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EFFECT OF ORGANIC AMENDMENTS ON VEGETATIVE GROWTH, FRUIT AND YIELD QUALITY OF STRAWBERRY

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ABSTRACT:- Organic agricultural techniques are utilized globally to protect our environment and prevent health issues resulting from pesticides and hazardous chemicals. In this regard, studies were conducted using six different organic amendments on strawberry (*Fragaria ananassa* Duch.) cv. Chandler which included T_1 = planting media (soil + silt + farm yard manure); T_2 = planting media + 400 mgl^{-1} humic acid; T_3 = planting media + 200 g kg^{-1} leaf manure; T_4 = planting media + 200 g kg^{-1} vermicompost; T_5 = planting media + 200 g kg^{-1} plant fertilizer and T_6 = planting media + 200 g kg^{-1} bio-compost during 2011-12 at PMAS-Arid Agriculture University, Rawalpindi. Treatment T_1 (soil + silt + FYM) induced positive influence on plant height (15.21 cm), canopy spread (20.37 cm), crown diameter (1.47 cm), fresh weight of plant (10.71 g), number of runners per plant (2), total number of flowers (58), total number of fruits (42), fruit size (3.04 cm), fruit weight per berry (8.82 g) while T_4 (soil + silt + 200 g^{-1} kg vermicompost) improved fresh leaf weight (0.92 g), number of leaves (6.67), leaf area (43.07 cm^2) and days required for first bloom (96.67). Leaf manure based treatment (T_3) enhanced root length (20.11 cm), T_4 improved quality parameters like total solid soluble (TSS) (8.88) and ascorbic acid contents (64 mg) while T_1 improved total sugar contents in fruits (6.82%). Hence farm yard manure(FYM) and vermicompost based organic amendments enhanced vegetative growth and improved quality of strawberry fruits.

Key Words: Fragaria ananassa; Cultivar; FYM; Humic Acid; Leaf Manure; Vermicompost; Vegetative Growth; Crop Yield; Yield Component, Pakistan.

INTRODUCTION

Strawberry (*Fragaria ananassa* Duch.) is a soft fruit crop which belongs to the family Rosaceae and genus Fragaria. The fleshy fruit of strawberry is classified as an aggregate fruit (Green, 1971). Strawberries are unique with highly desirable taste, flavor, and excellent source of vitamins, potassium, fibre and sugars (Sharma and Sharma, 2004). As compared to other berry fruits, strawberries contain a higher percentage of vitamin C, phenolics and flavonoids (Hakkinen and Torronen, 2000). In Pakistan the strawberry is mainly cultivated in Chars-

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adda, Gujrat, Haripur, Islamabad, Karachi, Lahore, Mansehra, Mardan and Swat. The cultivar, Chandler is widely cultivated in Islamabad and Pothwar region while Douglus, Pajaro and Commander are only cultivated for research purposes. The soil pH range for strawberry production is about 4.6-6.5 (Milosevic, 1997). Indiscriminate use of commercial fertilizers has posed a serious threat to our environment and soils. Organic fertilizers are utilized globally to protect the soils against deterioration and food pollution. 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). Compost addition is also known to enhance microbial biomass and soil respiration (Bhattacharyya et al., 2003). Soil microbial health can be related to soil enzyme activity which is enhanced by fermentation of compost (Crecchio et al., 2001). Organic fertilizers improve soil fertility by modifying soil structure, pH, biophysical conditions and availability of essential nutrients (Atiyeh et al., 2002). Considering the future prospects of organic agriculture, studies were carried out to evaluate the influence of different organic amendments on growth related parameters, productivity and fruit quality of strawberry cv. Chandler.

