EFFECT OF TEMPERATURE MODIFICATION AND GROWTH SUBSTRATES ON PRODUCTIVITY AND FRUIT QUALITY OF STRAWBERRY PLANTS GROWN UNDER WAlk-IN TUNNELS

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ABSTRACT

Two experiments were carried out under plastic walk-In tunnels during the two successive seasons of 2013/14 and 2014/15 on strawberry plants Carmelo cultivar at the Protected Agriculture Location, Faculty of Agriculture, Kafrelshiekh University. This work aimed to study the effect of the temperature modification, growth substrates(soil, perlite, peat, peat:perlite peat:vermic and peat:perlite:vermic) and their combined interactions on vegetative growth parameters, productivity, fruit quality and leaves chemical analysis.

The results indicated that the plants grown under modified plastic tunnel had higher values of number of leaves, number of crowns, total green color (SPAD), leaf area, weight of early and total yields per plant and m^2, average fruit weight, reducing and nonreducing sugars and acidity than those grown under traditional one.

It was observed that the plants grown in peat substrate resulted in the highest number of leaves, number of crowns, leaf area per plant, number and weight of early yield and P leaf content, but perlite substrate gave darkeness leaves. Besides, peat mixed with vermiculite substrate gave the highest number, weight and average fruit weight of total yield. plants grown in peat:vermic:perlite, peat:vermic and peat:perlite substrates gave the highest N leaf content compared to those grown in soil cultivation which had the highest K leaves content.

The combined interaction between temperature modified tunnel and peat growth substrate treatments had highest records of number of leaves and leaf area/plant at 90 days, number of crown/plant at 60 days after transplanting, early yield/plant and average fruit weight of both early and total yields in both seasons, total yield/plant and m^2 in in the second one, total and nonreducing sugars and acidity in both seasons. Plants grown in modified tunnel and perlite substarte had the highest values of P leaves content in both seasons compared to those grown under traditional one and perlite substrate which recorded the highest K values, plants grown in either peat:vermicn:perlite or peat:vermic substrates under traditional tunnel had darkness leaves in both seasons.

Keywords: strawberry, temperature modification, growth substrates.

INTRODUCTION

Strawberry (*Fragaria* x *ananassa* Duch.) is the most refreshing and delicious fruit crop which belongs to the Family Rosaceae.It is considered one of the very important cash crops for exportation in Egypt and all over the world as well as its importance in local fruit fresh consumption, juice and food processing, rich source of vitamins and minerals with delicate flavors**(Sharma, 2002)**, used as a regular diet by many peoples in the world**(Hancock, 1999)**, contains a high percentage of phenolics and flavonoids**(Hakkinen and Torronen, 2000)**.In Egypt, acreage planted with strawberry was 14,100 feddans with an average yield of 18.7 ton/fed. according to **Ministry of Agriculture and Land Reclamation Statistics, (2014).**

The cultivated strawberry is generally grown in different temperature regions of the world because its optimum growth range from 10 to 26°C **(Strik, 1984)**, strawberries are also grown in the cooler high Philippines lands **(Aspuria *et al*., 1996)**, and has a wide range of climates from tropics to the near of Arctic Circle **(Barney, 1999)**, Subtropical and Mediterranean countries **(Hancock, 1999).** Low and high temperatures are considered one of limiting factors in the distribution and productivity of the plants. Minor increase or decrease in the temperature even for a short period has an effect on the biochemical and physiological processes of the plant **(Arteca, 2014)**.

So, exposure strawberry plants to elevated temperature can cause morphological,anatomical,biochemical changes in plant tissues and,as a consequence can affect the growth and development of different plant organs **(Palencia *et al*., 2013)**. Heat stress factor is considered one of the most challenges environmental conditions affects strawberry production and reduce vegetative and root growth **(Hellman and travis, 1988)**, produce fewer and smaller fruit **(Renguist *et al*., 1982, and Palencia *et al*., 2013)**, affect all stages of reproductive growth from flower bud initiation through flower development, pollination and fertilization, achenes development to fruit development **(Chan, 2013)**. An increase in average temperature of 3 ° C when comparing two different regions of strawberry production made a difference in the number of fruits **(Radin *et al*., 2011)**. Higher temperature than normal one affects the photosynthetic process through the modulation of enzyme activity **(Sage and Kubien, 2007)**, most important factors affecting strawberry are good aeration and lower bulk density (**Li *et al*., 2010**).

On the other hand, low temperature has a significant effect on plant growth through photosynthesis, water and nutrients uptake, further production and quality of many economically crops including strawberry **(Boyer, 1982; Sharma *et al*., 2005 and Zhang *et al*., 2013)**.

In Kafrelsheikh Governorate, the most important problem faces strawberry production in the soil is the losses of plants due to heavy soil texture, high salinity, high underground water table and prevailing pathogens and nematodes. Therefore, strawberry soilless cultivation under high tunnels can be a good alternative to solve abovmentioned problems, and this may improve plant growth, yield, quality and earliness **(Takeda, 1999).**

Growth substrates (peat, perlite, vermiculite and their mixture) used in soilless culture should have higher water holding capacity,good aeration and lower bulk density to avoid weight loads to the tunnels construction and also, free of pathogens and nematodes **(Gardner, 1986 and Klute, 1986)**. **Tehranifar *et al*.(2007)** reported that the vegetative growth parameters, number of fruits and yield of strawberry cultivars were higher in substrates contain peat and coco peat than other substrates.Soilless strawberry culture using greenhouses extends the crop period, allows out of season production and increases the yield **(Jafarnia *et al*., 2010a)**. Many investigators studied the effect of substrates on vegetative growth parameters of strawberry plants, they indicated that the substrates gave most vigor strawberry plants (**Ahmed, 2003; Ercisli *et al*., 2005; Cantliffe *et al*., 2007; Jafarnia *et al*., 2010b; AL-Raisy *et al*., 2010, Ameri *et al*., 2012 and Adak and Gubbuk, 2015)**.

