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Effects of vertical staking and different types of manures on growth, yield and quality of strawberry (*Fragaria* × *ananassa* Duch.)

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ABSTRACT

Strawberry is a very popular, refreshing and nutritious fruit having powerful antioxidant and a safe, delicious addition to any diet. An experiment was conducted at the Landscaping section of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from October 2018 to April 2019 to develop a sustainable technology for optimum growth, yield and quality of strawberry *cv*. RU-1 (Festival) through vertical farming. The experiment comprised three vertical staking *viz*., 1.5, 3.0 and 4.5 feet (ft) above ground staking, and five organic manures *viz*., control (no manures), cowdung @ 500 g/plant, mustard oilcake (MOC) @ 100 g/plant, poultry manure @ 500 g/plant and cowdung+MOC+poultry manure @ (500+100+500) g/plant. The two-factor experiment was conducted in randomised complete block design with three replications. Significant variations were observed due to vertical staking and organic manures on all the parameters studied. Highest plant height (15.95 cm), number of leaves (27.62), number of flowers (24.86), number of runner (4.73) and number of fruits per plant (22.90), fruit length (3.70 cm) and diameter (3.04 cm), individual fruit weight (13.87 g), yield per plant (318.82 g) and TSS (8.23%) were observed at 4.5 ft above ground staking and application of cowdung+MOC+poultry manure @ (500+100+500) g/plant, while the lowest plant height (9.61 cm), number of leaves (15.02), number of flowers (12.40), number of runner (2.18) and number of fruits per plant (22.90), fruit length (3.70 cm) and diameter (3.04 cm), individual fruit weight (13.87 g), yield per plant (124.48 g) and TSS (6.40%) were recorded at 1.5 ft above ground staking with control. Thus, combined treatment of 4.5 ft above ground staking with cowdung+MOC+poultry manure @ (500+100+500) g/plant was found to be better in respect of optimum growth, yield and quality of strawberry.

Introduction

Strawberry (*Fragaria* × *ananassa* Duch.) is one of the most delicious, delicate flavoured, refreshing, and attractive red fruit of the world (Sharma, 2002). It is a nutritious, quick growing and exotic fruit in Bangladesh and suitable for adaptation in our cropping pattern. Strawberry produces fruits during November to April (Badiyala and Bhutani, 1990) when most of the fruits are not available which may help to increase the availability of fruits in the lean period of Bangladesh. However, decreasing production area due to the change of farming land use into settlements has become one of major obstacles for sustainable production in agriculture (Sitawati *et al.,* 2016). Vertical farming or verticulture could overcome this problem, and ensure sustainable and nutritional food security in Bangladesh (Salam *et al*., 2016). Vertical farming does not require wide area, and it may utilize the land efficiently with beautiful background (Pongarrang *et al*., 2013). Therefore, vertical farming could be solution of sustainable and nutritional food security and safety in Bangladesh. For strawberry, vertical farming could increase number of fruits per plant on a given area for about 3-10 times than on flatland of the same width and produce quality fruits which depends on the applied model such as low cost wood/bamboo framework (Noverita, 2005). For optimal growth, sustainable production and harvest of strawberry, irrigation management, aeration, fertilizer application, appropriate planting medium (well-decomposed cowdung, mustard oilcake, poultry manure, compost) and the application of verticultural materials as container for the strawberry plants should be used (Kapur *et al*., 1991). These will ensure high resistance, have micro-pores for drainage, good aeration and water absorbability, and may not create any root rots or stem rots (Gustia, 2013). Meanwhile, materials of the vertical farming include gunnysack, carpet, and plastics. Interaction between planting medium, framework and verticulture's container could increase yield and quality of strawberry (Noverita, 2005). For optimum growth and development of plants different nutrients such as nitrogen (N), phosphor (P), potassium (K), etc. plays an important role to stimulate photosynthetic process,

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extend the root growth, formation of flowers, fruits, and seeds, as well as could accelerate fruit yield, quality and ripening. Farmer shows tendency of more chemical fertilization for strawberry production to improve yield. However, organic manures are also required, which not only supply nutrients for the plants but also plays an important part in the process of enhancing soil fertility by improving its structure and hydro-physical properties, increasing organic matter concentration and reducing the application of synthetic fertilizers (Grandy *et al*., 2002). Unlike inorganic fertilizers, organic manures have a longer lasting impact on chemical properties of the soil and consequently on the yield of grown crops, even several years after application (Gutser *et al*., 2005). It is excellent source of nutrients and it could maintain high microbial population's activities. In Bangladesh the interest for organic farming has been increased recently. Fruit quality of strawberry is also influenced by agro-technical treatments i.e., mulching, irrigation, fertilization, crop rotation, intercropping, proper field preparation, planting time, health status and type of seedlings (LaMondia *et al.*, 2002).

