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Effect of Planting Dates and Environmentally Friendly Fertilizer Rates on Productivity and Quality of Strawberry

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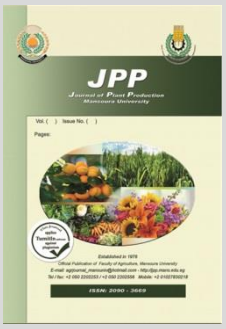

ABSTRACT

This study was conducted during two sequential seasons 2016/2017 and 2017/2018 at Protected Agriculture Location, Agriculture Research Center, Dokki, Giza governorate, Egypt. The major goals of this study were determining the suitable planting date for strawberry cv.Festival grown under climate change impacts and improve vegetative growth, productivity and quality characteristics of strawberry cv.Festival by using environmentally friendly fertilizers as a soil amendments. The experiment was arranged in a spilt plot design, the main plots were represented by two planting dates (15th of September and 15th of October) and the sub plot were split by four different application levels of natural mixed mineral ore (NMO) as following 0g, 6g, 12g, 18g and 24g which added as a soil amendments in pots culture under open field conditions. Results showed that under different planting dates, 15th of October gave the highest values of vegetative parameters, total and early yield per plant, average fruit weight, TSS and vitamin C and NPK% contents in leaves than 15th of September during the two successive seasons. Increasing the level of natural mixed mineral ore (NMO) up to 24g enhanced vegetative parameters, total and early yield per plant, average fruit weight, TSS and vitamin C. Leaves mineral content showed that increase (NMO) level led to increase nutrient percentage for PK contents in strawberry leaves in comparison with control treatment. The highest vegetative growth, yield and fruit quality were obtained from the 15th of October combined with 24g of (NMO).

***Keywords*:** Strawberry, planting dates, natural mixed mineral ore, soil amendments, fruit quality and leaf mineral content.

INTRODUCTION

Strawberry (*Fragaria × ananassa* Duch.) has global significance because of its unique taste and diversity of biological compounds which are found at a high concentration such as antioxidants, phenolics, carotenoids, ascorbic acid, vitamins, and sugars Galli (2016). According to Agricultural Statistics Institute (2019) the strawberry cultivated area is 31606 Faddan which produced 539482 Tons.

Strawberry can be grown under varied climatic conditions while it is mainly a crop of the temperate climate which can be grown in a sub-tropical climate and even at high altitudes of tropical climate Sharma and Negi (2019).

Transplanting date has a direct relation on daily maximum and minimum temperature, daylight intensity, and sunshine duration, which affect the flowering, fruit quality, and production. Then, the transplanting date of strawberry considers and important for dry matter production and yield Bhatia *et al.* (2017). In line with previous studies, Anna *et al.* (2003) observed better growth of strawberry plants when planting after the second week of October because the temperature in these areas usually started to decrease after the first fortnight of October. In addition to high-temperature stress during September, Anwar *et al.* (2016) concluded that there was a decrease in the success of seedlings, on the contrary during the first two weeks of October which favorite to plant growth, flowering, yield, and fruit quality. Finally, prevailing weather conditions play a decisive role in transplant success and fluctuations in mean temperature, rainfall, relative humidity, and frost incidence may influence final yield and fruit quality.

Increasing limitations in agrochemical law regulations led to the need for modern methods in plant nutrition and plant protection Ronga *et al.* (2019). In recent years, more research has been performed to find safe alternatives which are used to stimulate growth and improve yield without causing environmental pollution problems and at the same time are much cheaper and more convenient to use than conventional mineral fertilizers.

Natural mixed mineral ore (NMO) is one of these alternatives which consist of thirteen oxide elements such as SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, SO_3, MgO, CaO, Na_2O, K_2O, P_2O_5 and L.O.I. Some of these elements are very important for strawberry production not only to increase the yield but also increasing fruit quality. Silicon is the major element in (NMO) which reached about 38.5% SiO_2 in addition to 3.4% K_2O, 6.1% P_2o_5, and 3.5% F_2O_5. Recently, silicon has been listed as a beneficial element according to International Plant Nutrition Institute (2015) Georgia,USA. Silicon plays a vital role in several plants for being tolerant to anti-effects of biotic stresses caused by diseases, pests, and abiotic stresses, caused by environmental stress like salinity, heavy metals, drought, frost, high and low temperature, water flooding, etc. Sonali and Byoung (2014) and Carrasco-Gil *et al.* (2018). Applications of silicon induce metabolic changes in strawberry plants, however, applications of silicon increased chlorophyll and organic acid content and enhanced plant growth Wang and Galletta (1998). There are some studies on NMO that provide useful information, so there is a need for more studies to provide proper recommendations to apply for commercial farms Mansour and Mubarak (2014).

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Silicon also helps in the formation of organic defense compounds through the alternation of gene expression Ordeñana (2002) or relieving diseases such as Botrytis or Spodoptera Snyder *et al.* (2007).

Therefore, this study was aimed to improve strawberry quality and production in sand culture by determining the most proper planting date and optimum addition rate of NMO as a friendly environment plant growth promoter.