Anagnostou *et al*. (1995) reported that the substrates type affected on strawberry productivity which grown in different substrates including 100% perlite, 80% perlite + 20% peat, 60% perlite + 40% peat and 20% perlite + 80% peat. They cleared that 100% perlite substrate gave the highest early yield, while both 100% perlite and 60% perlite +40% peat substrates gave the highest total yield. **Ahmed (2003)** evaluated productivity of strawberry plants grown on soilless substrates (sand: peat: perlite 3:1:1 v/v, perlite and soil cultivation), he cleared that strawberry plants grown in sand: peat: perlite followed by sand: peat: vermiculite (3:1:1 v/v) and perlite gave the highest fruit yield compared with the soil cultivation. Many studies cleared that the yield quality of strawberry fruits,i.e., vitamin C, total acidity and total soluble solids were not affected with soilless substrates system**(Celikel, 1999; Ahmed, 2003 and Adak and Gubbuk, 2015)**.

On the other side, **Jafarnia *et al*.(2010b)** cleared that the highest total soluble solids content of strawberry fruit was related to plants which were grown in 60% perlite: 40% peatmoss in vertical hydroponics system. So, the objectives of this work were to study the effect of temperature modification and growth substrates on productivity and fruit quality of strawberry plants grown under walk-In tunnels.

MATERIALS AND METHODS

The experiments were carried out under plastic walk-In tunnels during the two successive seasons of 2013/14 and 2014/15 at the Protected Agriculture Location, Faculty of Agriculture, Kafrelshiekh University. The objective of this work was to study the effects of the temperature modification, growth substrates and their combined interactions on vegetative growth parameters, productivity, fruit chemical characters and leaves chemical analysis of strawberry Carmelo cultivar.The experiment included 12 treatments representing the combinations of two temperature modifications and six growth substrates.

The effect of solar energy as a temperature modification (cooling and heating systems) on growth and yield of strawberry plants was studied under walk-In tunnels, galvanized steel frame was oriented in east-west direction with 6m width, 30m length and 3m height with total area of 180m², UV treated plastic polyethylene sheet (LDPE) with 200 µm thickness was used as cover for the tunnels.The treatments included two high tunnels designated as modified tunnel and non-modified or traditional one.

The modified tunnel was equipped with three exhaust fans 0.7m in diameter, two of them were located 0.5m above the ground and the third one on the middle of the top of entrance on the eastern end, also it was provided with direct evaporation cooling pad with surface area 6m² (3m width x 2m height), the electricity power resource came from photovoltaic model (2KW) working by solar radiation. The heating system contained one solar heater (200L) with tube net among the plants on the soil surface of the tunnel; 2 main steel tubes 1.5inch in diameter provided the hot water and 2 PVC tubes for return water.The cooling and heating systems must be done when the temperature in tunnel was more 28 and less 18 $^{\circ}$C during heat and cold monthes, respectively.

Six types of growth substrates were used as follows: Conrol (soil cultivation), Peat, Perlite, Peat: Perlite (1:1 V/V), Peat: Vermiculite (1:1 V/V) and Peat: Perlite:Vermiculite (1:1:1 V/V/V). The growth substrates treatments were placed in horizontal PVC pipes approximately 6m long and 4inch diameter, the pipes were fixed end-to-end double rows on two sites of galvanized steel frame walls of the tunnels which cover the dead area (60cm width and 30m length) at both sides of the tunnel, two of them were right and the others were left with 1m between the centers of each other's and the lowest one located 1m above the soil surface, after the system was constructed the upper pipes surface was perforated 3inch diameter holes for the cups containing the plants to site into using a power drill and 3inch diameter hole-saw.

The holes were put on 25cm spacing to ensure that all plants will receive direct sun light, each pipe contained 24 holes. The lower pipe surface was opened one hole (16mm diameter) for drainage water at 1m spacing.Each row contains 5 pipes as every one contains one type of substrate, every substrate consists of 4 tubes (4 replications).

Fresh strawberry Carmelo cv., seedlings (supplied by private nursery in both seasons) were transplanted in disposable plastic cups (the upper diameter of plastic cup was 6cm, while the lower one was 4cm and the height was 6cm with multiholes at the lower portion for emerging roots) which were filled with mixture of peat and vermiculite (1:1 V/V), chemical fertilizers and fungicides were added as follow: 300gm ammonium sulfate (20% N), 400gm calcium super phosphate (15.5% P_2O_5), 500gm potassium sulfate (48% K_2O), 50ml nutrient solution as a source of trace elements and 50gm fungicide for each 50kg of the peat. The plants were placed for three weeks in greenhouse under mist fogging till recovering and rooting, after that they were ready for planting in their final place in different types of media at 2*nd* November in the first season and 15*th* October in the second one.

