EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH, FLOWERING AND YIELD OF STRAWBERRY (*FRAGARIA* X *ANANASSA* DUCH) GROWN UNDER GREENHOUSE CONDITIONS IN THE JORDAN VALLEY

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ABSTRACT

A greenhouse experiment was carried out during the 2004/2005 season at Abu-Ghannam's farm in Kreimeh in the northern Jordan Valley-Jordan, to study the effects of fermented organic matter (made from sheep manure and annual weeds) used at four rates of 1.5, 3.0, 4.5 and 6.0 kg/m^2 in comparison to conventional system (chemical fertilizers and pesticides) on growth, flowering and yield of the strawberry cultivar Honor. A randomised complete block design (RCBD) with four replicates was adopted.

The highest vegetative growth (leaves/plant, leaf area, plant fresh and dry weight) was found in the conventional treatment, while the highest root/canopy ratio was obtained by the 4.5 kg /m^2 treatment. Organic matter advanced flowering date, while the conventional treatment delayed it. Runner production was not significantly affected by the type of treatment.

The conventional treatment produced the highest fruit weight, total yield per replicate, and total yield per plant.

Key words: Conventional, flowering, *Fragaria X ananassa*, organic, strawberry, vegetative growth, yield.

1.0 INTRODUCTION

World strawberry production has reached about 3.1 million tons from total planted area of 214,200 ha in 2004, with the USA alone producing about 840,000 tons (FAO, 2004). In Jordan, strawberries are mainly cultivated for fresh consumption, both for local and export markets in the winter growing season that extends from December to March. The protected cultivated area (in Jordan) increased from 2.75 ha in 1989 with a total production of 17 tons to 55.4 ha, with a total production of 959 tons in 2004 (Ministry of Agriculture, 1989 and 2004). Environmental issues are capturing more and more of the world's attention. Therefore, researchers and scientists are looking for more environmental friendly means and techniques (Hamdar and Rubeiz, 2000).

Conventional agriculture practices utilise high-yielding cultivars, chemical fertilizers and pesticides, irrigation and mechanisation (Ames and Kuepper, 2000). Organic farming, which essentially excludes the use of many chemical inputs such as synthetic pesticides and fertilizers, relies upon crop rotations, crop residues, animal manure, legumes, green manure, off-farm organic wastes, mechanical cultivation, mineral-bearing rock powders, and biological pest control (Ames and Kuepper, 2000; Brandt and Molgaard, 2001; Kadir, 2003). These components improve soil productivity, supply plant nutrients, and help in combination with biological pest and weeds control (Ames *et al.*, 2003).

Pollution is becoming a serious problem in agricultural regions. For example, various mineral fertilizers and agrochemicals lead to pollution and serious human health problems, hence alternative production techniques which employ biological and / or organic compounds for disease and pest control are needed (Turemis, 2002). Organic cultivation techniques for berry and vegetable production in the field and in greenhouses have been developed in response to these demands (Palomaki *et al.*, 2002).

Under organic culture, strawberry yielded 8-12 tons/ha, with an average decrease of about 43% compared to conventional culture in Denmark (Lindhard *et al.*, 2000). Other researchers found a decrease in yield when using organic growing methods, compared to conventional farming methods, but the differences were not significant (Palomaki *et al.*, 2002). Marketable strawberry yield was consistently lower in the organic system, but the margin of difference decreased over the course of the study from 39 to 28%. However, market conditions resulted in greater returns/ha in the organic production system, since prices were 50% higher, making the organic system more profitable (Ames *et al.*, 2003; Gliessman *et al.*, 1996; Lindhard *et al.*, 2000; Palomaki *et al.*, 2002; Turemis, 2002,). Other researchers (Hamdar and Rubeiz, 2000) used two rates of poultry manure (7 and 14 ton/ha), in addition to inorganic fertilizer (ammonium nitrate) application, and found that the yield in all three treatments was higher than the control, with the highest yield obtained from the 14 tons/ha treatment. Organic cultured strawberries produced 0.51 root/canopy ratios, while the conventionally cultured strawberries produced 0.42 root/canopy ratios (Palomaki *et al*., 2002).

In Jordan, no research has been done regarding organic strawberry production in spite of good sources of organic matter, especially animal manure and plant residues, which are available at very low costs. The present work aimed at making a comparison between strawberries grown using organic and conventional production systems, in regard to vegetative growth and fruit productivity.

2.0 MATERIALS AND METHODS

This study was conducted on a virgin site during the period from mid October 2004 to the end of May 2005, in a greenhouse (9 m x 56.5 m) at Abu-Ghannam's farm in Kreimeh in the northern Jordan Valley, located about 53 km from Amman. The climate in this region is hot and dry during summer, warm and rainy in winter.