Sweetness of strawberry is a major problem in Bangladesh. Organically grown strawberry increase total soluble solids (TSS) content, hence produce high quality fruit with sweeter in taste, longer shelf life (by thickening fruit peel) and better flavour (Reganold *et al.*, 2010). Various organic manures such as cowdung, compost, vermin compost, mustard oilcake (MOC), green manure and poultry manure are excellent source of organic matters commonly used for crop production (Hasan, 2013; Rahman, *et al.,* 2018). Moreover, use of poly-tunnel has forcing and prolonging the harvesting season of strawberry by protecting the plants from vagaries of adverse weather conditions (wind and rain damage) (Sharma, 2001). It could reduce fungal diseases and gives early and very high returns per unit area compared to other fruits because its crop is ready for harvesting within six months after planting (Mitra, 1991). The flowering in plastic covered strawberries may be advanced by 20-25 days and fruiting by 15-20 days. Therefore, fruit yield and quality increases substantially and the availability of strawberry can be staggered at least a month or so, which is otherwise not possible under open fields. More researches related to ecological functions of vertical farming for strawberry have been conducted, but less research was conducted on other aspects, such as sustainable growth, development and nutritional quality production, which concerning with materials, framework and planting media. Therefore, extensive research is required to obtain a verticultural model/framework along with some combinations of planting media; efficient fertilizer application and verticultural materials for strawberry production that can be applied extensively with widespread popularity to Bangladeshi farmers. The present study was, therefore, been undertaken to develop a sustainable technology for optimum growth, yield and quality of strawberry through vertical farming.

Materials and Methods

Experimental site and materials

The experiment was conducted to develop a sustainable technology for optimum growth, yield and quality of strawberry *cv*. RU-1 (Festival) through vertical farming at the Landscaping section of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from October 2018 to April 2019. The experimental area is situated in the sub-tropical climate zone and characterized by the winter or dry season (November to February) and pre-monsoon or hot season (March to April). The experimental site was medium high land belonging to the Old Brahmaputra Floodplain under the Agro-Ecological Zone 9 having non-calcareous dark gray floodplain soil (UNDP and FAO 1988). The soil of the experimental plot was silty loam in texture and about neutral (pH 6.5-7.0) in reaction. Healthy and uniform size seedlings of strawberry cultivar RU-1 (Festival) were collected from the nursery of Professor Dr. Monzur Hossain, University of Rajshahi, Rajshahi, Bangladesh.

Experimental design and treatments

The two-factor experiment was laid out in a randomised complete block design (RCBD) with three replications. First factor of the experiment consisted of three vertical staking *viz*., V_1 = 1.5 feet (ft) above ground, V_1 = 3.0 ft above ground and V_1 = 4.5 ft above ground staking, and second factor of the experiment comprised five organic manures *viz*., T_0 = Control (no manures), T_1 = Cowdung @ 500 g/plant, T_2 = Mustard oilcake (MOC) @ 100 g/plant, T_3 = Poultry manure @ 500 g/plant and T_4 = Cowdung+MOC+poultry manure @ (500+100+500) g/plant.

Construction of vertical framework

The vertical structure was made using bamboo, wood and high-density polyethylene tube of 10-inch diameter. Then the manures treatments were applied randomly in the experimental polyethylene tube. Finally, the polyethylene tubes were placed in such as a way that they were staked at 1.5, 3.0 and 4.5 ft above the ground. The space between vertical staking was 30 cm so that the plants can get sufficient sunlight and air. The seedlings were transplanted in the evening of 7 November 2018 at the respective area of the polyethylene tube by making a hole and keeping a distance of 30 cm (Fig. 1). Therefore, the spacing was considered as 30 cm × 30 cm. The spacing between blocks was 50 cm Nine plants were planted under each treatment under each replication. Hence, altogether for 15 treatment combinations 405 plants (9×15×3) were used for this experiment. Different small sizes holes were made on the polyethylene tube, which were used for the application of irrigation water and drainage channel for the plants.