For the soil cultivation under walk-in tunnels, strawberry seedlings were transplanted at the same time of both seasons, on both sides of each ridge (0.75m width and 30m long) at a space of 0.25m between plants, drip irrigation was used . Each sub plot consisted of two ridges having an area of 5.63m^2. Plant density was 13.3 plant/ m^2, open nutrient solution system was pumped via submersible pump 80 watts capacity. The nutrient solution was delivered to each pipe via emitter 4liters per hour per plant**.**

The complete nutrient solution delivered a final nutrient concentration containing 200 ppm N, 70 ppm P, 300 ppm K, 190 ppm Ca, 50 ppm Mg, 5ppm Fe,0.04 ppm Cu, 0.04 ppm Zn, 1.0 ppm Mn, 0.17 ppm B and 0.1 ppm Mo **(El-Behiary, 1994)**. A maximum of six irrigation events per day during daylight hours were determined by time with an irrigation controller, the same irrigation timing and delivery system were used during October and November (10 min), December and January (15 min) and February, March and April(20 min).

The control of pests and diseases was carried out when it was necessary. Maximum and minimum monthly air temperature (°C) were recorded twice daily during the two growing seasons at 7a.m.(minimum) and 14p.m. (maximum) by using the thermometer and average air temperature was calculated as monthly average (Table 1).

Table(1): Maximum, minimum and average monthly air temperature (°C) as affected by modified and traditional tunnels at 2013/14 and 2014/15 seasons

Month	2013/14 Season					
	Modified tunnel			Traditional tunnel		
	Max.	Min.	Av.	Max.	Min.	Av.
November	26	19	22.5	20	17	18.5
December	25	18	21.5	20	16	18
January	22	19	20.5	18	14	16
Febtuary	23	19	21	19	15	17
March	24	18	21	21	17	19
April	22	20	21	27	22	24.5
2014/15 Season						
October	29	19	24	34	21	27
November	23	18	20.5	19	16.5	17.8
December	25	16	18	20	13.7	16.9
January	24	17	20.5	20	12	16
Febtuary	24	19	21.5	20.6	15.4	18
March	25	17	21	23.2	16	19.6

Split–plot system in a randomized complete blocks design was used with four replications, the temperature modifications were randomly arranged in the main plots while, the growth substrates treatments were randomly distributed in the sub- plots.

Data recorded:

Vegetative growth parameters including number of leaves, number of crowns and total green colour(SPAD) were determined at 30,60 and 90 days, while leaf area/plant(dm^2) was recorded at 90 days after transplanting on five random plants per sub plot.Total green colour was determined by the SPAD-501 (Minolta crop, Ramsey.N.J.) used for green measurements(**Marquad and Tipton, 1987)** for the third leaf from the plant apex. The early yield as number and weight of fruit per plant and square meter was calculated as first seven pickings(1.5 month) as well as average fruit weight of both early and total yields were recorded starting of 75 and 65 days after tranplating for a total of 18 harvests(3 months) in both seasons, respectively.

Ten fruits from each sub- plot were taken randomly to determine the fruit chemical characters; Total, reducing and nonreducing sugars were determined of each fruit sample according to **Malik and Singh (1980)** method. The total soluble solids percentage in the fruits juice was estimated by a hand refractometer and total titratable acidity according to **A.O.A.C, (1965**). Ascorbic acid content was determined in mg/100g fresh weight by using the 2,6 Di-chlorophenol method **(A.O.A.C., 1965)**. Leaves chemical analysis: N,P and K were determined at 90 days after transplanting according to **Pregel (1945)**, **King (1951)** and **Jackson (1967)** method ,respectively**.**

Data were tested by analysis of variance according to **Little and Hills (1972)**. Duncan's multiple range test was used for comparison among treatments means(**Duncan, 1965)**.

RESULTS AND DISCUSSION

1-Vegetative Growth :

Data in Tables (2 and 3) showed that the modified plastic tunnel (temperature modification treatment) had significantly increased of vegetative growth parameters including number of leaves and crowns per plant at 30, 60 and 90 days and leaf area per plant at 90 days after transplanting in both seasons, except for number of crowns per plant at 30 days which was not significant. On the other hand, leaf total green color(SPAD) showed reverse trend,which the plants grown in traditional tunnel had darker green color compared to those grown in modified one. The positive effect of modified tunnel on vegetative growth parameters of strawberry plants may be due to its effect on average maximum and minimum temperature degree (Table 1) during cold or heat months during cultivation **(El-Aidy and Sharaf Eldin, 2015)**. Incontrast, the plants grown under traditional tunnel can be exposed to high temperature, that causes significant damage such as sunburn on leaves, anticipated leaf senescence and abscission and shoot and root growth inhibition **(Yamada *et al*., 1996 and Almeida and Valle, 2007)**.

With respect to the effect of substrates on vegetative growth parameters, the results in Tables (2 and 3) indicated that the substrates treatments significantly increased number of leaves, number of crowns per plant at all sampling dates (30,60 and 90 days), total green color at 60 days only and leaf area per plant at 90 days after transplanting in both seasons. Plants grown in peat substrate had the highest number of leaves, number of crowns and leaf area /plant compared to those grown in other substrates. On contrary, highest value of total green colour was obtained from plants grown in perlite substrate. These results may be due to the peat substrate had higher holding and cation exchange capacity and good aeration **(Kacar, 1989)**. These results are in agreement with the finding of **Ercisli, *et al*.(2005)** on strawberry, they indicated that peat substrate had positive effects on vegetative growth parameters compared to other substrates. The strawberry plants grown under modified tunnel and peat substrate had the highest number of leaves at 90 days, number of crowns at 60 days and leaf area/plant at 90 days after transplanting in both seasons compared to those grown in peat:vermic:perlite and peat:vermic substrates under traditional one which had the highest total green colour of leaves at 60 days after transplanting. .