MATERIALS AND METHOD

The studies were conducted at the nursery area of Horticulture Department, Pir Mehr Ali Shah-Arid Agriculture University, Rawalpindi, Pakistan during winter season of 2011 – 2012 to examine the effect of different organic fertilizers on strawberry (*Fragaria ananassa*) cv. Chandler. Runners of strawberry plants were taken from Swat. Plants were grown in medium size (3l) pots. The studies comprised six treatments of organic amendments namely T_1 as control = planting media (soil + silt + FYM in equal proportion); T_2 = planting media + 400 mgl^{-1} humic acid; T_3 = planting media + 200 g kg^{-1} leaf manure; T_4 = planting media + 200 g kg^{-1} vermicompostl; T_5 = planting media + 200 g kg^{-1} plant fertilizer and T_6 = planting media + 200 g kg^{-1} bio-compost.

Vegetative traits including plant height, canopy spread, crown diameter, number of runners, number of leaves, leaf area and root length were observed while reproductive growth parameters as number of days taken to flower, number of trusses, total number of flowers, total number of fruits, fruit set percentage, fruit size and fruit weight were assessed.

Fruit quality parameters play a major role for assessing final quality of the produce and for this purpose, total soluble solid contents, total sugars, titratable acidity and ascorbic acid contents were evaluated in laboratory (Hortwitz, 1960). Randomized complete block design was employed for six treatments with three replications each having 15 plants (AOAC, 1990). Uniform application of irrigation and weeding was ensured for better growth and development of runners. The observations were taken and results were compiled for treatment comparison. The data were analyzed using MSTAT-C and means were compared by using Least Significant Difference

(LSD) test at 5% probability level (Steel et al., 1997).

RESULTS AND DISCUSSION

Maximum plant height (15.21 cm) was recorded in T_1 while minimum plant height (8.9 cm) was observed in T_2 (Table 1). Maximum plant height may be due to better uptake of nutrients like nitrogen which has a major role in increasing cell division and improving plant growth. Organic amendments improve vegetative growth characters in strawberry by increasing soil enzyme activity and improving soil aeration (Bhattacharyya et al., 2003). These results are in agreement with those of Arancon et al. (2004) and Shehata et al. (2011). Maximum canopy spread (20.37 cm) was obtained in T_1 followed by T_4 (17.88 cm). Farm yard manure treatment (T_1) significantly enhanced plant canopy which might be due to the fact that manures were rich source of essential nutrients as nitrogen, phosphorus and potassium (Kuepper, 2003). Singh et al. (2008) reported upto 20% increase in plant spread on vermicompost dose at 10 t ha^{-1}. Maximum number of leaves (6.66) was recorded in T_4 followed by T_1 with 6.55 leaves per plant. These results are in line with those of Odongo et al. (2008) who reported increase in plant height and number of leaves in strawberry with farm yard manure @ 36-54 tha^{-1} which might be due to increase in crown diameter resulting in better plant growth. Maximum leaf area (43.07 cm^2) was recorded from T_4 which was significantly higher than other treatments followed by T_1 whereas T_5 showed minimum leaf area. Arancon et al. (2003) reported enhanced leaf area and crown diameter with vermicompost application. This may be due to enhanced soil properties as cation exchange capacity and soil microbial activity. Ogendo et al. (2008) reported that farm yard manure contained proportionate amount of potassium which promoted leaf growth and enhanced sugar accumulation thus increasing leaf area. Minimum leaf area in T_5 may be attributed to inadequate proportion of macro and micro nutrients and their decreased availa-

Table 1. Vegetative growth parameters of strawberry as affected by different organic amendments