2.1 Organic Matter Preparation and Soil Solarisation

The organic matter for this experiment was prepared, according to Preusch *et al.* (2004) recommendations. Two months before planting, a compost pile with about 0.7 m x 3 m x 6 m height, width and length, respectively, was prepared at the experimental location by piling multi layers of 1:1 ratio of sheep manure with available plant residues (annual weeds) with, soil from the experimental field. Water was added to moisten the layers (which were maintained at around 50% relative humidity). The pile was covered with clear green mulch to avoid heat and moisture loss, and to prevent flies from laying eggs. The pile was turned every 10 days, until fermentation was completed and the green mulch was removed. Soil solarisation which is recommended in organic cultivation as an alternative method to methyl bromide (Ames *et al.,* 2003) was applied to the soil of the experimental site during hot summer months (from the 15th of August to the 13th of October), according to procedures outlined by Abu-Blan and Abu-Gharbieh (1994).

2.2 Treatments, Planting and Crop Management

The width of the greenhouse was divided into nine sections of 1 m each and the length into four sections, each 14 m long. Thus, each experimental unit (bed) had an area of 14 m^2. The remaining 0.5 m from the length was left at the entrance of the greenhouse. The conventional planting was done according to the system applied in the farm where the experiment was conducted, which included the use of pesticides and inorganic fertilizers; UNEC (34 N: 10 P: 27 K), Calboron (30 Ca:1 B), EDDHA (6% Fe), Humate (18% Humic acid) and Multisource N (40% N). However, in organic culture treatments, all types of chemicals (pesticides and inorganic fertilizers) were excluded, and the fermented compost at the rates of 1.5; 3; 4.5 and 6 kg/m^2 were spread and incorporated into the beds. In addition to the conventional treatment and the four organic treatments a control treatment (no organic and no inorganic fertilizers and pesticides) was included in the study. A randomised complete block design (RCBD), with four replicates per treatment was used. Prior to planting, strawberry plants (cv. Honor obtained from Plant Science Incorporation in California, USA) were soaked in water in order to prevent wilting and improve their viability status. Planting took place on the 18th of October 2004. Raised beds were prepared and covered with black mulch, and 40 cm left between beds as walking area. Two rows per raised bed were planted at a spacing of 20 cm between rows and 25 cm between plants within a row. Each experimental unit was planted with 112 plants. To improve pollination and fruit set, one Bumble beehive was placed in the middle of the greenhouse after the polyethylene cover was installed, and doors closed with a white sieve sheet. Any holes or openings in the greenhouse cover or in the white sheet were sealed to keep the bees inside the structure and to protect plants from pests.

2.3 Vegetative Growth Measurements

2.3.1 Number of Leaves per Plant

At the end of the experiment, ten strawberry plants per replicate were randomly selected and their leaves counted, then the total number of leaves averaged.

2.3.2 Leaf Area

Twenty leaves per replicate were collected at the end of April, 2005 and their area was measured using a portable area meter (Patent Pending, LI-3000A, SR. No. 2516. LI-COR, U. S. A.), and the average leaf area was calculated.

2.3.3 Root/Canopy Ratio

Root per canopy fresh weight ratio was measured for ten freshly harvested plants per replicate. Plants were removed from the beds, the roots washed with water, then separated from the crown of the plants using hand shears, weights were measured by digital scale balance for roots and canopies separately for each replicate and the root/canopy fresh weight ratio was calculated.

2.3.4 Plant Fresh Weight

Ten freshly harvested plants per replicate were weighed using a digital scale balance and average weight calculated.

2.3.5 Plant Dry Weight

Ten freshly harvested plants per replicate were dried in an oven at 60°C for 48 hours to a constant weight, and then placed in desiccators until their temperature dropped (Leskinen *et al.*, 2002). Weight of dried plants was taken by digital scale balance, and the average calculated.

3.3 Leaf Area

Leaf area was highest (129.8 cm^2) in the conventional treatment, which did not differ significantly from any of the high organic matter treatments (4.5 and 6 kg O.M/m^2). On the other hand, the lowest leaf area was obtained from the control treatment and low organic matter treatments of 1.5 and 3 kg O. M/m^2 (Table 1).

3.4 Plant Fresh Weight

The highest plant fresh weight was obtained by the conventional treatment in comparison to all other treatments. Regardless of the dose of organic matter, no significant differences were observed in the plant fresh weight for all organic matter treatments, which in turn differed significantly from the control, with the exception of the 1.5 kg/m^2 organic matter dose (Table 1).

3.5 Plant Dry Weight

In the case of plant dry weight, the conventional treatment gave the highest plant dry weight compared to all other treatments, whereas the control gave the lowest dry weight. No significant effect was found between the organic matter treatments and the control on dry weight of the strawberry plants (Table 1).