Table (2): Effect of temperature modification, growth substrates and their interaction on number of leaves and crown of strawberry plants during 2013/14 and 2014/15seasons

Treatments		Number of leaves/plant			Number of crowns/plant		
		2013/14 season					
		Days after transplanting					
Temperature modification	Substrates	30	60	90	30	60	90
Traditional tunnel		7.59b	11.79b	16.41b	1.14	2.36b	2.80b
Modified tunnel		9.76a	13.26a	21.49a	1.47	2.61a	3.68a
F. test		**	*	**	NS	*	**
	Soil	7.48b	10.48c	14.52d	1.00b	2.10b	2.52c
	Perlite	9.05ab	11.18c	15.80cd	1.50ab	2.28b	2.93bc
	Peat	9.87a	15.78a	25.92a	1.42ab	3.13a	3.96a
	Peat: perlite	8.51ab	12.68bc	17.58c	1.58a	2.47ab	3.18abc
	Peat: vermic	8.48ab	13.64ab	21.47b	1.25ab	2.29b	3.77ab
	Peat: vermic: perlite	8.64ab	11.38bc	18.42c	1.08ab	2.63ab	3.08abc
F. test		*	**	**	*	**	**
Traditional tunnel	Soil	7.00c	10.32	13.93f	1.00c	2.20c	2.37
	Perlite	7.60	10.20	14.60ef	1.00c	2.57bc	2.87
	Peat	9.07	14.50	20.83c	1.17bc	2.77abc	3.67
	Peat: perlite	6.85	12.65	16.17def	1.50abc	2.27c	2.87
	Peat: vermic	6.95	12.75	16.60def	1.00c	2.33c	2.87
	Peat: vermic: perlite	7.10	10.33	16.33def	1.17bc	2.00c	2.17
Modified tunnel	Soil	8.00	10.63	15.10ef	1.00c	2.00c	2.67
	Perlite	10.50	12.17	17.00de	2.00a	2.00c	3.00
	Peat	10.67	17.07	31.00a	1.67ab	3.50a	4.25
	Peat: perlite	10.1	12.70	19.00cd	1.67ab	2.67bc	3.50
	Peat: vermic	9.87	14.53	26.33b	1.50abc	2.25c	4.67
	Peat: vermic: perlite	9.33	12.43	20.50c	1.00c	3.25ab	4.00
F. test		NS	NS	**	*	*	NS
		2014/15 season					
Traditional tunnel		6.52b	10.14b	14.11b	1.00b	2.02b	2.41b
Modified tunnel		8.39a	11.40a	18.48a	1.27a	2.25a	3.17a
F. test		**	*	**	NS	**	**
	Soil	6.42b	9.01c	12.48d	1.00b	1.81b	2.16c
	Perlite	7.78ab	9.62c	13.59cd	1.29ab	1.96b	2.52bc
	Peat	8.49a	13.57a	22.29a	1.22ab	2.69a	3.40a
	Peat: perlite	7.32ab	10.90bc	15.12c	1.36a	2.12ab	2.74abc
	Peat: vermic	7.30ab	11.73ab	18.46b	1.08ab	1.97b	3.24ab
	Peat: vermic: perlite	7.43ab	9.79bc	15.84c	1.00ab	2.26ab	2.65abc
F. test		*	**	**	*	**	**
Traditional tunnel	Soil	5.98	8.87	11.98f	1.00b	1.89c	2.04
	Perlite	6.54	8.77	12.56ef	1.00b	2.21bc	2.47
	Peat	7.80	12.47	17.92c	1.00b	2.38abc	3.15
	Peat: perlite	5.89	10.88	13.90def	1.29ab	1.95c	2.47
	Peat: vermic	6.11	10.97	14.28de	1.00b	2.01c	2.47
	Peat: vermic: perlite	6.84	8.89	14.05def	1.00b	1.72c	1.86
Modified tunnel	Soil	6.88	9.14	12.99ef	1.00b	1.72c	2.29
	Perlite	9.03	10.46	14.62de	1.72a	1.72c	2.58
	Peat	9.17	14.68	26.66a	1.43ab	3.01a	3.66
	Peat: perlite	8.74	10.92	16.34cd	1.43ab	2.29bc	3.01
	Peat: vermic	8.49	12.50	22.65b	1.29ab	1.94c	4.01
	Peat: vermic: perlite	8.03	12.69	17.63c	1.00b	2.80ab	3.44
F. test		NS	NS	**	*	*	NS

**,* and NS indicate significant differences at $P < 0.01$, $P < 0.05$ and not significant, respectively according to F test. Values having the same alphabetical letter withieach column are not significantly different at the 5% level, according to Duncan's test.