Treatment	Plant height (cm)	Crown diameter (cm)	No. of leaves	Fresh wt. of leaves (g)	Dry wt. of leaves (g)	Leaf area (cm^2)	Canopy spread (cm)	Root length (cm)
T_1	15.21 ^{a}	1.47 ^{a}	6.55 ^{a}	0.86 ^{b}	0.44 ^{a}	33.91 ^{b}	20.37 ^{a}	15.14 ^{c}
T_2	8.90 ^{d}	1.03 ^{c}	4.67 ^{c}	0.63 ^{c}	0.21 ^{c}	32.10 ^{c}	13.55 ^{c}	16.00 ^{c}
T_3	9.45 ^{cd}	1.22 ^{b}	5.66 ^{abc}	0.63 ^{c}	0.22 ^{c}	32.46 ^{c}	15.67 ^{bc}	20.11 ^{a}
T_4	13.00 ^{c}	1.43 ^{a}	6.66 ^{a}	0.92 ^{a}	0.31 ^{b}	43.07 ^{a}	17.88 ^{ab}	19.77 ^{ab}
T_5	9.69 ^{cd}	1.13 ^{bc}	6.12 ^{ab}	0.69 ^{bc}	0.27 ^{bc}	30.98 ^{d}	14.44 ^{c}	19.76 ^{ab}
T_6	11.33 ^{bc}	1.18 ^{b}	5.11 ^{bc}	0.75 ^{bc}	0.28 ^{bc}	31.86 ^{cd}	15.11 ^{bc}	17.22 ^{bc}

Means followed by same letters do not differ significantly at 5% probability level according to LSD test

bility under prevalent soil conditions. These results are also in agreement with those of Abu-Zahra and Tahboub (2009).

Organic amendments affect metabolic plant processes as cell division and enzyme activity and produce ameliorating effect on vegetative parameters of strawberries (Ogendo et al., 2008). Maximum fresh weight of strawberry leaves (0.92 g) was observed in T_4 followed by T_1 (0.86 g). This increase in fresh weight may be due to balanced mineral composition and better nutrient acquisition with T_1 and T_4. Plants treated with T_1 produced significantly higher dry weight of leaves (0.44 g) than any other organic treatments (Table 1). Among the other treatments, T_4 also significantly enhanced the dry weight of leaves (0.31 g). These results are supported by Arancon et al. (2004) who reported an increase in shoot and root biomass in strawberries with application of vermicompost leachates. Herencia et al. (2011) attributed this increase in fresh and dry weight of strawberry to high utilization of nutrients leading to deficiency of essential nutrients and plants tended to enhance synthesis of starch or cellulose instead of amino acids. Maximum crown size (1.47 cm) was observed in T_1 plants which was non-significant with T_4 (1.43 cm) but significant over other organic treatments. Increase in crown size was effective for increasing number of leaves, lateral branches and flowering trusses in strawberry resulting in better plant growth and increase in plant weight (Odongo et al., 2008). Maximum root length (20.11 cm) was observed in T_3 which was non significant with T_4 (19.77 cm) and T_5 (19.76 cm). Odengo et al. (2008) investigated the nutritional content of farm yard manure and concluded that high nitrogen percentage in manures reduced root growth due to enhanced vegetative growth. Relative decrease in root length in strawberry can be attributed to mineral imbalance and slow mineralization of nutrients. Preusch et al. (2004) reported an increase in root length in strawberries with fresh and composted poultry litter compost compared to control (no manure) which was attributed to the role of potassium in root proliferation. Ogendo et al. (2008) 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.

The flowering in strawberry plants is associated with water regime and nutrient status of plant. Fertilization near blooming period enhances the number of crowns thereby increasing inflorescences. Minimum days (96.67 days) for flower opening (Table 2) were recorded in T_4 followed by T_1 (103 days). Herencia et al. (2011) investigated the effect of organic fertilized soils on flowering and fruiting in strawberry and found that vegetative stages of strawberries completed earlier on farm yard manure and vermicompost leading to early onset of reproductive stage. Odongo et al. (2008) reported an increase in photosynthate production due to phosphorus contents in farm yard manure which helped to break bud dormancy and increased flowering sites. Number of flowers per truss (6.44) in T_1 was significantly

Table 2. Reproductive growth parameters of strawberry as affected by different organic amendments

