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Organic production of strawberry: A review

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Abstract
Now-a-days, organic foodstuffs are being illustrious for all people around the world. Owing to the great local and global market demand of organic fruits, production of organic fruit has rapidly increased in the past one decade to prevent health issues resulting from pesticides and hazardous chemicals. Organic farming enhances soil organic carbon, soil moisture content; improve soil health, increasing productivity, microbial and earthworm population and enzymatic activity in the fruit plant. Application of different organics in combinations and in a cumulative manner can supply the nutrient requirement of fruit crops to augment the sustainability in yield and quality. The excessive usage of chemical fertilizers and pesticides particularly on those fruits, which can be eaten without removing peels such as strawberry fruit, are harmful for human health as well as decline in the bio-environmental and conventional cropping system which can be solved through organic farming. It is need of hour to protect the environment and advancing degradation of soils, the negative impact of intensive fruit production, and the worsening effects of climate change (Dobrzyński *et al.* 2014). Keeping in view the application of chemicals fertilizers and vulnerability of diseases, the people are becoming more health consciousness thereby the demand of organic fruits are increasing which resulted in more income to the growers.

Keywords: strawberry, organic production, bio-fertilizers, yield, quality

Introduction
Strawberry is one of the important delicious and soft fruit among the berries. Diverse strawberry species grow wild in all over the world, but the cultivated strawberry is based upon two American species *Fragaria chiloensis* and *Fragaria verginiana*. Hybrid between these two species was the ancestor of all the modern strawberry cultivar (John, 1994) [33]. The fleshy fruit of strawberry is classified as an aggregate fruit (Green, 1971) [24]. Cultivated strawberry (*Fragaria* x *ananassa* Duch) is one of the legendary fruit in temperate countries. However, it can also be grown in the tropical and sub-tropical climatic conditions. It is the easiest fruits to grow in kitchen garden, decorative pots, hanging basket and are also grown in flat or raised beds as well as protected structure. It is paying back within six months after planting. In the world, the high demand on organic berry fruit plants has increased in last decades which make strawberry cultivation very demanding enterprise (Asad, 1997) [6]. Its fruit is a good source of Vitamin-C (40-120 mg/100g of fruit), protein and minerals like potassium, phosphorus, calcium and iron (Kanupriya, 2002) [34] as well as foliate and photochemical compound such as the elligic acid. As compared to other berry fruits, strawberries contain a higher percentage of vitamin-C, phenolics and flavonoids (Hakkinen and Torronen, 2000) [25]. India, although comes at second place with respect to total number of certified organic farms (44,926), occupies 13th position as far as the area under organic agriculture concerns. In India, about 5, 28,171 ha area is under organic agriculture (including certified and area under organic conversion) accounting for about 0.3% of total agricultural land. Organic fertilizers are utilized globally to protect the soils against deterioration and environment pollution. The present requirement of bio-fertilizer is 4, 26,000 MT against total supply 65,528 MT. For organic manures, the total requirement is 710 million tonnes and supply is 105 million tones. Organic nutrients increase soil enzyme activity, available nitrates, carbon to total organic carbon ratio and metabolic quotients resulting in enhanced soil fertility (Okwuagwu *et al.*, 2003) [47]. Addition of compost is also known to enhance microbial biomass and soil respiration (Bhattacharyya *et al.*, 2003) [10]. Soil microbial health can be related to soil enzyme activity which is enhanced by fermentation of compost (Crecchio *et al.*, 2001) [17]. Organic fertilizers improve soil fertility by modifying soil structure, pH, biophysical conditions and availability of essential nutrients (Atiyeh *et al.*, 2002) [7].