Data collection

The observations were recorded at 15 days intervals starting from one week after transplanting of seedlings up to the harvesting of fruits from all nine plants under each treatment and replications on growth and yield contributing characters like plant height (cm), number of leaves, flowers, runner and fruit per plant, individual fruit weight (g) and fruit yield per plant (g) and quality characters like fruit length (cm) and diameter (cm) and TSS (sweetness). Plant height of each plant was measured in cm by using meter scale and mean was calculated. Number of leaves and runner per plant were recorded by counting all leaves and runners from each plant and mean was calculated. After 60 days of transplanting number of runners was not counted and all of runners including newly emerged were removed for better yield and quality of strawberry fruits. Fruit length and diameter were measured using Slide Caliper in millimeter (mm) and converted into centimeter. Mean was calculated each treatment (Fig. 2). Fruit weight was measured by a Table Top Electric Balance (BP 2100, Sartorius, Germany) and expressed in gram (g). Total fruit weight (yield/plant) of each pot was obtained by addition of weight of the total fruit number and individual fruit weight was obtained from division of the total fruit weight by total number of fruit. Total soluble solids (TSS) content of strawberry was determined from fruit juice by using a hand refractometer (Model N-1 α, Atago, Japan). Before measurement, the refractometer was calibrated with distilled water to give a zero reading. One or two drops of the filtrate were placed on the prism glass of the refractometer to obtain the %TSS reading. The reading was multiplied by dilution factor to obtain an original %TSS of the pulp tissues. Since differences in sample temperature could affect the TSS measurement, temperature corrections were made by using the methods described by Ranganna (1994).

Statistical analysis

The collected data on various parameters were analysed statistically using MSTAT computer programme. The means for all the treatments were calculated and analysis of variance (ANOVA) was performed by F-test. The mean difference between a pair of treatments was evaluated by least significant difference (LSD) at 5 % level of probability.

Results and Discussion

Effect of vertical staking on growth, yield and quality characters of strawberry

Vertical staking had significant effects on all the parameters under study such as plant height, number of leaves, runners, flowers and fruits per plant, fruit length, fruit diameter, individual fruit weight, fruit yield per plant and TSS content of strawberry fruits (Table 1 and Fig. 3). The highest plant height (14.12 cm) and number of leaves per plant (23.22) were obtained from 4.5 feet (ft) above ground staking, whereas the lowest plant height (13.39 cm) and number of leaves per plant (20.82) were recorded from 1.5 ft above ground staking (Table 1). This might be due to the more above ground staking plants get more light integral, hence cause more photosynthesis and increased vegetative growth of strawberry plants (Noverita, 2005).

The maximum number of flowers (21.49) and fruits per plant (19.75) were recorded from 4.5 feet (ft) above ground staking, while the minimum number of flowers (17.71) and fruits per plant (16.04) were found from 1.5 ft above ground staking, respectively (Table 1). This might be due to the higher rate of photosynthesis and air movement in the above ground plants cause higher rate of pollination and fertilization and therefore produce more number of flowers and fruits per plants of strawberry (Pongarrang *et al*., 2013). Maximum number of runners per plant (4.05) was found from 4.5 feet (ft) above ground staking, while minimum number of runner per plant (3.12) were observed from 1.5 ft above ground staking, respectively (Table 1). This might be due to the maximum number of leaves per plant, flowering and fruit setting at the mature stage that enables the plants enhanced carbohydrates concentration in crown and increased runner at the fruiting (Salam *et al*., 2016).