Treatment	No. of days to flower	No. of flowers per truss	Total No. of flowers	Total No. of fruits	Fruit set (%)	Fruit size (cm)	Fruit weight (g)
T_1	103.00 [bc]	6.44 [a]	58.83 [a]	42.00 [a]	72.40 [a]	3.04 [a]	8.82 [a]
T_2	113.33 [a]	2.22 [c]	20.01 [c]	10.00 [e]	50.00 [e]	2.36 [ab]	5.01 [b]
T_3	109.00 [ab]	2.57 [d]	22.00 [d]	12.00 [c]	54.50 [d]	2.33 [b]	4.47 [b]
T_4	96.67 [c]	3.89 [b]	31.07 [b]	24.00 [b]	68.50 [b]	2.27 [ab]	5.47 [b]
T_5	106.00 [ab]	2.22 [c]	20.00 [e]	8.00 [f]	45.00 [f]	2.73 [ab]	6.10 [b]
T_6	113.00 [a]	3.43 [c]	31.00 [c]	18.00 [c]	58.10 [c]	2.15 [b]	5.85 [b]

Means followed by same letters do not differ significantly at 5% probability level according to LSD test

higher than other treatments (Table 2). Minimum number of flowers per truss (2.22) was observed in T_2 and T_5. The optimum level of nutrients as N, P and K and hormones provided by vermicomposts played a significant role in increasing Gibberellic acid in roots thus breaking bud dormancy and increasing flowering buds and fruiting sites (Tagliavini et al. 2005). Total number of flowers 58.8 produced in T_1 was significantly higher than all other treatments. Minimum number of flowers (20.01) was observed in T_2. Fruits are the major sink for nitrogen, phosphorus and potassium in strawberries. Nutrient availability should be moderate but continuous throughout blooming to satisfy high nutritional requirements of strawberry plants (Mahadeen, 2009). It was found that nitrogen availability resulted in increasing number of crowns per plant, flower size and fruit yield and reduced abortion of female flower parts (Tagliavini et al., 2005). Farm yard manure and vermicompost based fertilizer proved better for flowering in strawberries than other treatments. Ali et al. (2003) found that farm yard manure produced maximum number of flowers and fruits in C.V. Chandler strawberry compared to inorganic fertilizers.

Maximum number of fruits (42) was recorded in T_1. Herencia et al. (2011) reported that composts contained nitrogen and phosphorus which enhanced vegetative growth and flower bud initiation. Arancon et al. (2003) reported that vermicompost applications enhanced flowering and fruiting in strawberry. Vermicomposts enhance soil properties as cation exchange capacity and nutrient availability. Minimum number of fruits (8) observed in T_5 may be attributed to increase in soluble salts in specific manures leading to reduction in yield in strawberry (Ogendo et al., 2008). Treatment T_1 significantly increased the percentage of fruit set in strawberry (72.4%) while minimum fruit set percentage (45) was observed in T_5. Our findings are in agreement with those of Ali et al. (2003) and Odongo et al. (2008) who found

significant increase in fruit set with application of farm yard manure. 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). Maximum fruit weight per berry (8.82 g) was recorded in T_1. In T_5, T_6, T_4 and T_2 fruit weight of 6.1 g, 5.85 g, 5.47 g and 5.01 g, respectively was observed (Table 2). Manures contain favorable amounts of macro and micro nutrients and enhance fruit weight by the formation of carbohydrates. These findings are in accordance with Odongo et al. (2008) who reported that farm yard manure had a pronounced effect on berry size and weight compared to inorganic triple phosphate fertilizer. During the process of fruit ripening, fruits represent sink for potassium and nitrogen and composts contain significant amounts of these essential nutrients. Arancon et al. (2004) found that growth, flowering and yield of field strawberries exhibited a marked increase after applications of food and paper waste vermicomposts in cv Chandler. Singh et al. (2008) found significant increase in fruit yield and flowering with vermicompost based fertilizer. Ali et al. (2003) also found significant increase in strawberry fruit yield and berry size with combination of farm yard manure and inorganic fertilizers.