- **Impact of organic manures on growth characteristics of strawberry**

a. Plant growth

Increasing demand of organic fruit, makes it highly lucrative per unit area. The macro and micro-elements are considered very essential because of sustainable growth and development of plant. Tucker (1926) [64] reported that the application of stable manure increased vegetative growth which was observed by production of more runners and their branching had direct relation to the amounts of manure applied. The stable manure also increased vegetative growth in strawberry while chemical fertilizers apparently decrease it. The nitrogen content in fresh poultry manure has almost double amount of nitrogen as compared to farmyard manure and has higher phosphorus and potassium level as reported by Cooke (1972) [16]. Sufficient amount of FYM 80-85 tonnes/ ha has been recommended per planting dose during land preparation.

b. Flowering

In strawberry varied flowering season has been reported with respect to place and year to year Desai (1963). On the basis of photoperiodic responses, strawberry cultivars are mainly categorized as June bearers, ever bearers or day neutrals. June bearer cultivars are facultative as short day (SD) plant (Darrow, 1936) [18]. Long day (LD) plants required below 16º C temperature for flower bud differentiation so evergreen plants classified as Long day plants (Ito and Saito, 1962; Heide, 1977) [30]. Day neutrals strawberry cultivars were tested by Durner *et al.* (1984). In vigorous plants, some extra parts are common while as under unfavourable conditions, some flower plants may be suppressed. The extent to which sepals, petals and epicalyxes open in are partly genetically as well as environmentally affected (Darrow, 1966). Arancon *et al.* (2004) [5] found that growth, flowering and yield of field strawberries exhibited a marked increase after applications of food and paper waste vermi-composts in cv. Chandler. Odongo *et al.* (2008) [45] reported an increase in photosynthetic production due to phosphorus contents in farm yard manure which helped to break bud dormancy and increased flowering sites. The quantum of nutrients as N, P and K and hormones provided by vermin-composts plays a significant role in increasing gibberellic acid in roots thereby breaking bud dormancy and increasing flowering buds and fruiting sites Tagliavini *et al.* (2005) [62]. An early onset of reproductive stage by the application of organic fertilizers has been reported by Herencia *et al.* (2011) [28].

c. Fruit setting

Manures containing favourable amounts of macro and micro nutrients and enhance fruit setting and fruit size and weight by the formation of carbohydrates than inorganic triple phosphate fertilizer (Odongo *et al.* 2008) [45]. During the process of fruit ripening, fruits represent sink for potassium and nitrogen and composts contain significant amounts of these essential nutrients. Reduction in number of fruits and flowers can be attributed to deficiency of nitrogen and phosphorus at the time of flowering which leads to reduction in flower size and abortion of female flower parts Tagliavini *et al.* (2005) [62].

d. Yield

Albregts and Howard (1981) [2] recorded increased yield at 27.5 mt/ha with the use of poultry manure at 18 mt/ha in the first year and reported that 36 mt/ha poultry manure caused plant damage and reduction in marketable yield due to fruit rot. Knight and Wallace (1932) [37] reported that treated with FYM were more vigorous than with chemical fertilizers. Nitrogen applied at the rate of 100 and 140 lbs. per ha gave excessive plant growth (Linberry *et al*., 1944) [41]. Wallace (1936) observed more yield with organic manures in strawberry. The chemical fertilizers mainly contain NPK which are leached down to sub-soil, thus contaminate it, whereas organic manures are slowly available to plants and are eco-friendly, increases yield and soil fertility (Kaul, 1998) [36]. Knight and Wallace (1932) [37] found dung much superior to chemical fertilizer in increasing yields and the best results were obtained with light annual dressing of dung at 12-13tonnes/acre. The manure applied was 20 tones FYM; check no manure fertilizer at 40 kg N, 150 kg P_2O_5, 50 kg K_2O, however, a yield of 227.21 kg was recorded where FYM were added in combination with fertilizers. The plant grown in soil deficient or not receiving nitrogen or phosphoric acid shows varied relative yield (about 2,000 quartz/ acre) but satisfactory yields (4000 quartz or more) were obtained when fertilizer contained 160 lbs P_2O_5 (Linberry *et al*., 1944) [41]. The manure as a whole *i.e.* averaging the effects of dung and chemical showed an increase of about 12 percent, dung gave somewhat larger increase than chemical about 8 percent approximately with improved fruit size and quality. An application of 30 tonnes /acre increased the yield over 12 tonnes /acre.