Table (3): Effect of temperature modification, growth substrates and their interaction on leaf total green color (SPAD) and leaf area (dm^2) of strawberry plants during 2013/14 and 2014/15 seasons

Treatments		2013/14 season				2014/15 season			
		Total green color (SPAD)			leaf area/ plant (dm^2)	Total green color (SPAD)			leaf area/ plant (dm^2)
		Days after transplanting							
Temperature modification	Substrates	30	60	90	90	30	60	90	90
Traditional tunnel		48.94a	52.93a	54.64a	11.78b	41.60a	45.52a	48.57a	8.08b
Modified tunnel		45.77b	50.03b	52.72b	23.75a	38.91b	41.53 b	45.10b	13.78a
F. test		**	*	*	**	**	**	*	**
	Soil	47.95	49.10b	54.58	11.74d	40.76	41.49b	45.83	6.91d
	Perlite	47.24	53.13a	53.11	13.13cd	40.16	44.90a	48.20	10.02bcd
	Peat	45.60	51.52ab	55.49	27.96a	38.76	43.55ab	47.17	15.60a
	Peat: perlite	49.74	51.24ab	52.40	13.24cd	42.28	43.33ab	46.11	8.66cd
	Peat: vermic	46.58	52.02ab	52.87	22.58b	39.60	43.99ab	46.52	13.07ab
	Peat: vermic: perlite	47.05	51.88ab	53.63	17.96bc	39.99	43.88ab	47.19	11.32bc
F. test		NS	*	NS	**	NS	*	NS	**
Traditional tunnel	Soil	48.40	49.00c	51.85bcd	7.37f	41.14	42.14bc	45.63	5.43f
	Perlite	48.55	53.00ab	54.92abc	9.93ef	41.27	45.58a	51.26	6.92def
	Peat	46.80	53.07ab	54.65abc	17.66d	39.78	45.64a	48.09	10.82cde
	Peat: perlite	51.85	53.45ab	54.70abc	9.67ef	44.07	45.97a	48.14	6.34ef
	Peat: vermic	48.90	54.10a	55.77abc	14.00de	41.57	46.53a	49.07	9.38c-f
	Peat: vermic: perlite	49.17	54.95a	55.95ab	13.07de	41.79	47.26a	49.24	9.61c-f
Modified tunnel	Soil	47.50	49.20c	57.30a	16.10d	40.38	40.84c	46.02	8.38def
	Perlite	45.93	53.27ab	51.30cd	17.34d	39.04	44.21ab	45.14	13.12bc
	Peat	44.40	49.97bc	56.33ab	38.25a	37.74	41.47bc	46.26	20.38a
	Peat: perlite	47.63	49.03c	50.10d	16.81d	40.49	40.70c	44.09	10.99cd
	Peat: vermic	44.27	49.93bc	49.97d	31.17b	37.63	41.44bc	43.97	16.76ab
	Peat: vermic: perlite	44.93	48.80c	51.30cd	22.86c	38.19	40.50c	45.14	13.03bc
F. test		NS	*	**	**	NS	*	NS	*

**,* and NS indicate significant differences at $P < 0.01$, $P < 0.05$ and not significant, respectively according to F test. Values having the same alphabetical letter within each column are not significantly different at the 5% level, according to Duncan's test.

2- Yield and its components:

The effect of temperature modification (modified and traditional tunnels) treatments on fruit weight, fruit number and average fruit weight of both early and total yields are shown in Tables(4 and 5). The plants grown under modified plastic tunnel had higher fruit weight per plant or square meter as well as average fruit weight of early and total yields compared to those grown under traditional one. The number of fruits of early and total yields were not significantly affected by temperature modification treatments in both seasons.The positive effect of modified tunnel on weight of yield might be due to that appropriate temperature stimulate vegetative growth parameters and also increased buds and flowers induction **(Sage and Kubien, 2007 and Kositsup *et al*., 2009).** On the other hand, fluctuation of temperature either temporary or constant under traditional tunnel might be the reason for poor fruit set, fruit discoloration and damage.

Similar results have been reported by **Wang *et al*., (2003) and Wahid *et al*., (2007) .**

With respect to the effect of growth substrates on early and total fruit yields, data presented in Tables (4 and 5) indicated that the growth substrates significantly increased fruit weight and number of both early and total yields and also average fruit weight in both seasons. Strawberry plants grown in peat substrate gave the highest weight and number of early yield, while such results of average fruit weight was obtained from plants grown in peat or peat mixed with perlite substrate in both seasons. The peat mixed with vermiculite substrate increased significantly total fruit weight in both seasons and fruit number in the second one, while plants grown in perlite substrate had the highest total fruit number per plant or square meter in the first season only compared with the other substrates. These results might be due to sufficient aeration and improved water retention capacity in the substrates **(Issa *et al*., 1997)**. In this concern, **Permuzic *et al*. (1998)** showed that the quantity of tomato fruits in the organic substrates was better than inorganic one. Morever,the peat as 100% organic substrate was preferable to the others due to its cation exchange capacity was the highest.

Concerning The effect of combined interaction between temperature modification tunnels and growth substrates on yield and its components, data in Tables(4 and 5) clreaed that plants grown in the combined interaction between modified tunnel and peat substrate treatment had the highest fruit yield per plant and average fruit weight of early yield in both seasons and total fruit yield per plant, m^2 and average fruit weight of total yield in the second one. On the other hand, the highest fruits number per plant and m^2 of either early yield in both seaons or total yield in the second one were obtained from plants grown in peat substrate under traditional tunnel, the plants grown in peat:vermicn:perlite substrate under modified tunnel had the highest fruit weight per plant, m^2 and average fruit weight of total yield in the frist season only. The differencesof the obtained yield results between the two seasons may be a resultant of the variations in air temperature (Table, 1) and N,P nd N leaves content (Table, 7) in turn, on vegetative growth parameters and fruit yield of strawberry plants in this study.

