) under naturally ventilated polyhouse condition was studied by Subraya et al. (2017) [61] and application of 75% of recommended dose of fertilizer + Azospirillum + PSB found best in terms of quality and yield of strawberry. The study also emphasized that by incorporating biofertilizer, inorganic fertilizer application can be reduced to 25%. Hammad et al. (2014) [25] made an experiment to study the influence of compost, effective microorganisms and potassium on strawberry production in sandy soils and revealed that application of compost @ 8.3 kg/m² and effective microorganisms resulted in highest yield (1023 g/plant) and quality of strawberry but the fresh and dry weight as well as nitrogen, phosphorus and potassium uptake were significantly increased in compost @ 12.5 kg/m² and effective microorganisms treated strawberry plot. Marketable and total fruit yield (1048 g/plant) and total soluble solids (10.65%) and firmness significantly increased in potassium treated plots. From the study it can be concluded that integrated application of effective microorganisms with organic and inorganic nutrients increase strawberry yield. Integrated application of inorganic and organic sources of nutrients positively affect the vegetative, reproductive and yield of strawberry plant and 75% of organic fertilizer integrated with 25% of inorganic fertilizer gave the best result (Wani et al., 2013. [69] Wani et al., 2015) [70]. Beer et al., (2017) [11] studied the effect of organic, inorganic and bio-fertilizers on different growth parameters and yield of strawberry and found that integrated application of vermicompost (25 ton/ha) + Azotobacter (6 kg/ha) + NPK (70:80:80 kg/ha) needed minimum number of days to produce first flower, produced maximum number of flowers per plant, number of fruit set per plant, superior fruit quality and highest yield of strawberry. Integrated application of organic, inorganic and biological sources of optimum nutrients enhance the quality of strawberry fruits like size, TSS, sugars, acidity, anthocyanin pigmentation etc. (Yadav and Khokhar, 2012) [74]. Integrated application of Azotobacter (50%) + Azospirillum (50%) + NPK (50%) + FYM (30 t/ha) gave maximum plant height, number of leaves per plant, length of leaves and width of leaves of strawberry plant (Lata et al., 2013) [39]. Verma and Rao (2013) [68] made an experiment to study the impact of INM on soil properties, plant growth and yield of strawberry Cv. Chandler and reported that application of Azotobacter + PSB + vermicompost + 50% recommended dose of NPK recorded maximum plant height, plant spread, leaf area per plant, fruit weight, number of fruits and yield per plant and yield per hectare.

References


40. Mahadeen AY. Influence of organic and chemical fertilization on fruit yield and quality of plastic house
71. Webster GR. The effect of sawdust, straw, compost and manure on the yield and chemical composition of

http://www.phytojournal.com