e. Fruit quality

Knight and Wallace (1932) [37] observed large berries by the application of FYM than control. A light dressing of bone meal (150 pound/ acre) at the end of December was reported to improve the flavour of the fruit (Anon, 1956). Moreover, application of organic manures significantly reduced the acid content of strawberry fruits over control. Wood ward (1972) [71] reported that the composition of strawberry varies from stage to stage during maturity. Advancement of maturity increases the weight, soluble solid and acidity while as chlorophyll, pH and carotenoids decrease. Similar reports were recorded wherein total phenol decreased with the advancement of fruit maturity (Spayed and Morris, 1981) [60]. El-Hamid *et al.* (2006) [21] registered that organic manures treated plants increase in total sugars, TSS and juice percentage.

f. Runner production

Strawberries are propagated very easily by runners in temperate areas having well moisture soil, fertilizes and proper draining system while it is very intricate to propagate in those areas where temperature goes above of 40^0 C during regeneration period and water logging site. Tucker (1926) [64] observed that application of stable manure increased [24] vegetative growth which was observed by production of more runners and their branching owing to sufficient organic carbon in soil Bailey (1963) [8] stated that the FYM to be the best manure for strawberry cultivation. Hughes *et al.* (1969) [29] observed that 20-30 tons per acre Farm Yard Manure prior to the planting runners enhances runner production. Widjajanto and Widodo (1982) [70] concluded that organic manure treated plants increased plant height, plant spread, proper growth, development and to obtain healthy runners production.

g. Root development

The strawberry plant, a herbaceous one is exceptionally shallow rooted, hence needs extra care in the nutrition as well as growing strategy. Almost 90 per cent of the roots of this

crop are spread in top six inches of soil. Usually, strawberry has two types of roots, the large primary ones and small secondary lateral roots. Rooting is active as long as soil temperature is above 45° F. Preusch *et al.* (2004) [49] reported an increase in root length in strawberries with fresh and poultry litter compost compared to control (no manure) which was attributed to the role of potassium in root proliferation. Davis (1925) [19] attributed damage to to strawberry owing to the chemical fertlizers, which increases ion concentration of soil solution. In general, there is lack of agrrement with regard to strawberry nutrition with organic manures or inorganic fertilizers alone. However, since the roots of this plant are mainly present in top soil, hence respond better to organic manures than inorganic fertilizers. Ogendo *et al.* (2008) [46] found that cytokinin production in roots enhanced vegetative growth and number of leaves in strawberry, and high shoot to root ratio was observed with farm yard manure and phosphorus interaction compared to control. Great variability in the nitrogen availability from different sources of organic fertilizers has been reported (Pang and Letey, 2000) [48].

- **Impact of bio-fertilizers on strawberry**

Bio-fertilizers are naturally stirring products with living microorganisms which are resulted from the roots or cultivated soil and don't have any ill effect on plants health, soil health, climate and environment. Bio-fertilizers have significant role in fixing atmospheric nitrogen and phosphorous solubilisation, and these are also helpful in stimulating the plant growth hormones. Biofertilizers *viz*., Azotobacter, Phosphate Solubilizing Bacteria (PSB) and Azospirillum fix atmospheric nitrogen and solubilize phosphorus to increase fertility and biological activities of soil. Strawberry plants inoculated with Azotobacter significantly improve yield. Besides this, inoculated plants increased the fruit size (Rana and Chandal, 2003) [50]. Tiwari *et al.* (1998) [63] reported that in banana the sugar content of fruit pulp was high in plants those treated with Azotobacter. Colonization of the root system by AM fungi can change its morphological structure, e.g. the size of the roots, their topographical arrangement, and also their surface area and volume (Kapoor *et al.* 2008) [35]. High levels of fertilization, often occurring in intensive horticulture, have a negative effect on root growth and root colonization by mycorrhizal fungi (Smith and Read 2008) [58].

An innovative solution involves microbiological enrichment of organic fertilizers, composts, and liquid plant growth promoters with consortia of beneficial microorganisms (Sas Paszt *et al*., 2015) [20]. Application of native mycorrhizal fungi and beneficial strains of bacteria incorporated in new bio-products ensures their better adaptation and survival in the prevailing environmental conditions, which is beneficial for long term effects on plants (Regvar *et al*., 2003) [52].