The longest fruit length (3.12 cm) and diameter (2.52 cm) were found from 4.5 feet (ft) above ground staking, whereas the shortest fruit length (2.68 cm) and diameter (2.07 cm) were observed in 1.5 ft above ground staking, respectively (Table 1). This might be due to the higher rate of photosynthesis in the more above ground staking plants produce more stored food materials and consequently increased fruit length and diameter of strawberry. Morgan (2006) found that final size of berry depends on number of achene's formed, which was determined by pollination and fertilization at the time of blooming. The highest individual fruit weight (12.18 g) was recorded from 4.5 feet (ft) above ground staking, while the lowest individual fruit weight (10.11 g) was found from 1.5 ft above ground staking (Table 1). Large size fruit closely correlates with the average fruit weight which is controlled by dimension of receptacle, number of achene's position of fruits on the inflorescence (Hortynski *et al.*, 1991). The maximum fruit yield per plant (258.73 g) was obtained from 4.5 feet (ft) above ground staking, while the minimum fruit yield per plant (172.08 g) was observed in1.5 ft above ground staking (Fig. 3). This might be due to the increased fruit length and diameter cause larger sized fruits and hence greater yield per plant of strawberry. The maximum TSS content (8.92%) was found from 4.5 feet (ft) above ground staking, while the minimum TSS content (5.87%) was recorded in 1.5 ft above ground staking (Table 1). Total soluble solids (TSS) content of strawberry fruits varies from 4-11% depending on cultivars and surrounding environmental conditions (Perkins-Veazie, 1995).

Fig. 1. Planting of strawberry seedlings on the vertical framework

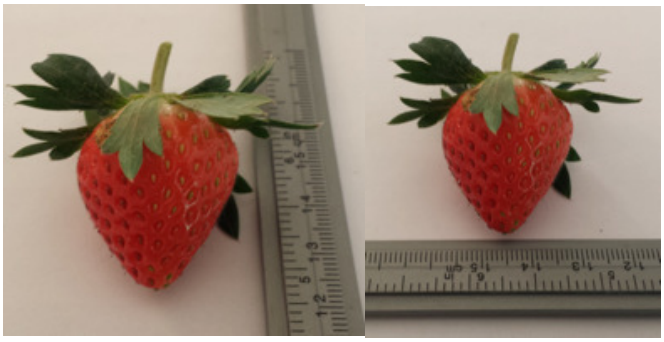

Fig. 2. Methods of measuring length and diameter of strawberry fruit

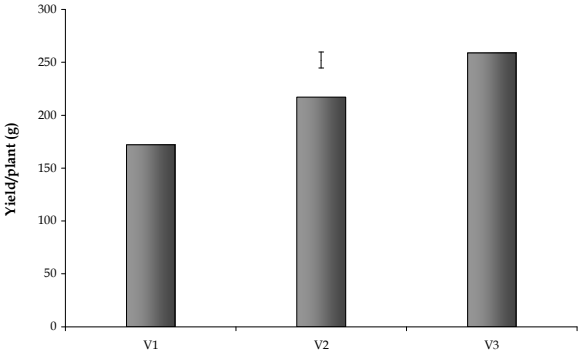

Fig. 3. Main effect of vertical staking on fruit yield (g/plant) of strawberry. The vertical bar represents LSD at 5% level of probability. V_1 = 1.5 feet (ft) above ground, V_1 = 3.0 ft above ground and V_1 = 4.5 ft above ground staking

Effects of organic manures on growth, yield and quality characters of strawberry

The data presented in Table 1 and figure 4-5 revealed that organic manures significantly affected the growth, yield and quality characters of strawberry plants. The tallest plant (15.56 cm) was recorded from T_4 (Cowdung+MOC+poultry manure @ 500+100+500 g/plant), followed by 14.82 cm in T_2 (MOC @ 100 g/plant), while the shortest plant (10.16 cm) was obtained from T_0 (control) (Table 1). The treatment T_4 (Cowdung+MOC+poultry manure @ 500+100+500 g/plant) produced maximum number of leaves per plant (26.31) followed by 24.33 in the treatment T_2 (MOC @

100 g/plant), whereas the minimum numbers of leaves per plant (15.57) was noticed with T_0 (control) (Table 1). This might be due to the supply of by nitrogen especially through organic manures, which accelerates the synthesis of amino acids, which might have indirectly exhibited increase in plant height of strawberry (Kumar *et al*., 2015). Organic manures are also helpful in cell elongation and cell division in meristematic region of plant; this was due to the production of plant growth substances (IAA and GA) (Kumar *et al*., 2015). Presence of higher nitrogen (Gopalreddy, 1997; Sims, 1987; Willrich *et al.*, 1974) and phosphorous on MOC compared to other organic manures (Malone *et al*., 1992) and more water retention capacity may lead to the more plant vegetative growth especially on plant height and number of leaves per plant.