MATERIALS AND METHODS

This experiment was conducted at Protected Agriculture Location, Agriculture Research Center, Dokki, Giza governorate, Egypt in open field conditions during the two successive seasons of 2015/2016 and 2016/2017.

Plant material:

Strawberry (*Fragaria Xananassa* Duch.) cv. Festival F1 hybrid fresh seedlings were obtained from Techno green Farms – New El-Salhia location. Strawberry were transplanted at two planting dates on 15th of September and 15th of October in the 1st and 2nd cultivated seasons, respectively. The seedlings was selected according to crown diameter, all seedlings was above 0.5 cm crown diameter before transplanting.

System materials:

Plastic pots 8 Liters (25 cm diameter x 30 cm height) were used, the pots were filled by sand in open system of sand culture. Sand was primarily washed with diluted nitric acid to get rid from the undesirable salts, then with running tap water to wash nitric acid compounds from the sand.

After sand was getting dry, it mixed with natural mixed mineral ore in different rates regarding to the treatments under the study and filled the pots in specific volume 8 L. The sand was mixed with compost with 0.5% rate to enhance the sand as a substrate for all treatments. Black polyethylene sheets were mulched the soil before arranging the pots to prevent plant roots to penetrate soil. Low tunnel was used for protect all the treatments from mid of November till mid of February.

The pots were arranged in rows. Every two rows of pots contained one bed. The width of each bed was 50 cm. The distance between each two plants in each row was 30 cm.

The chemical fertilizers were injected within irrigation drip system. Sub-miserable pump (1H) at water tank 1000 L for all experimental plot was used to pump the fertigation via drippers of 4 l/hr capacity. The fertigation was programmed to work 4 times / day and the duration of irrigation time depended upon the season. Crop management practices were in accordance with standard recommendations for commercial growers.

The study treatments:

The experiment was designed to study the effect of two factors on strawberry growth and yield. The first factor was planting date of strawberry seedling 15th of September and 15th of October. The second factor was five levels of natural mixed mineral ore (0, 6, 12, 18 and 24 g per plant). The experimental design was a split plot with three replicates. The planting date was assigned as main plot and natural mixed mineral ore levels was allocated in subplots. Each experimental plot contained 10 plants.

Table 1. Chemical constituents of natural mixed mineral ore (NMO).

	SiO_2	TiO_2	$Al2O_3$	Fe_2O_3	MnO	SO_3
Component %	38.56	0.76	7.8	3.58	0.61	5.38
	MgO	CaO	Na_2O	K_2O	P_2O_5	L.O.I
	2.47	13.45	1.32	3.37	6.14	7.01

Measurements:

Samples of three plants of each experimental plot were taken to determine growth parameters after 120 days from the transplanting date as follows:

1.Number of leaves.
2.Plant height (cm).
3.Crown diameter (cm).
4.No. of secondary crowns per plant.

Yield:

Total yield per plant was recorded during the harvesting season as g/plant. The early yield was determine during the first two months of harvesting. Average number of fruits for different treatments during the two seasons was recorded.

Fruit quality:

Samples of plant fruits from different treatments was taken during mid of February. Random samples of 15 fruits were taken to determine the physical and chemical fruit quality as follow:-

a.Physical Fruit quality:

1.Average fruit firmness (g/cm^2) by Ballouf Pressure Tester according to A.O.A.C. (1990).
2.Average fruit weight (g).

b. Chemical Fruit quality:

It was estimated according to A.O.A.C. (1990) as follow:

1.Total soluble solids (TSS %) sing a hand refractometer.
2.Total acidity was determined in fruit juice as (mg/100g).
3.Vitamin C (mg/100 g).

Leaf mineral content:

Five plant samples (12 fully mature leaves) from each experimental plot were taken after 90 days from transplanting for mineral analysis. Samples were dried at 70ºC in an air forced oven for 48 hr. Wet digestion was performed according to FAO (1980) 0.5g oven – dried plant material was added in 50 ml volumetric flask and digest with 10 ml H_2SO_4 conc. on a hot plate at approximately 270 °C. Small quantities of H_2O_2 was added repeatedly until the digest remains clear. The solution left to cool and diluted to 50 ml with redistilled water according to the method described by Allen (1974).

1. Total nitrogen was determined by Kjeldahl method according to the procedure described by FAO (1980).
2. Phosphorus content was determined using spectrophotometer according to Watanabe and Olsen (1965).
3. Potassium content was determined photometrically using Flame photometer as described by Chapman and Pratt (1961).

Statistical analysis:

Analysis of the data was determined by computer, using SAS program for statistical analysis and the differences among means for all traits were tested for significance at 5 % level according to the procedure described by Sendecor and Cochran (1980).

RESULTS AND DISCUSSION

Results

Effect of maximum daily air temperature on different planting dates:

The maximum daily air temperature during the two planting dates illustrated in Figure 1.The maximum air temperatures during the first week in September 2016 and 2017 were ranged from 33 - 36 °C. The maximum air temperature gradually decreased (with some fluctuation) during the next week to be almost around 32°C. The maximum air temperature

tended to decrease again to be around 30°C from 1st week of October till Mid of October 2017. During 2016 the maximum air temperature remained around 30°C till Mid of October then gradually decreased to be below 30°C. The maximum air temperatures after mid of October of 2016 and 2017 till Mid of November were ranged from 24 to 29°C. The obtained maximum air temperature data revealed that the maximum air temperatures were optimum for vegetative growth of strawberry in the second planting date.