- **Impact of vermi-compost on strawberry**

Vermi-composts are organic materials broken down by interactions between earthworms and micro-organisms, in a mesophilic process (up to 25°C), to produce fully-stabilized organic soil amendments with low C: N ratios. They contain both plant growth hormones and humic acids which can act as plant growth regulators. Compost is the traditional source of nutrient for small fruit crops. It can be used as a supplement or alternative and help concentrate fertility and microorganisms so that the compost treated plants increase fruit yield. Turemis (2002) [65] reported that the highest fruit yield was noticed with banana compost treated strawberry plants. Vermi-compost (compost made from earthworm waste) application significantly increased growth and yield of strawberry (Arancon *et al.*, 2003) [5]. Application of compost is safeguard against toxicity/ plant injury and also improves the physico-chemical and biological properties of soil *viz.*, water holding capacity, attain soil moisture of field and low nutrients supply. Moreover, it is beneficial for soil microbial population.

- **Impact of organic mulches on strawberry**

a. Soil water

Application of surface organic (straw) mulch resulted in strong more precipitation water in soil by reducing storm runoff, increasing infiltration, and decreasing evaporation (Bond and Willis, 1969; Unger, 1983) [15, 11]. Abdul- Baki and Teasdale (1993) [1] observed that application of mulches increased N; recycling of nutrients; abridged soil erosion, weed emergence, reduces water loss; addition of organic matter to the soil; moderate soil temperature during the hot summer months. Mathews *et al.* (2002) [42] reported that a synthetic mulch controlled evaporative water loss as effective as organic mulches, but it lacked some of the other benefits organic material in the soil. These results are in consonance with the findings of (Ali and Radwan 2008) [3].

b. Soil mineral content

Lakatos *et al.* (2001) stated that nearly all the transformation of N and C from organic material is done by micro-organisms in the soil. These micro-organisms also play a significant role in the availability and transformation of minerals like Ca, Mg, P, Mn, K, Fe and Zn, and therefore influence plant nutrition. They further revealed that the application of manure mulch to the surface also increases the number of nitrification and cellulose degrading bacteria in the soil. Microbial decomposition of organic materials like animal manure or bio-solids with high amounts of N result in a high level of N mineralization (Forge *et al.*, 2003) [23]. Shredded paper and sawdust decomposition result in the N-immobilization, because of the greater C: N ratio (Forge *et al.*, 2003) [23].

c. Vegetative growth

Significant effects of organic and synthetic mulches on vegetative growth, flowering traits and yield on strawberry plants have been reported by several investigators (Blatt, 1984; Nestby, 1985; Haynes, 1987; Lareau and Lamarre, 1990; Lieten and Baets, 1991) [14, 26, 39, 40]. Fear and Nonnecke (1989) [22] observed that the both vegetative and reproductive strawberry plant responses can be modified by the different type organic mulches. Rebandel and Przysiecka (1981) [51] reported that application of organic mulching materials *viz.*, cocoa shells, sphagnum peat and composted pin bark increases number of leaves and leave size. La Mondia *et al.* (2002) [38] found that a sorghum-sudan grass hybrid "killed" cover crop suppressed pathogens and weeds but adversely affected strawberry growth and yields**.**

d. Weed control

Weed management is one of the major challenges for strawberry growers and nurserymen. Weed growth can also change the micro-climate around the runner plants, leading to higher disease pressure in regeneration of runners and fruiting stage. Among the weed control methods, mulches are important for weed control (Bilalis *et al.*, 2002 and Jodaugienė *et al.*, 2006) [11, 32]. Mulches reduce water evaporation from soil and help maintain stable soil

temperature (Ji and Unger, 2001) [31]. A similar result was registered by Tukey and Schoff (1963) as they suggested that the release of nutrients from decomposing mulches.

- **Integrated Management of Strawberry diseases and pests**

Diseases are very similar for both organic and conventional fruits cultivation. Major components of the organic strawberry diseases management program include: developing knowledge of the pathogen and timely application of organically approved fungicides or biological control agents or products when needed.

a. Foliar diseases

Leaf scorch (*Diplocarpon earliana*), Leaf spot (*Mycosphaerella fragaria)* and leaf blight (*Phomopsis obscurans*), powdery mildew caused by *Sphaerotheca macularis* and angular leaf spot or bacterial blight of strawberries caused by the bacterium *Xanthomonas fragaria* are common foliar diseases occurring on strawberry plant and their runners. These diseases can infect leaves, petioles, runners, and peduncles of the flowers, fruit stalks and caps of strawberry plants (Singh, 1996) [56]. Infected leaves show characteristics dark red coloured blotches usually on the upper surface (Hughes *et al.*, 1969) [29]. However, leaves are coated with a grayish-white powdery mold and turn purplish or red. In irrigated fields, the fungus may also attack the fruit.