Table 1. Main effect of vertical staking and organic manures on growth, yield and quality characters of strawberry

Treatments	Plant height (cm)	No. of leaves/plant	No. of flowers/plant	No. of fruits /plant	No. of runner /plant	Fruit length (cm)	Fruit diameter (cm)	Individual fruit wt. (g)	TSS (%brix)
Factor A: Vertical staking									
V_1	13.39	20.82	17.71	16.04	3.12	2.68	2.07	10.11	5.87
V_2	13.74	22.03	19.76	17.86	3.56	2.92	2.31	11.27	7.54
V_3	14.12	23.22	21.49	19.75	4.05	3.12	2.52	12.18	8.92
$LSD_{0.05}$	0.071	0.162	0.336	0.146	0.033	0.024	0.041	0.085	0.049
$LSD_{0.01}$	0.096	0.219	0.453	0.197	0.045	0.032	0.055	0.115	0.075
Level of significance	**	**	**	**	**	**	**	**	**
Factor B: Organic manures									
T_0	10.16	15.57	13.41	12.29	2.63	2.19	1.65	8.97	5.53
T_1	13.81	21.04	19.36	17.49	3.40	2.75	2.16	10.68	6.21
T_2	14.80	24.33	21.65	19.57	3.91	3.17	2.54	12.03	8.69
T_3	14.42	22.89	20.76	19.03	3.71	2.99	2.38	11.47	7.80
T_4	15.56	26.31	23.08	21.03	4.22	3.44	2.77	12.80	9.74
$LSD_{0.05}$	0.092	0.209	0.434	0.188	0.043	0.031	0.053	0.110	0.11
$LSD_{0.01}$	0.124	0.282	0.585	0.254	0.058	0.041	0.071	0.149	0.16
Sig. level	**	**	**	**	**	**	**	**	**

*, **=5 and 1% levels of probability, respectively, V_1 = 1.5 feet (ft) above ground, V_1 = 3.0 ft above ground and V_1 = 4.5 ft above ground staking, T_0 = Control (no manures), T_1 = Cowdung @ 500 g/plant, T_2 = Mustard oilcake (MOC) @ 100 g/plant, T_3 = Poultry manure @ 500 g/plant and T_4 = Cowdung+MOC+poultry manure @ (500+100+500) g/plant.

The maximum number of flowers (23.08) and fruits per plant (21.03) were obtained from the treatment T_4 (Cowdung+MOC+poultry manure @ 500+100+500 g/plant), followed by 21.65 and 19.57, respectively, in T_2 (MOC @ 100 g/plant), while the minimum number of flowers (13.41) and fruits per plant (12.29) were recorded from T_0 (control) (Table 1). Makinde and Ayoola (2012) found that poultry manure supports more of vegetative growth and number of flower and fruit setting of a plant and for this strawberry plants respond well to poultry manures in terms of plant height and reproductivity. The treatment T_4 (Cowdung+MOC+ poultry manure @ 500+100+500 g/plant) provided the maximum number of runner per plant (4.22) followed by 3.91 in T_2 (MOC @ 100 g/plant), while the treatment T_0 (control) gave the minimum number of runner per plant (2.63) (Table 1). The number of runner can be increased due the presence of plant-growth regulating substances in organic matters and soil biological function improvement through the application of MOC and poultry manure in soil (Cristina and Jorge, 2011).