The present results showed in general a decrease in vegetative growth of the organic treatments compared to the conventional treatment, which could be due to the higher availability of nutrients especially nitrogen (8.2 kg N/treatment). Conventionally grown strawberries received different fertilizer forms during the experimental period compared to other organic treatments. These results agree with those of Palomaki *et al.* (2002), who found a significant decrease in vegetative growth of strawberry in organic growing methods, compared to conventional growing methods. Similarly, Gliessman *et al.* (1996) found that plant vegetative growth, measured as leaf number, leaf area and vegetative biomass, was less in the organic production system than in the conventional system.

3.6 Root/Canopy Ratio

Root/canopy ratio of plants treated with high rates of organic matter (4.5 and 6 kg) was significantly greater than that of the conventional treatment (Table 1). Palomaki *et al.* (2002) found similar results in which organically grown strawberries produced higher root/canopy ratios, than strawberries grown under conventional systems. These results indicate that an increase in organic matter led to an increase in root growth too. This may due to improved soil physical conditions by organic matter, which in turn facilitates root growth and penetration. Moreover, the conventional treatment resulted in a large canopy with small roots, thus the root/canopy ratio was small, while the organic matter treatments produced small canopy with large roots, resulting in a large root/canopy ratio.

2.3.6 *Flowering (Days to 50 % of Plants per Replicate in Bloom)*

The number of days from planting until 50 % of all plants per replicate were in bloom was determined.

2.4 Yield Measurements

One month after flowering, the harvest of fruits began. Ripe berries were picked by snapping the fruit stem by the fingers. A short stem was left attached to allow the fruits to keep for a longer period. Each replicate was harvested alone, then weighed and packed in the field. Harvesting was done early in the morning when temperature was low.

2.4.1 *Total Yield*

This parameter was measured directly in the field by weighing the total freshly harvested fruits per replicate and harvest date, using a digital scale balance. At the end of the experiment, all weights for each replicate were summed.

2.4.2 *Average Fruit Weight*

This parameter was measured at weekly intervals, by weighing and counting all harvested fruits per replicate, then dividing total weight by total number of fruits.

2.4.3 *Yield per Plant*

This parameter was calculated at the end of the experiment by dividing total yield per replicate over the number of plants in that replicate.

Data were evaluated by analysis of variance (Steel and Torrie, 1980) and means were separated by the LSD test ($p = 0.05$) using SAS.

3.0 RESULTS AND DISCUSSION

3.1 Vegetative Growth

The effect of organic matter and chemical fertilizers on vegetative growth parameters, such as number of leaves per plant, leaf area, plant fresh and dry weight, root/canopy ratio and number of runners per plant is reported in Table 1.

3.2 Number of Leaves per Plant

The highest number of leaves/plant (34.86) was obtained from the conventional treatment in comparison to other treatments (organic and control). For organic matter treatments, the rates of 4.5 and 6 kg O.M/m^2 produced significantly more leaves/plant than the two other rates of 1.5 and 3 kg O.M/m^2. The control produced the lowest number of leaves/plant (Table 1).

3.7 Number of Runners per Replicate

The number of runners was not significantly affected by treatments. In contrast, more runners were produced when using synthetic fertilizers (Preusch *et al.*, 2004). This when the plants were still producing fruits. Moreover, temperatures were relatively low during the growing season. If the data collection was delayed until summer when difference could be due to the early collection of the runner data in the present study, it was warmer the number of runners per replicate would probably have been different.

3.8 Flowering

Flowering date was advanced by the organic matter treatments, and delayed by the conventional treatment (Table 2). The earliest onset of flowering was obtained by the 6 kg O.M/m^2 after 58.75 days, while the latest onset of flowering was obtained by the conventional treatment which needed 65.5 days to reach flowering stage. Furthermore, significant differences existed between the conventional and all organic treatments, while the control treatment was intermediate in this respect (Table 2). These results are in agreement with results of Turemis (2002), who found that all composts accelerated blooming date. This effect may be due to continued decomposition of composts after application, resulting in increased temperature in the rhizosphere. This increase in temperature and the higher amounts of potassium in the soil (950 ppm K, data not shown in tables) may be responsible for the acceleration of the onset of flowering in the organically treated plants. On the other hand, the use of different forms and amounts of inorganic nitrogen fertilizers may be responsible for the delay in the onset of flowering in the conventionally treated plants.

3.9 Yield Measurements

Data on yield are shown in Table 2. The highest total yield per replicate (38.52 kg) was obtained by the conventional treatment which exceeded all other treatments. Moreover, yield of all organic treatments, except the 1.5 kg O.M/m^2 treatment, exceeded significantly that of the control. On the other hand, no significant differences were observed between the 3, 4.5, and 6 kg O.M/m^2 treatments.