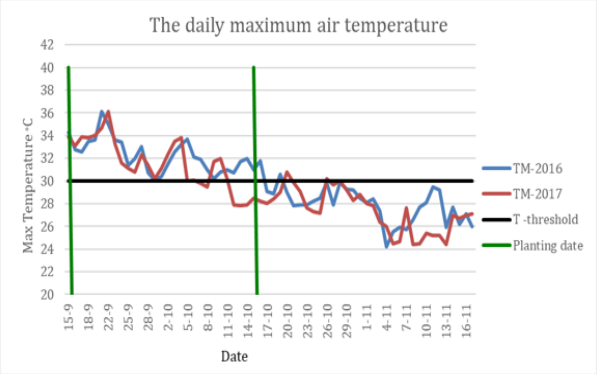

Figure 1. The maximum daily air temperatures during mid of September till Mid of November in 2016 and 2017 seasons.

1- Vegetative growth characteristics of strawberry:

The results in Table 1 demonstrated the effect of planting dates of cv. strawberry Festival and levels of natural mixed mineral ore on vegetative characteristics of strawberry (number of leaves per plant, plant height, number of secondary crowns per plant and crown diameter).

Regarding the effect of planting dates in both seasons, the 15th of October (second planting date) gave the highest values of No. of leaves per plant, plant height, No. of secondary crowns per plant, and crown diameter while the lowest data was recorded by 15th of September (first planting date).

Concerning the effect of applied natural mixed mineral ore rates, the differences among treatments were significant except in strawberry plant height during both seasons.

The highest No. of leaves per plant obtained by 24g of mixed mineral ore per plant followed by 18g; using 12g per plant came in the third option, whereas control treatments gave the lowest No. of leaves per plant. There were no significant differences between control and 6g per plant of mixed mineral ore.

The obtained results showed that using 24 g per plant of natural mixed mineral ore gave the highest secondary crowns per plant and crown diameter; there were no significant differences between 24 and 18g per plant. The lowest secondary crowns per plant and crown diameter were obtained by control. There were no significant differences between control treatment compared to applying 6 or 12 g per plant of natural mixed mineral ore.

The interaction effect between planting date and natural mixed mineral ore, as presented in Table 1 showed that the second planting date combined with 24 g gave the highest No. of leaves followed by the second planting date combined with 18 g of natural mixed mineral ore. First planting date combined with control demonstrated the lowest No. of leaves per plant. The same trend was obtained during the second season

Regarding to strawberry plant height, data presented that 15th of October (second date) combined with 24 g natural mixed mineral ore per plant gave the highest values plant height, followed by the second planting date combined with 18g of natural mixed mineral ore per plant. The lowest values observed in 15th of September (first date) combined with control. There were no significant differences between the first plant date combined with control and first plant date combined with 12g of natural mixed mineral ore per plant.

Table 2. Effect of planting dates and natural mixed mineral ore levels on number of leaves, plant height, number of secondary crowns and crown diameter.

Planting dates	Mixed Mineral ore rate					
	Control	6 g	12 g	18 g	24 g	Mean A
Number of leaves/plant						
First season 2016/2017						
15th of September	32.7 g	33.7 g	35.7 fg	37.0 ef	38.7 def	35.5 B
15th of October	39.3 de	41.7 d	45.7 c	49.7 b	54.3 a	46.1 A
Mean B	36.0 D	37.7 D	40.7 C	43.3 B	46.5 A	
Second season 2017/2018						
15th of September	34.7 g	35.7 g	37.7 fg	39.7 ef	41.7 de	37.9 B
15th of October	41.7 de	43.7 d	48.7 c	53.7 b	57.7 a	49.0 A
Mean B	38.2 D	39.7 D	43.2 C	46.7 B	49.7 A	
Plant height (cm)						
First season 2016/2017						
15th of September	23.3 b	23.1 ab	23.3 b	23.2 ab	23.4 ab	23.2 B
15th of October	24.7 ab	25.3 a	25.1 ab	25.5 a	25.3 a	25.1 A
Mean B	23.8 A	24.3 A	24.2 A	24.3 A	24.3 A	
Second season 2017/2018						
15th of September	24.3 c	24.7 bc	24.7 bc	25.5 abc	25.2 abc	24.8 B
15th of October	26.2 abc	27.1 ab	26.7 abc	27.3 a	27.4 a	26.8 A
Mean B	25.1 A	25.8 A	25.6 A	26.3 A	26.1 A	
Number of secondary crowns/plant						
First season 2016/2017						
15th of September	5.5 d	5.5 d	5.5 d	5.8 d	6.6 cd	5.6 B
15th of October	7.6 bc	8.6 ab	8.4 ab	9.3 ab	9.8 a	8.7 A
Mean B	6.5 B	7.0 B	6.9 B	7.6 AB	8.1 A	
Second season 2017/2018						
15th of September	5.9 d	5.9 d	5.9 d	6.2 d	7.0 cd	6.1 B
15th of October	8.1 bc	9.2 ab	8.9 ab	9.9 ab	10.5 a	9.3 A
Mean B	7.0 B	7.5 B	7.4 B	8.0 AB	8.7 A	
Crown diameter (cm)						
First season 2016/2017						
15th of September	1.4 e	1.4 e	1.5 de	1.6 cde	1.7 cde	1.5 B
15th of October	1.8 cd	1.8 bc	1.9 abc	2.1 ab	2.1 a	1.9 A
Mean B	1.6 C	1.6 C	1.7 BC	1.8 AB	1.9 A	
Second season 2017/2018						
15th of September	1.5 e	1.5 e	1.6 de	1.7 cde	1.8 cde	1.6 B
15th of October	1.8 cd	1.9 bc	1.9 bc	2.2 ab	2.2 a	2.0 A
Mean B	1.7 B	1.7 B	1.8 B	1.9 A	2.0 A	