Results revealed that the longest fruit length (3.44 cm) and diameter (2.77 cm) were found from the treatment T_4 (Cowdung+MOC+poultry manure @ 500+100+500 g/plant) followed by 3.17 cm and 2.54 cm, respectively, in T_2 (MOC @ 100 g/plant), while the shortest fruit length (2.19 cm) and diameter (1.61 cm) were observed in control (T_0) (Table 1 and Fig. 4). This might be due to the effects of different organic manures on germination, growth, flowering, fruiting and yields of strawberry plants (Mamta *et al.,* 2012). It was found that mixture of different organic manure application increases the length and breadth in strawberry fruit (Atefe *et al.*, 2012). The treatment T_4 (Cowdung+ MOC+poultry manure @ 500+100+500 g/plant) gave the highest individual fruit weight (12.80 g) (Fig. 5) and fruit yield per plant (271.97 g), followed by 12.03 g and 237.68 g, respectively, in T_2 (MOC @ 100 g/plant), while the lowest individual fruit weight (8.97 g) and fruit yield per plant (163.02 g) were obtained from control (T_0). This might be due to the higher nutrient content of mixed manure especially and leading to increase uptake of NPK which help the plant to get adequate food and nutrients thus may help to enhance the number and fruit weight (Mamta *et al.,* 2012; Subbaiah *et al.*, 1985). Pringle *et al*. (2002) and Schopplein *et al*. (2002) reported that a significant difference was observed on fruit yield between mixture of manures and single application of other organic matter source treatments. The highest TSS content (9.74) was recorded from T_4 (Cowdung+MOC+poultry manure @ 500+100+500 g/plant), 8.68% in T_2 (MOC @ 100 g/plant), while the lowest TSS content (5.53%) was observed in T_0 (control) as shown in Table 1.

T_0 T_1 T_2 T_3 T_4

Fig. 4. Photograph showing the differences in single effect of organic manures on fruit length and diameter of strawberry. T_0 = control (no manures), T_1 = cowdung @ 500 g/plant, T_2 = mustard oilcake (MOC) @ 100 g/plant, T_3 = poultry manure @ 500 g/plant and T_4 = cowdung+MOC+poultry manure @ (500+100+500) g/plant

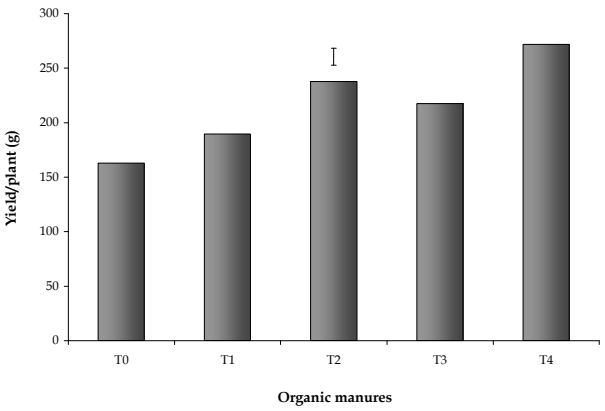

Fig. 5. Main effect of organic manures on fruit yield (g/plant) of strawberry. The vertical bar represents LSD at 5% level of probability. T0 = Control (no manures), T1 = Cowdung @ 500 g/plant, T2 = Mustard oilcake (MOC) @ 100 g/plant, T3 = Poultry manure @ 500 g/plant and T4 = Cowdung+MOC+poultry manure @ (500+100+500) g/plant.

Such an increase in TSS percentage have arisen due to synergistic effect of nitrogen due to cowdung, MOC and poultry manure on the effect of these nutrients as well as other in the sugar metabolism of strawberry fruits reported by El-Hamid *et al*. (2006). All the nutrients significantly reduced the acid content of strawberry fruits over control and increased sweetness

Combined effect of vertical staking and organic manures on growth, yield and quality of strawberry

The combined effect of vertical staking and organic manures had significant influence on all the parameters under study viz. plant height, number of leaves, runners, flowers and fruits per plant, fruit length, fruit diameter, individual fruit weight, fruit yield per plant and TSS content of strawberry fruits (Table 3 and Fig. 6). The tallest plant (15.95 cm) was recorded from the combined treatment of 4.5 ft above ground staking and Cowdung+MOC+poultry manure @ 500+100+500 g/plant (V_3T_4), followed by 15.19 cm in V_1T_4 (4.5 ft above ground staking with Cowdung+MOC+poultry manure @ 500+100+500 g/plant), whereas the shortest plant (9.61 cm) was obtained from V_1T_0 (1.5 ft above ground staking with control) (Table 3). The maximum number of leaves per plant (27.62) was obtained from the combined treatment of 4.5 ft above ground staking and Cowdung+MOC+poultry manure @ 500+100+500 g/plant (V_3T_4), followed by 26.23 in V_2T_4 (3 ft above ground staking with Cowdung+MOC+poultry manure @ 500+100+500 g/plant), while the minimum number of leaves per plant (15.02) was observed in V_1T_0 (1.5 ft above ground staking with control) (Table 3). From the experiment it was also observed that plant growth had started to stop which may be due to cease of cell division after flowering (Morgan, 2006). Similar result was also found by Beer *et al*. (2017) who reported that plant height, number of leaves per plant, runners per plant and number of crown per plant was found maximum in the mixed manures treatment.