The highest yield obtained by the conventional treatment could be due to the supply of inorganic fertilizers. On the other hand, the low availability and the slow release of nutrients from the organic matter, is supposed to be responsible for the low yield in the organic treatments compared to the conventional treatment. Even the higher organic matter rates were not able to supply the strawberry plants with the required nutrients, and it seemed that more time was needed for these nutrients to be available for plant absorption. On the other hand, there was an increase in yield response with increasing soil organic matter up to 4.5 kg O.M./m^2. This increase in yield could be due to the generation of carbon dioxide during compost decomposition, which improved carbon assimilation as concluded by Turemis (2002).

On average, the yield of the control and the organic treatments was between 8.6 - 18.6% less than the yield of conventional treatment. A 43% decrease in average yield under organic culture was observed (Lindhard *et al.*, 2000). Others reported the yield in organic systems to be about two thirds of that obtained in conventional system (Ames *et al.*, 2003). On the other hand, Palomaki *et al.* (2002) found a decrease in fruit productivity of strawberry plants, when using organic growing methods, compared to conventional growing methods, but the differences were not significant.

3.10 Total Yield per Plant

Average total yield per plant followed the same trend as total yield per replicate. The highest yield (334.88 g/plant) was obtained from conventional treatment which differed significantly from all other treatments, while the lowest yield was obtained from the control and the 1.5 kg O.M/m^2 treatment. In addition, no significant differences were observed between all other organic matter treatments (Table 2). Yield per plant in the present study was relatively low and varied from 280-334 g depending on the production system. Others (Pringle *et al.*, 2002, and Schopplein *et al.*, 2002) reported higher yields per plant. The low productivity per plant in the present study could be due to the low temperature that prevailed, especially during January and February; which delayed plant growth and restricted the bumble bee activity resulting in low fruit set, low yield and relatively inferior fruit quality during both months.

3.11 Average Fruit Weight

The conventional treatment had the highest average fruit weight compared to other treatments, while the lowest average fruit weight was obtained from the control (Table 2). Only small and non-significant differences between organic and conventional systems have been previously reported in respect to fruit weight (Birkeland *et al.*, 2002). According to Hortynski *et al.* (1994), fruit weight depends on the cultivar (number of achens) and temperature rather than on the culture system (organic or conventional).

4.0 CONCLUSIONS

The results obtained from this work concerning the parameters related to strawberry vegetative growth indicate that the highest number of leaves/plant, the largest leaf area and the highest plant weight (fresh and dry) were found in the conventional treatment while the highest root/canopy percent was obtained by the 4.5 and 6 kg O.M./m^2 treatments. Number of runners was not significantly affected by treatment type. On the other hand, organic matter hastened flowering date, while the conventional treatment delayed it. The highest fruit weight, total yield per replicate, and total yield per plant were obtained from the conventional treatment, while the control and the organic matter treatment decreased yield by 8.6 to 18.6 % compared to the conventional treatment.

ACKNOWLEDGEMENTS

Special thanks to Mr. Khalil Abu-Ghannam for help, hosting of this work and support throughout the research period.

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Table 1: Effect of organic inorganic fertilizers on vegetative characteristics of strawberries

Treatments	**Leaves**		**Plant weight (g)**		**Root/canopy ratio**
	Number/plant	Area (cm^2)	Fresh	Dry	
Conventional	34.86	129.8a	197.60a	43.56	0.0833c
Control	22.09d	112.8c	111.52c	27.89b	0.0813c
1.5kg O.M.*/m^2	26.20c	115.9c	138.34	29.76b	0.0909bc
3.0kg O.M./m^2	24.83	118.8bc	152.24b	31.83b	0.0948bc
4.5kgO.M./m^2	29.08b	126.9ab	151.76b	32.47b	0.1065ab
6.0 kgO.M./m^2	30.75b	128.6a	151.76b	32.47b	0.1065ab

* O.M.: Organic matter.
**: Means within columns having the same letters, are not significantly different at 5% level.

Table 2: Effect of organic and inorganic fertilizers on productivity of strawberries

Treatments	**Days to 50% of plants per replicate in bloom**	**Total yield (kg/replicate)**	**Yield/plant (g)**	**Average fruit weight**
Conventional	65.50	38.52a	343.88a	23.12a
Control	62.75	31.36c	279.98c	20.01c
1.5kg O.M.*/m^2	60.25	31.44c	280.67c	20.48bc
3.0kg O.M./m^2	59.75	34.49b	307.97b	21.58b
4.5kgO.M./m^2	59.25	35.22b	314.49b	21.15bc
6.0 kgO.M./m^2	58.75	34.94b	311.93b	21.59b

* O.M.: Organic matter.
**: Means within columns having the same letters, are not significantly different at 5% level.