As regards the number of secondary crowns per plant, results showed that the second planting date combined with all-natural mixed mineral ore rates gave a higher number of secondary crowns per plant than the control treatment. There were no significant differences between the second planting dates combined with the different mixed mineral ore. The lowest number of secondary crowns per plant was observed in the first planting date with control treatment. There were no significant differences between the first planting dates combined with different natural mixed mineral ore except the first planting date combined with 24g of mineral mixed ore. A similar trend was found in the second season.

In both seasons according to crown diameter, data existing that the second date combined with different levels (12, 18, and 24 g per plant) of natural mixed mineral ore

gave a higher crown diameter than the second planting date combined with control. The lowest results were obtained on the first date combined with control. There were no significant differences between the first planting date combined with control and the first planting date combined with 6 g of natural mixed mineral ore per plant.

Yield and fruit quality characteristics of strawberry:

The effect of planting dates of cv. strawberry Festival and levels of natural mixed mineral ore on yield (total yield per plant and early yield per plant) and physical quality characteristics of strawberry (average fruit weight and fruit firmness) were established in Table 2.

The different planting dates had a significant effect on total yield per plant, early yield per plant, average fruit weight, and fruit firmness for the duration of the two studied seasons.

The second planting date gave the highest total and early yield per plant compared to the early planting date (15th of September). According to the total yield per plant, there was an increase of about 28.2% and 21.3% than the 15th of September date at the first and second seasons, respectively. While 15th of October enhanced early yield per plant by around 84.9% more than the 15th of September date in both seasons.

With regard to average fruit weight, data prepared that the second planting date had the highest outcome compared with the first planting date which gave the lowest outcome. On the other hand, the 15th of September (first planting date) gave higher fruit firmness than The 15th of October (second planting date).

Data showed that there were significant variances among all application rates of natural mixed mineral ore treatments during both seasons. The highest total yield per plant was obtained by using (24g, 18g, 12g, and 6g of mixed mineral ore respectively) which increasing the total yield percentage per plant as 16.1%, 11.5%,7.8% and 2.8% correspondingly, more than control treatment during the first season and 15.7%, 11.2%, 7.6%, and 2.7% respectively for the second season. Control recorded the lowest total yield per plant.

On the subject of early yield per plant, data revealed that using 24g of mixed mineral ore gave the highest early yield per plant followed by using 18g then using12g. The lowest early yield per plant was found by using control. There were no significant differences between using 6g of mixed mineral ore and control. Expressing the early yield increase as a percentage, it was clear that using 24g, 18g and 12g of mixed mineral ore gave 22.7%, 15.4%, and 8.9% more than control at the two seasons.

Concerning the average fruit weight data showed that using 24g of mixed mineral ore provided the highest fruit weight followed by using 18g then using 12g of the natural compound. The lowest fruit weight was found using control. The same trend was observed in the second season.

Regarding fruit firmness there were significant differences among all treatments, it was clear that control gave the value of the highest followed by using 6g, 12g and 18g of mixed mineral ore respectively. The application of 24g of mixed mineral ore recorded the lowest fruit firmness.

The interaction influence between planting date and natural mixed mineral ore, as presented in Table 2 exposed that the second planting date combined with 24 g gave the highest total yield per plant chased by the second planting date combined with 18 g of natural mixed mineral ore. The first planting date combined with control demonstrated the lowest total yield per plant. A similar trend was gotten during the second season.

Referring to the early yield per plant, there were significant variations between treatments in both seasons. The second planting date combined with 24 g of natural mixed mineral ore gave the highest early yield per plant pursued by the second planting date combined with 18 g of natural mixed mineral ore and then the second planting date combined with 24 g of natural mixed mineral ore. The lowest values were observed in the first planting date combined with control. There were no significant differences between the first planting date combined with control and the first planting date combined with 6g of natural mixed mineral ore per plant.

Table 3. Effect of planting dates and natural mixed mineral ore levels on total yield per plant, early yield per plant, average fruit weight and fruit firmness.