Table (4): Effect of temperature modification, growth substrates and their interaction on early fruit yield and average Fruit weight (g) of strawberry plants during 2013/14 and 2014/15 seasons

Treatments		Early fruit yield				
		2013/14 season				
		Weight		Number		Average fruit weight (g)
Temperature modification	Substrates	Per plant (g)	Per m^2 (kg)	Per plant	Per m^2	
Traditional tunnel		181.6b	2.3b	9.9	125.0	18.54b
Modified tunnel		226.3a	3.0a	9.3	124.7	24.12a
F. test		*	*	NS	NS	**
	Soil	119.8d	1.2d	6.9d	66.2d	17.48b
	Perlite	181.4c	2.4c	8.4cd	111.4c	21.54ab
	Peat	292.9a	4.0a	12.6a	174.8a	24.44a
	Peat: perlite	195.5bc	2.4c	8.6cd	103.8cd	23.33a
	Peat: vermic	236.5b	3.4ab	11.4ab	163.9ab	20.96ab
	Peat: vermic: perlite	197.8bc	2.6bc	9.7bc	129.1bc	20.24ab
F. test		**	**	**	**	**
Traditional tunnel	Soil	106.0g	0.6	6.9e	41.7e	15.36f
	Perlite	151.7ef	2.0	7.8de	103.2d	19.57c-f
	Peat	271.3b	3.9	14.9a	212.2a	18.17ef
	Peat: perlite	169.3ef	2.3	8.4cde	107.5d	21.70b-e
	Peat: vermic	228.3bc	3.0	12.2b	161.6bc	18.99def
	Peat: vermic: perlite	163.2ef	2.2	9.3cde	124.1bcd	17.44ef
Modified tunnel	Soil	133.6fg	1.2	6.8e	90.7d	19.61c-f
	Perlite	211.2cd	2.8	9.0cde	119.6cd	23.52bc
	Peat	314.6a	4.2	10.3bcd	137.4bcd	30.70a
	Peat: perlite	221.7cd	2.5	8.9cde	100.0d	24.95b
	Peat: vermic	244.6bc	3.8	10.7bc	166.1b	22.94bcd
	Peat: vermic: perlite	232.3bc	3.1	10.1bcd	134.2bcd	23.03bcd
F. test		*	NS	*	**	*
		2014/15 season				
Traditional tunnel		151.5b	2.0b	8.7	105.4	19.54b
Modified tunnel		202.5a	2.7a	8.5	105.1	25.46a
F. test		*	*	NS	NS	**
	Soil	11.4c	1.1d	6.4b	54.0d	18.98b
	Perlite	161.5bc	2.2c	7.0b	92.7c	23.04ab
	Peat	269.0a	3.6a	11.7a	155.0a	23.94a
	Peat: perlite	185.1b	1.9c	7.6b	86.4cd	24.83a
	Peat: vermic	248.8a	3.1ab	11.0	136.3ab	22.46ab
	Peat: vermic: perlite	176.0b	2.3bc	8.1b	107.1bc	21.74ab
F. test		**	**	**	**	**
Traditional tunnel	Soil	117.9e	5.7	7.2de	34.9e	16.36f
	Perlite	135.0e	1.8	6.6de	87.3d	20.57de
	Peat	258.1ab	3.4	13.5a	179.0a	19.17ef
	Peat: perlite	150.1de	1.7	7.1de	90.3d	22.70cd
	Peat: vermic	203.2c	2.7	10.3bc	136.5b	19.99de
	Peat: vermic: perlite	145.2de	1.9	7.9cde	104.4bcd	18.43ef
Modified tunnel	Soil	118.9e	1.6	5.5e	73.2d	21.61de
	Perlite	188.0cd	2.5	7.4de	98.0cd	25.52abc
	Peat	280.0a	3.7	9.9bc	131.0bc	28.70a
	Peat: perlite	219.5bc	2.2	8.2cd	82.4d	26.95ab
	Peat: vermic	294.3a	3.4	11.8ab	136.0b	24.94bc
	Peat: vermic: perlite	206.8c	2.8	8.3cd	109.9bcd	25.03bc
F. test		*	NS	*	*	*

**,* and NS indicate significant differences at $P < 0.01$, $P < 0.05$ and not significant, respectively according to F test. Values having the same alphabetical letter within each column are not significantly different at the 5% level, according to Duncan's test.

Table (5): Effect of temperature modification, growth substrates and their interaction on total fruit yield and average fruit weight (g) of strawberry plants during 2013/14 and 2014/15 seasons