The maximum number of flowers (24.86) and fruits per plant (22.90) were found from the combined treatment of 4.5 ft above ground staking and Cowdung+ MOC+poultry manure @ 500+100+500 g/plant (V_3T_4), followed by 23.44 and 21.59, respectively, in V_3T_2 (4.5 ft above ground staking with MOC @ 100 g/plant), while the minimum number of flowers (12.40) and fruits per plant (11.25) were recorded from V_1T_0 (1.5 ft above ground staking with control) (Table 3). The maximum number of runner per plant (4.73) was obtained from the combined treatment of 4.5 ft above ground staking and Cowdung+ MOC+poultry manure @ 500+100+500 g/plant (V_3T_4), followed by 4.34 in V_3T_2 (4.5 ft above ground staking with MOC @ 100 g/plant), while the minimum number of runner per plant (2.18) was found from V_1T_0 (1.5 ft above ground staking with control) (Table 3). This might be due to the genetic characters of the cultivar and above ground staking effects along with mixed manures (Turkben *et al*., 1997).

Table 2. Combined effects of vertical staking and organic manures on growth, yield and quality characters of strawberry

Treatment combination	Plant height (cm)	No. of leaves/ plant	No. of flowers/ plant	No. of fruits/ plant	No. of runner/ plant	Fruit length (cm)	Fruit diameter (cm)	Indivi dual fruit wt. (g)	TSS (% brix)
V_1T_0	9.61	15.02	12.40	11.25	2.18	2.05	1.48	7.85	6.40
V_1T_1	13.49	19.48	16.77	15.06	2.95	2.53	1.95	9.67	7.03
V_1T_2	14.55	23.23	19.75	17.71	3.48	2.93	2.32	11.03	7.30
V_1T_3	14.10	21.31	18.25	17.02	3.24	2.73	2.12	10.35	7.67
V_1T_4	15.19	25.08	21.38	19.14	3.75	3.18	2.50	11.67	7.87
V_2T_0	10.15	15.50	13.50	12.35	2.67	2.17	1.65	8.97	6.68
V_2T_1	13.79	21.13	19.85	17.76	3.37	2.78	2.17	10.80	7.20
V_2T_2	14.82	24.41	21.76	19.41	3.92	3.23	2.58	12.24	7.40
V_2T_3	14.41	22.89	20.66	18.77	3.65	2.98	2.36	11.49	7.70
V_2T_4	15.54	26.23	23.01	21.04	4.19	3.44	2.78	12.87	8.13
V_3T_0	10.71	16.18	14.33	13.27	3.03	2.34	1.82	10.10	6.81
V_3T_1	14.16	22.50	21.45	19.67	3.89	2.95	2.37	11.57	7.30
V_3T_2	15.04	25.35	23.44	21.59	4.34	3.35	2.73	12.82	7.47
V_3T_3	14.76	24.46	23.35	21.30	4.26	3.25	2.67	12.57	7.73
V_3T_4	15.95	27.62	24.86	22.90	4.73	3.70	3.04	13.87	8.23
$LSD_{0.05}$	0.159	0.363	0.752	0.326	0.075	0.053	0.092	0.191	0.321
$LSD_{0.01}$	0.214	0.489	1.010	0.440	0.101	0.071	0.124	0.257	0.591
Level of significance	**	**	**	**	**	**	*	**	*

*, **=5 and 1% levels of probability, respectively, V_1 = 1.5 feet (ft) above ground, V_1 = 3.0 ft above ground and V_1 = 4.5 ft above ground staking, T_0 = Control (no manures), T_1 = Cowdung @ 500 g/plant, T_2 = Mustard oilcake (MOC) @ 100 g/plant, T_3 = Poultry manure @ 500 g/plant and T_4 = Cowdung+MOC+poultry manure @ (500+100+500) g/plant.