Planting dates	Mixed Mineral ore rate					
	Control	6 g	12 g	18 g	24 g	Mean A
Total yield/plant (g)						
First season 2016/2017						
15th of September	493.3 j	507.1 i	532.4 h	550.5 g	573.8 f	531.4B
15th of October	633.3 e	650.6 d	682.6 c	705.4 b	734.7 a	681.3A
Mean B	563.3 E	578.8 D	607.5 C	627.9 B	654.2 A	
Second season 2017/2018						
15th of September	533.8 j	547.8 i	573.7 h	592.2 g	615.9 f	572.7B
15th of October	646.2 e	663.6 d	696.2 c	719.5 b	749.4 a	694.9A
Mean B	589.9 E	605.7 D	634.9 C	655.8 B	682.6A	
Early yield/plant (g)						
First season 2016/2017						
15th of September	207.2 h	202.8 h	223.6 g	247.7 f	258.2 e	227.9B
15th of October	386.3 d	390.3 d	423.2 c	437.3 b	470.2 a	421.4A
Mean B	296.7 D	296.5 D	323.4 C	342.5 B	364.2A	
Second season 2017/2018						
15th of September	211.3 h	206.8 h	228.1 g	252.7 f	263.3 e	232.4B
15th of October	394.1 d	398.1 d	431.6 c	446.1 b	479.6 a	429.9A
Mean B	302.7 D	302.5 D	329.8 C	349.3 B	371.4A	
Average fruit weight(g)						
First season 2016/2017						
15th of September	25.3 f	26.4 f	27.2 ef	28.3 de	29.7 cd	27.3B
15th of October	31.4 bc	31.3 bc	33.1 b	35.7 a	37.7 a	33.7A
Mean B	28.2 D	28.7 D	30.5 C	32.2 B	33.7 A	
Second season 2017/2018						
15th of September	26.7 g	27.7 fg	28.7 ef	29.3 e	31.2 d	28.7B
15th of October	32.7 d	33.1 d	35.4 c	37.5 b	39.2 a	35.3A
Mean B	29.7 D	30.3 D	31.8 C	33.2 B	35.2 A	
Firmness (g/cm^2)						
First season 2016/2017						
15th of September	155.1 a	151.3 b	148.2 cd	145.6 ef	143.5 fg	148.5A
15th of October	150.3 bc	147.3 de	146.4 def	141.7 g	140.3 g	145.1B
Mean B	152.7 A	149.3 B	147.2 C	143.3 D	141.5E	
Second season 2017/2018						
15th of September	158.1 a	154.3 b	151.5 cd	147.7 efg	145.7 fgh	151.3A
15th of October	153.3 bc	150.3 de	149.2 def	144.8 gh	143.2 h	148.1B
Mean B	155.7 A	152.3 B	150.2 C	146.5 D	144.3E	

In relation to average fruit weight, it was clear that the second planting date combined with 24g or 18g of natural mixed mineral ore per plant recorded the highest fruit weight. There were no significant differences between the second planting date combined with 24g or 18g of natural mixed mineral ore per plant. The second planting date combined with 12g of natural mixed mineral ore per plant came in second place. There were no significant variances between the second planting date combined with 6g of natural mixed ore and control. The lowest fruit weight was noticed in the first planting date combined with control. The same trend was found through the second season.

Concerning fruit firmness in both seasons, data offered that the first planting date combined with control gave the highest worth of fruit firmness followed by the first planting date combined with 6g of natural mixed ore. The

second planting date combined with 18g of natural mixed ore gave the lowest values. There were no significant differences between the second planting date combined with 18g of natural mixed ore and second planting date combined with 24g of natural mixed ore.

Chemical fruit quality characteristics of strawberry:

The influence of planting dates of cv. strawberry Festival and levels of natural mixed mineral ore on chemical quality characteristics of strawberry (TSS, fruit acidity, and vitamin C) were recognized in Table 3.

On the subject of the effect of planting dates in both seasons, the second planting date gave the highest values of total soluble solids and vitamin C, however the lowest data was recorded by the first planting date. Concerning fruit acidity, data reflected that there were no significant differences between the 15th of September and the 15th of October.

Regarding the effect of applied natural mixed mineral ore rates, the differences among treatments were significant during both seasons.

Data showed that TSS and vitamin C gave the same trend, increasing natural mixed mineral ore rates led to increasing TSS and vitamin C. the highest values was obtained by using 24g of mixed mineral ore per plant followed by using 18g. Using 12g of natural mixed mineral ore came in the third option. The lowest TSS and vitamin C were obtained by control treatments during both seasons.

Concerning fruit acidity, it was clear that control gave the highest fruit acidity. There were no significant variances between control and 6g per plant of mixed mineral ore. Using 12g per plant of mixed mineral ore came in the second option, followed by 18g per plant of mixed mineral ore. The lowest fruit acidity was obtained by using 24g per plant of mixed mineral ore.

Table 4. Effect of planting dates and natural mixed mineral ore levels on total soluble solids, fruit acidity, and vitamin C contents.