Treatments		Total fruit yield				
		2013/14 season				
		Weight		Number		Average fruit weight (g)
Temperature modification	Substrates	Per plant (g)	Per m^2 (kg)	Per plant	Per m^2	
Traditional tunnel		577.9b	7.7b	40.0	531.6	13.76b
Modified tunnel		750.7a	10.0a	48.5	644.5	15.46a
F. test		*	*	NS	NS	*
	Soil	300.0d	4.0d	26.0c	345.8c	11.48b
	Perlite	849.1ab	11.3ab	57.2a	760.3a	14.96a
	Peat	652.6ab	8.7bc	45.5ab	605.2ab	14.24ab
	Peat: perlite	598.8c	8.0c	38.8bc	516.5bc	14.36ab
	Peat: vermic	997.5a	13.3a	62.0a	824.6	16.44a
	Peat: vermic: perlite	587.8c	7.9c	35.8bc	476.1bc	16.16a
F. test		**	**	**	**	**
Traditional tunnel	Soil	159.0g	2.1f	14.0	186.2	11.36d
	Perlite	558.6c-f	10.2de	35.0	465.5	13.87bcd
	Peat	753.5bcd	10.0bc	51.0	678.3	14.99bc
	Peat: perlite	538.5def	7.2de	40.0	532.0	13.44bcd
	Peat: vermic	500.5ef	5.9e	32.3	430.0	15.57ab
	Peat: vermic: perlite	957.0ab	12.6ab	67.5	897.8	14.17bcd
Modified tunnel	Soil	441.0f	5.7e	38.0	505.4	11.61cd
	Perlite	617.0c-f	8.2cde	36.6	486.8	16.95ab
	Peat	944.7ab	12.7ab	63.3	842.3	14.94bc
	Peat: perlite	766.7bc	6.7bc	51.0	678.3	15.03bc
	Peat: vermic	697.0cde	9.3cd	45.3	602.9	15.52ab
	Peat: vermic: perlite	1038.0a	13.8a	56.5	751.5	18.70a
F. test		*	*	NS	NS	*
		2014/15 season				
Traditional tunnel		514.3b	6.8b	30.3	403.4	16.76b
Modified tunnel		668.1a	8.9a	34.2	454.2	19.46a
F. test		*	*	NS	NS	**
	Soil	267.0d	3.6d	17.5d	232.8d	14.98b
	Perlite	755.7ab	10.1ab	41.1ab	546.2ab	18.46a
	Peat	580.8bc	7.7bc	32.5bc	431.7bc	17.74ab
	Peat: perlite	532.9c	7.1c	29.7	394.6c	17.86ab
	Peat: vermic	887.8a	11.8a	45.4a	604.0a	19.94a
	Peat: vermic: perlite	523.1c	7.0c	25.3cd	363.4cd	19.66a
F. test		**	**	**	**	**
Traditional tunnel	Soil	141.5f	1.9g	9.9	131.1f	14.36e
	Perlite	445.5de	5.9ef	24.0	319.6e	18.57bcd
	Peat	851.7ab	11.3ab	49.6a	659.5a	17.17cde
	Peat: perlite	411.9e	6.6c-f	25.2e	335.5e	16.87cde
	Peat: vermic	670.6bc	8.9bcd	37.7bcd	501.3bcd	17.99bcd
	Peat: vermic: perlite	479.3de	6.4def	29.1de	386.6de	16.44cde
Modified tunnel	Soil	392.5e	5.2f	25.2e	334.5e	15.61de
	Perlite	620.3cd	8.3cde	31.9cde	424.4cde	19.52abc
	Peat	923.8a	12.3a	41.2abc	548.5abc	22.70a
	Peat: perlite	549.1cde	7.3c-f	26.3de	350.1de	20.95ab
	Peat: vermic	840.8ab	11.2ab	44.5ab	591.1ab	18.94bcd
	Peat: vermic: perlite	682.3bc	9.1bc	35.9b-e	476.8b-e	19.03bcd
F. test		*	*	*	*	*

**,* and NS indicate significant differences at $P < 0.01$, $P < 0.05$ and not significant, respectively according to F test. Values having the same alphabetical letter within each column are not significantly different at the 5% level, according to Duncan's test.

3- Fruit chemical characters:

Data presented in Table (6) cleared that reducing and nonreducing sugar and TSS in both seasons and acidity in the second one were sgnificatly affected by temperature modification treatments, the highest fruit reducing sugar content was obtained from plants grown in traditional tunnel, while the highest nonreducing sugar and acidity contents were observed by plants grown in modified one. But TSS and ascorbic acid fruit content were not significantly affected by temperature modification in both seasons.These results are in harmony with those obtained by **Paranjpe and Caniliffe, (2003**) they found that at high temperatures (>80^{0}F)fruit quality characteristics may be adversely affected. Concerning, the effect of growth substrates, plants grown in peat mixed with vermiculite substrate had significantly increased in total sugar, reducing sugar and acidity in both seasons, peat mixed with vermiculite plus perlite substrate gave the highest fuit content of TSS in both seaons, but reducing sugar in both seasons and ascorbic acid in the second one were not significant, supporting earlier results by **Ameri *et al*. (2012)** on strawberry**,** who found that the maximum TSS contents were obtained when the plants grown in 5% vermiccompost+45% perlite+50% cocopeat as compared to the other substrates. On the other hand, **Ahmed (2003)** found that the quality of strawberry fruits as vitamin C, total acidity and total soluble solids content were not affected with soilless substrates.

With respect to the effect of combined interaction, the results cleared that plants grown under modified tunnel had the highest values of total sugars, non-reducing sugars and acidity in peat substrate and total soluble solids content of fruit from plants grown in peat:vermic substrate in both seasons. In the second season, plants grown in perlite and peat substrate under traditional tunnel had the highest record of reducing sugars content.