Maximum total soluble solids (8.33 ^{o}Brix) were found in T_4 followed by T_1 (7.66 ^{o}Brix) and T_2 (6.67 ^{o}Brix) (Table 3). Odongo et al. (2008) reported that farm yard manure significantly enhanced total soluble solid contents of strawberry fruits however in other organic fertilizers, the dilution of K due to vegetative growth led to reduction in total soluble solids. Potassium promotes sugar accumulation in berries and balance of N, P and K is essential for proper availability of those nutrients to strawberry plants. Ali et al. (2003) found an increase in TSS with farm yard manure treatment. Singh et al. (2008) reported that increasing the dose of vermicompost from 2.5 to 10 tha^{-1} not only reduced the number of days to first bloom but also enhanced TSS and sugar contents of fruit. The sugars and acid contents in fruit are

Table 3. Qualitative parameters of strawberry fruit as affected by different organic amendments

Treatment	Total soluble solids (^{0}Brix)	Titratable acidity (%)	Total sugars (%)	Ascorbic acid (mg) 100^{-1} ml juice
T_1	7.66 ^{ab}	1.28 ^{bc}	6.82 ^{a}	62.23 ^{a}
T_2	6.67 ^{ab}	1.49 ^{ab}	5.88 ^{bc}	56.33 ^{b}
T_3	5.00 ^{c}	1.80 ^{a}	6.00 ^{abc}	61.67 ^{ab}
T_4	8.33 ^{a}	1.00 ^{c}	6.53 ^{ab}	64.00 ^{a}
T_5	5.67 ^{bc}	1.47 ^{ab}	5.25 ^{c}	62.23 ^{a}
T_6	5.33 ^{c}	1.60 ^{ab}	6.10 ^{abc}	60.67 ^{ab}

Means followed by same letters do not differ significantly at 5% probability level according to LSD test

considered important for fruit quality attributes in strawberries (Wozniak et al., 1997). It was observed that titratable acidity was significantly low in T_4 (1.0%) and highest for T_3 (1.81%). In fresh strawberries, sucrose, glucose and fructose form 99% of the total sugars. Wang and Lin (2002) investigated the effect of different organic fertilizers on "Allstar" and "Honoeye" strawberries and found increase in sugar contents, organic acids, soluble solids and titratable acidity. Maximum total sugars percentage (6.82) was found in T_1 followed by T_4 (5.53). T_6 and T_3 were non significant to each other with total sugar contents of 6.10 and 6, respectively. Organic crops have low nitrate levels and higher ascorbic acid contents than conventional crops (Herencia et al., 2011). T_4 significantly enhanced ascorbic acid contents upto 64.00 mg per 100 ml juice followed by T_1, and T_5 each with 62.23 mg 100 ml^{-1} juice. In another study, different levels of farm yard manure enhanced ascorbic acid contents in strawberries (Bhat, 1999). Ali et al. (2001) reported increase in ascorbic acid contents in strawberries with farm yard manure. Organic fertilizers are hydrophilic in nature and absorb moisture and nutrients which persist longer thus improving the soil structure and indirectly enhancing fruit quality and ascorbic acid contents. Hence these findings are in accordance with those of Wang and Lin (2002); Arancon et al. (2004) ; Singh et al. (2010) and Ayesha et al. (2011).

The results obtained for plant height, dry matter contents, leaf area and fresh and dry weight of runners and canopy spread showed increasing trends with farm yard manure and vermicompost treatments whereas root length was higher for leaf manure based treatment. Fruit quality parameters like fruit size, fruit weight and number of fruits was higher for vermicomposts followed by farm yard manure. It can be concluded that organic amendments have a positive impact on qualitative parameters in strawberries. Thus, organic fertilizers can play a major role to prevent water and food pollution resulting from hazardous chemical fertilizers.

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