Total soluble solids (%)						
Planting dates	**Mixed Mineral ore rate**					
	Control	**6 g**	**12 g**	**18 g**	**24 g**	**Mean A**
First season 2016/2017						
15th of September	7.2 f	7.6 ef	8.3 cd	9.3 b	10.4 a	8.6 B
15th of October	7.3 f	7.9 de	8.7 c	9.5 b	10.3 a	8.7 A
Mean B	7.3 E	7.8 D	8.5 C	9.4 B	10.4 A	
Second season 2017/2018						
15th of September	7.6 f	7.9 ef	8.7 cd	9.8 b	10.8 a	8.9 B
15th of October	7.7 f	8.3 de	9.2 c	10.1 b	10.8 a	9.2 A
Mean B	7.6 E	8.2 D	8.9 C	9.9 B	10.8 A	
Fruit acidity (mg/100 g dw)						
First season 2016/2017						
15th of September	0.61 a	0.59 ab	0.55 abc	0.49 cde	0.44 e	0.54 A
15th of October	0.61 a	0.59 ab	0.54 bcd	0.48 de	0.43 e	0.53 A
Mean B	0.61 A	0.59 A	0.54 B	0.49 C	0.44 D	
Second season 2017/2018						
15th of September	0.65 a	0.64 ab	0.58 abc	0.52 cd	0.47 d	0.57 A
15th of October	0.65 a	0.63 ab	0.57 bc	0.51 cd	0.46 d	0.56 A
Mean B	0.65 A	0.64 A	0.57 B	0.52 C	0.47 D	
Vitamin C (mg/100 dw)						
First season 2016/2017						
15th of September	64.2 h	67.3 fg	70.4 de	75.6 b	78.8 a	70.9 B
15th of October	65.5 gh	68.6 ef	71.8 cd	74.2 bc	80.4 a	72.4 A
Mean B	64.8 E	67.9 D	71.1 C	74.9 B	79.6 A	
Second season 2017/2018						
15th of September	65.5 h	68.6 fg	71.8 de	75.7 bc	80.7 a	72.4 B
15th of October	66.8 gh	69.9 ef	73.3 cd	77.2 b	81.9 a	73.8 A
Mean B	66.5 E	69.3 D	72.6 C	76.4 B	81.2 A	

In both two seasons regarding the interaction effect between planting date and natural mixed mineral ore, data existing that using 24g per plant of mixed mineral ore combined with the first or second planting dates gave the highest results of TSS, followed by using 18g per plant of mixed mineral ore combined with the first or second planting dates. Using 12g per plant of mixed mineral ore combined with the first and second planting dates came in the third selection. The lowest TSS was achieved with control combined with both planting dates.

In relation to fruit acidity, results showed that control combined with first or second planting dates gave the highest values of fruit acidity. There were no significant differences between control combined with first or second planting date and using 6g per plant of mixed mineral ore combined with the first or second planting date. The lowest values of fruit acidity were given by using 24g per plant of mixed mineral ore combined with the first or second planting date.

On the subject of vitamin C, data discovered that using 24g per plant of mixed mineral ore combined with both planting dates gave the highest results of vitamin C, followed by using 18g per plant of mixed mineral ore combined with the first or second planting dates. The lowest TSS were achieved by control combined with both planting dates.

Nitrogen, phosphorus and potassium contents in leaves:

The results in Table 4 were illustrated the effect of planting dates and natural mixed mineral ore on nitrogen, phosphorus, and potassium percentage in strawberry leaves.

Regarding the effect of planting dates in both seasons, the second planting date gave the highest N, P, and K contents in strawberry leaves, while the first planting date was presented the lowest N, P and K contents content in strawberry leaves.

Table 5. Effect of planting dates and natural mixed mineral ore levels on nitrogen, phosphorus, and potassium percentage in strawberry leaves.

N %						
Planting dates	**Mixed Mineral ore rate**					
	Control	**6 g**	**12 g**	**18 g**	**24 g**	**Mean A**
First season 2016/2017						
15th of September	3.013 a	3.031 a	3.020 a	3.010 a	3.013 a	3.01 B
15th of October	3.063 a	3.066 a	3.050 a	3.050 a	3.053 a	3.06 A
Mean B	3.028 A	3.051 A	3.035 A	3.035 A	3.038 A	
Second season 2017/2018						
15th of September	3.13 a	3.16 a	3.14 a	3.14 a	3.14 a	3.14 B
15th of October	3.16 a	3.19 a	3.17 a	3.17 a	3.17 a	3.17 A
Mean B	3.15 A	3.17 A	3.15 A	3.15 A	3.16 A	
P %						
First season 2016/2017						
15th of September	0.430 h	0.523 g	0.553 f	0.606 e	0.656 d	0.554 B
15th of October	0.536 fg	0.640 de	0.736 c	0.773 b	0.860 a	0.709 A
Mean B	0.483 E	0.581 D	0.645 C	0.690 B	0.758 A	
Second season 2017/2018						
15th of September	0.456 h	0.553 g	0.583 f	0.646 e	0.696 d	0.587 B
15th of October	0.563 fg	0.676 de	0.776 c	0.823 b	0.896 a	0.747 A
Mean B	0.510 E	0.615 D	0.680 C	0.735 B	0.796 A	
K %						
First season 2016/2017						
15th of September	1.57 g	1.74 f	1.83 f	2.05 de	2.27 bc	1.89 B
15th of October	1.94 ef	2.16 cd	2.24 cd	2.52 b	2.81 a	2.33 A
Mean B	1.75 D	1.95 C	2.04 C	2.28 B	2.54 A	
Second season 2017/2018						
15th of September	1.63 g	1.81 f	1.90 f	2.13 de	2.36 bc	1.96 B
15th of October	2.02 ef	2.24 cd	2.33 cd	2.62 b	2.92 a	2.43 A
Mean B	1.82 D	2.02 C	2.12 C	2.37 B	2.64 A	