b. Strawberry Root Diseases

Red stele is caused by the soil-borne fungus *Phytophthora fragaria* which may persist in fields for many years. During winter and spring, the cores, or steles, of diseased roots become pinkish-red, gradually turning cinnamon brown and ultimately black. Many commercial strawberry cultivars are susceptible to the red stele fungus. *Verticillium* wilt, caused by the soil-borne fungus *Verticillium albo-atrum*, can be a major factor limiting production.

c. Strawberry Fruit Rots

Botrytis Fruit Rot (gray Mold) is caused by the fungus *Botrytis cinerea*. The disease causes rotting of the green ripening under favourable environmental conditions, can devastate the crop (Hughes *et al.*, 1969) [29]. Anthracnose (*Colletotrichum acutatum*) disease which can affect foliage, runners, crowns and fruit (Hancock *et al.*, 1996) and ripening (Singh, 1996) [56] of strawberry under warm humid conditions.

Control

a. Cultural practices

Selected planting materials should be free from diseases, insects and pests infection and they have equal size. Virus-indexed plants obtained from a reputable nursery or govt. nurseries. Proper site selection, avoid low, poorly-drained wet areas and water lodging is especially important for control of Leather Rot and Red Stele. Removing leaves from the field as soon as the harvest season ends can significantly reduce the incidence of gray mold on fruit in June of the following year (Sutton *et al.*, 1988).

b. Use of disease resistant varieties

S. No	Diseases	Resistance cultivars/ tolerance
1	Leaf Spot	Midland, Redchief, Surecrop and Guardian
2	Leaf scorch	Katskill, Guardian, Midland, Redchief, Sunrise and Surecrop
3	Red Stele	Redglow, Sunrise, Guardian, Midway, Earliglownd, Redchief, Surecrop, Selite and Sparkle
4	Verticillium	Earliglow, Sunrise, Katskill, Guardian, Midway, Redchief, Surecrop, Selite and Sparkle

c. Mulch

It was observed that a good layer of straw mulch is very beneficial for controlling fruit rots, especially leather rot.

d. Organic fungicides and bio-control products for strawberry disease control

Copper fungicides, elemental sulfur and liquid lime sulfur arethe old "Normal" fungicides and have been used for many years in organic production systems. Protectant fungicides (Such as sulfur and copper) are not systemic and cannot move into plant tissues. The original material used was copper sulfate (also known as blue vitriol or bluestone).

S. No	Bio-pesticides	Crops	Diseases
1	AC10 (*Ampelomyces quisqualis*)	Strawberries	Powdery mildew
2	Armicarb100(potassium bicarbonate=baking powder)		Powdery mildew
3	Kaligreen (potassium bicarbonate = baking powder)		Powdery mildew
4	Oxidate (hydrogen dioxide) is a broad-spectrum bactericide/fungicide		It is a rather corrosive material and works by oxidizing fungal and bacterial cells.
5	Trichode (*Trichoderma harzianum)*		Botrytis fruit rot.
6	Trilogy (Clarified Hydrophobic Extract of Neem Oil).		Application of strawberries diseases

From the review, it is clear that the organic farming is very healthy and remunerative practice in strawberry production. It not only improves the quality of fruits but also provide sustainability in production for long term. Intelligent anticipatory management strategies and adaptation will be the critical components for successful and sustainable quality fruit production. The literature relevant to organic farming on soil properties, growth, yield and quality with special reference to strawberry cultivation reviewed in this paper. A thorough knowledge of the critical levels of different kinds of organics and their long term influence on soil and productivity is essential to get better growth and yields, and also to maintain optimum nutrient balancing, a prerequisite enhancing nutrient use efficiency. Efficient nutrient management plays an important role for better production of quality attributes of strawberry. This information will definitely be useful in better understanding of organic farming package for strawberry as a holistic and sustainable approach so as to improve the productivity and profitability of quality fruits as well as to improve soil health.

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