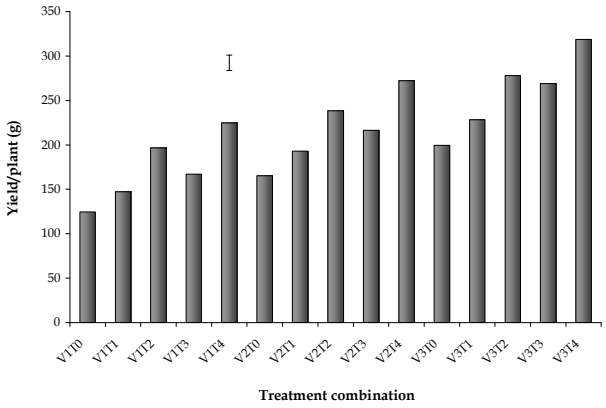

Fig. 6. Combined effects of vertical staking and organic manures on fruit yield (g/plant) of strawberry. The vertical bar represents LSD at 5% level of probability. V1 = 1.5 feet (ft) above ground, V1 = 3.0 ft above ground and V1 = 4.5 ft above ground staking, T0 = control (no manures), T1 = cowdung @ 500 g/plant, T2 = mustard oilcake (MOC) @ 100 g/plant, T3 = poultry manure @ 500 g/plant and T4 = cowdung+MOC+ poultry manure @ (500+100+500) g/plant.

The longest fruit length (3.70 cm) and diameter (3.04 cm) were recorded from the combined treatment of 4.5 ft above ground staking and Cowdung+MOC+poultry manure @ 500+100+500 g/plant (V_3T_4), followed by 4.34 cm and 2.78 cm, respectively, in V_2T_4 (3 ft above ground staking with Cowdung+MOC+poultry manure @ 500+100+500 g/plant), whereas the shortest fruit length (2.05 cm) and diameter (1.48 cm) were observed in V_1T_0 (1.5 ft above ground staking with control) (Table 3). This might be due to the effects of different organic manures on germination, growth, flowering, fruiting and yields of strawberry plants. It was found that mixture of different organic manure application increases the length and breadth in strawberry fruit (Atefe *et al.*, 2012). Similar result was also found by Uddin *et al*. (2013) who showed that fruit length and diameter was significantly influenced by the mixture of cocodust, cowdung and inorganic nutrients. Results showed that the maximum individual fruit weight (13.87 g) and yield per plant (318.82 g) were recorded from the combined treatment of 4.5 ft above ground staking and Cowdung+ MOC+poultry manure @ 500+100+500 g/plant (V_3T_4), followed by 12.87 g and 278.07 g in V_2T_4 (3 ft above ground staking with Cowdung+MOC+poultry manure @ 500+100+500 g/plant), while the lowest individual fruit weight (7.85 g) and yield per plant (124.48 g) were found in V_1T_0 (1.5 ft above ground staking with control) (Table 3 and Fig. 6). This might be due to the effects of mixed manures which reduces the C:N ratio (Nagavallemma *et al.*, 2004). Abu-Zahra and Tahboub (2008) also reported the similar findings where mixed organic manures (Sheep and Cattle) provided higher fruit weight and yield which were significantly different from that of the single application of poultry manure.

The highest TSS content (8.23%) was observed in V_3T_4 (combined treatment of 4.5 ft above ground staking and Cowdung+MOC+poultry manure @ 500+100+500 g/plant), followed by 8.13% in V_2T_4 (combined treatment of 3 ft above ground staking and Cowdung+ MOC+poultry manure @ 500+100+500 g/plant), while the lowest TSS content (6.40%) was recorded in V_1T_0 (combined treatment of 3 ft above ground staking and control) (Table 3). Use of organic manures significantly increased levels of organic acids (malic and citric acid), sugars (fructose, glucose and total sugars) (Shiow and Shin-Shan, 2002), soluble solids and insoluble solids (Federico *et al.*, 2007).

Conclusion

The combination of 4.5 ft above ground staking and application of cowdung + MOC + poultry manure @ 500, 100 and 500 g/plant, respectively, was found to be better in respect of optimum growth, yield and quality of strawberry.

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