Concerning the effect of applied natural mixed mineral ore rates, the differences among treatments were significant with the exception of N content in strawberry leaves during both seasons. There were no significant differences between the treatments in terms of nitrogen content in strawberry leaves.

The highest P and K contents in strawberry leaves were obtained by using 24g of mixed mineral ore per plant followed by 18g; using 12g per plant came in the third option, whereas using 6g per plant came in the fourth selection in case of P content in strawberry leaves, but there were no significant differences between using 6g per plant and 12g per plant of mixed mineral ore in case of K content in strawberry leaves. Control treatment gave the lowest P and K contents in strawberry leaves.

Referring to the interaction influence between planting date and levels of natural mixed mineral ore, as presented in Table 4, data showed that there were no significant differences between planting date combined with natural mixed mineral ore levels according to N content in strawberry leaves.

On the subject of P content in strawberry leaves, data revealed that the second planting date combined with 24 g natural mixed mineral ore per plant gave the highest values of P content, second planting date combined with 18 g natural mixed mineral ore per plant came in the second option, whereas second planting date combined with 12 g of natural mixed mineral ore per plant came in the third opportunity. The lowest value of P content was noticed with the first planting date combined with control.

In relation to K content in strawberry leaves, results showed that the second planting date combined with 24 g natural mixed mineral ore per plant gave the highest values of K content, followed by the second planting date combined with 18g of natural mixed mineral ore per plant. There were no significant differences between the second planting date combined with 18 g natural mixed mineral ore per plant and the first planting date combined with 24g of natural mixed mineral ore per plant. The second planting date combined with 12g of natural mixed mineral ore per plant came in the third option. The first planting date combined with control gave the lowest value of K content

Discussion

Vegetative growth parameters of strawberry such as number of leaves per plant, plant height, and number of secondary crowns per plant and crown diameter were shown to be significantly affected by air temperature. The obtained data revealed that maximum daily air temperature were optimum for vegetative growth of strawberry in the second planting date, because it was decreased below 30°C during the first two weeks after seedlings cultivation. These results reflect those of Sønsteby and Heide (2007) who also found that the number of leaves per plant was higher at 27°C. As well as, Hancock (1999) found that high temperatures slow down plant growth by promoting respiration rate and reducing photosynthesis process. Denis (2020) demonstrated that 30°C gave the highest vegetative growth with strawberry.

Application of natural mixed mineral ore has high potential in increasing performance of plant growth because it consists of important elements such as silicon, phosphorus and potassium. Silicon had positive effect on stimulation vegetative growth under different environmental conditions.

From results it was clear that using 24g per plant of (NMO) gave the highest values of vegetative growth parameters. Hossain (2002) reported that Silicon was increased leaves size due to Increase of cell number and cell dimensions which indicated the effect of Silicon on cell elongation. Ahmad *et al.* (2011) and Hasanuzzaman *et al.* (2012) had been assigned to increased photosynthesis and antioxidative enzyme activities. Ahmad *et al.* (2016) and Cao *et al.* (2018) showed that Silicon increase chlorophyll pigment content in different plants under stress and normal conditions.

The late planting date of strawberry plants gave the highest early and total yield; these results agree with both Sonsteby and Heide (2007) and Denis, (2020) who reported that air temperature around 30°C treatment enhanced earlier flowering in strawberry plants compared to the other treatments which had a higher air temperature above 30°C, that can interpret the reason of higher production of late planting (Mid of October) gave higher fruit weight than early planting date (Mid of September). Similar results have been adjusted with Kumakura and Shishido (1994) who reported that fruit size was significantly enhanced by lower temperature.

Regarding the application of natural mixed mineral ore (NMO), increasing the application of NMO from 6 up to 24g per plant of NMO led to increasing the highest yield and fruit weight. These results agree with Reis *et al.* (2007) who obtained similar results when observed that silicon application increased production, maybe because Si favored the phosphorus absorption by plants due to the molecular similarity between the anionic forms (H_2PO_4 and H_3SiO_4). Moreover, Korndorfer *et al.* (2010) observed that Si promoted the formation of a double layer of silica that reduces transpiration by stomata, limiting the loss of water and favoring greater production. Marodin *et al.* (2014) pronounced that Silicon increasing the commercial yield of tomato and reduced the occurrence of cracked fruits, and increasing significantly economic returns because of the higher productivity of tomato plants. Mansour and Mubarak (2014) decided that NMO was affected significantly by increasing the fruit weight of Navel orange. Liang *et al.* (2015) described that application of silicon to the soil increasing tomato yield by 8.7–15.9% compared with the control treatment. Prentice *et al.* (2017) found that using Agrisilica (26% of silicon) fertilizer in sugar beet cultivation increasing yield systematically up to 40% in relation to the control treatment. Gholami *et al.* (2019) suggested that increasing yield and fruit weight could be due to many reasons including increasing photosynthesis efficiency, leaf area, assimilate production, and increasing of water and mineral absorption by the root which ultimately increasing vegetative growth.

Data presented that using the highest rate of NMO which was calculated with 24g gave the lowest fruit firmness. Whereas using 6g of NMO gave the highest value. Zydlik *et al.* (2009) designated that silicon applications significantly increasing strawberry fruit firmness. On the contrary, Ouellette *et al.* (2017) observed that silicon was not translocated to strawberry fruits, thus it was not affect fruit firmness or fruit weight of strawberry.

Data showed that there was a consensual relationship between increasing NMO rate and increasing both TSS and vitamin C in strawberry fruits, on the contrary, was fruit acidity. Those results matching with Laster *et al.* (2006) when reported that the application of K in soil or on foliages during fruit growth in melons can improve fruit quality, sugar content, and ascorbic

acid. Also, Ebrahimi *et al.* (2012) who showed that increasing the concentration of potassium leading to increased vitamin C content and TSS. In addition to Mansour and Mubarak (2014) found that NMO increasing TSS significantly. Also, Valentinuzzi *et al.* (2017) observed that silicon application significantly increased glucose content in strawberry fruits. Finally, Francisco *et al.* (2020) reported that silicon application improves the berries' quality reaching the parameters of the marketable fruits.

Strawberry cv. Festival had a better response to higher concentration of K which existed in case of using different NMO application than control. There was a consensual relationship between increasing NMO rate and increasing both of potassium and phosphorus content in strawberry leaves. Mansour and Mubarak (2014) found that NMO increasing potassium and phosphorus content in leaves of Navel orange leaves. Also, Mansour and Ataya (2021) obtained the same results. Ghasem *et al.* (2018) found that Increasing K concentrations of nutrient solution of strawberry increased leaf and fruit K concentration than control with strawberry cv. Camarosa and Selva genotypes.

CONCLUSION

This study concludes that, the15th of October is ideal date for planting strawberry cv.Festival. Also, it could be evidently concluded that, application of natural mixed mineral ore (NMO) considers as environmentally friendly fertilizers and soil amendments for enhancing plant growth, yield and quality. The recommendation under this study could be summarized as; using the15th of October combined with 24g of (NMO) gave the highest results of vegetative growth, yield and quality characteristics as well as P and K contents of strawberry leaves.

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تأثير ميعاد الزراعة ومعدلات الأسمدة الصديقة للبيئة على إنتاجية وجودة الفراولة

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تم إجراء هذه الدراسة خلال موسمين متتاليين 2017/2016 و 2018/2017 في موقع الزراعة المحمية ، مركز البحوث الزراعية ، الدقي ، محافظة الجيزة ، مصر. تمثلت الأهداف الرئيسية لهذه الدراسة في تحديد موعد زراعة نباتات الفراولة المناسب للصنف فستيفال منزرع في ظل تأثيرات تغير المناخ وتحسين النمو الخضري والإنتاجية وخصائص الجودة لصنف الفستيفال باستخدام الأسمدة الصديقة للبيئة كمحسنات للتربة. تم توزيع التجربة في تصميم قطع منشقة مرة واحدة، وتم توزيع موعد زراعة فى القطع الرئيسية (15 سبتمبر و 15 أكتوبر) وتم توزيع أربعة مستويات مختلفة من مخلوط الخامات الطبيعية فى القطع الفرعية على النحو التالي (0 جرام ، 6 جرام ، 12 جرام ، 18 جرام ، 24 جرام) والتي تضاف كمحسِّن للتربة في أصص الزراعة تحت ظروف الحقل المكشوف. أوضحت النتائج أن ميعاد 15 أكتوبر أعطى أعلى قيم للصفات الخضرية ، والمحصول الكلي والمبكر للنبات ، ومتوسط وزن الثمرة ، والمواد الصلبة الذائبة وفيتامين ج ومحتوى الأوراق من النيتروجين ، والفسفور، والبوتاسيوم عن ميعاد 15 سبتمبر خلال الموسمين. زيادة مستوى مخلوط الخامات الطبيعية حتى 24 جرام أدى الى زيادة المحصول الكلي والمبكر للنبات ، متوسط وزن الثمرة ، المواد الصلبة الذائبة وفيتامين ج ، أظهر المحتوى المعدني للأوراق أن الزيادة في مستوى مخلوط الخامات الطبيعية أدى إلى زيادة نسبة الفوسفور والبوتاسيوم فى أوراق الفراولة بالمقارنة مع معاملة الكنترول. تم الحصول على أعلى معدل للنمو الخضري والمحصول وجودة الثمار فى ميعاد 15 أكتوبر مع إستخدام 24 جم من مخلوط الخامات الطبيعية.