4- Leaves chemical analysis:

Data in Table (7) showed that the temperature modification treatment had no significant differences in N, P and K % in strawberry leaves in both seasons.The plants grown in peat or peat mixed with vermiculite substrate had highly significant increased in P % of leaves compared to other ones. On the other hand, the plants grown in soil cultivation followed by peat mixed with vermiculite substrate had the highest significant values of K % in leaves in both seasons. These results may be due to high macronutrients content of these substrates, high availability and buffer capacity of organic substrates compared to perlite (**Ghehsareh *et al*., 2011).**

Table (6): Effect of temperature modification, growth substrates and their interaction on fruit chemical characters of strawberry plants during 2013/14 and 2014/15 seasons

Treatments		Fruit chemical characters					
		2013/14 season					
Temperature modification	Substrates	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	TSS (%)	Acidity (%)	Ascorbic acid (mg/100g f.w)
Traditional tunnel		2.09	0.85a	1.25b	3.78	0.050	88.49
Modified tunnel		2.25	0.52b	1.74a	4.23	0.050	85.37
F. test		NS	**	*	NS	NS	NS
	Soil	1.53c	0.54	1.01b	3.50b	0.051ab	84.82ab
	Perlite	1.99b	0.77	1.23b	3.52b	0.051ab	78.57b
	Peat	2.44a	0.70	1.74a	4.05ab	0.046ab	87.80ab
	Peat: perlite	2.20ab	0.78	1.42ab	4.38ab	0.050ab	95.09a
	Peat: vermic	2.47a	0.71	1.76a	3.82b	0.058a	78.42b
	Peat: vermic: perlite	2.40a	0.61	1.81a	4.80a	0.043b	96.88a
F. test		**	NS	**	**	*	*
Traditional tunnel	Soil	1.50f	0.53	0.99de	3.00e	0.051ab	89.29
	Perlite	1.80def	1.05	0.76e	4.37b	0.051ab	96.43
	Peat	2.38ab	0.39	1.34cd	4.33b	0.058a	89.88
	Peat: perlite	2.36ab	0.47	1.60bc	4.10bcd	0.038b	91.07
	Peat: vermic	1.92cde	0.87	1.06de	3.13de	0.045ab	75.00
	Peat: vermic: perlite	2.60a	0.87	1.74abc	3.80b-e	0.054a	89.29
Modified tunnel	Soil	1.56ef	0.54	1.02de	4.00b-e	0.051ab	80.36
	Perlite	2.59a	0.51	2.09ab	4.40b	0.048ab	93.75
	Peat	2.56a	0.39	2.17a	3.30cde	0.058a	66.96
	Peat: perlite	2.45ab	0.47	2.01ab	5.50a	0.048ab	102.68
	Peat: vermic	2.06bcd	0.67	1.40cd	3.90b-e	0.058a	82.14
	Peat: vermic: perlite	2.28abc	0.53	1.75abc	4.30bc	0.038b	86.31
F. test		**	NS	**	*	*	NS
		2014/15 season					
Traditional tunnel		1.84	0.75a	1.09b	3.22	0.044b	77.87
Modified tunnel		1.98	0.46b	1.52a	3.60	0.050a	75.12
F. test		NS	**	*	NS	*	NS
	Soil	1.35c	0.47	0.88b	2.98b	0.048ab	74.64
	Perlite	1.75b	0.67	1.08b	2.99b	0.048ab	69.14
	Peat	2.15a	0.61	1.53a	3.44ab	0.043ab	77.26
	Peat: perlite	1.93ab	0.68	1.25ab	3.72ab	0.046ab	83.68
	Peat: vermic	2.17a	0.63	1.54a	3.24b	0.054a	69.01
	Peat: vermic: perlite	2.11a	0.54	1.57a	4.08a	0.041b	85.25
F. test		**	NS	**	**	*	NS
Traditional tunnel	Soil	1.32f	0.47cd	0.85de	2.55e	0.045abc	78.57
	Perlite	1.58def	0.92a	0.66e	3.71b	0.045abc	84.86
	Peat	2.09ab	0.91a	1.18cd	3.68b	0.051ab	58.93
	Peat: perlite	2.07ab	0.67abc	1.41bc	3.49bcd	0.034c	90.36
	Peat: vermic	1.70cde	0.76ab	0.93de	2.66de	0.039bc	66.00
	Peat: vermic: perlite	2.29a	0.76ab	1.53abc	3.23b-e	0.048ab	78.57
Modified tunnel	Soil	1.37ef	0.48cd	0.90de	3.40b-e	0.051ab	70.71
	Perlite	2.28a	0.44cd	1.83ab	3.74b	0.048ab	82.50
	Peat	2.25a	0.34d	1.91a	2.81cde	0.057a	58.93
	Peat: perlite	2.15ab	0.41cd	1.74ab	4.68a	0.048ab	90.36
	Peat: vermic	1.81bcd	0.59bcd	1.23cd	3.32b-e	0.057a	72.29
	Peat: vermic: perlite	2.00abc	0.47cd	1.54abc	3.66bc	0.038bc	75.95
F. test		**	*	**	*	*	NS

**,* and NS indicate significant differences at $P < 0.01$, $P < 0.05$ and not significant, respectively according to F test. Values having the same alphabetical letter within each column are not significantly different at the 5% level, according to Duncan's test.

Table (7): Effect of temperature modification, growth substrates and their interaction on leaf total N, P and K content (% dry wt.) of strawberry plants during2013/14 and 2014/15 seasons

Treatments		2013/14 season			2014/15 season		
Temperature modification	Substrates	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
Traditional tunnel		3.35	0.183	2.30	2.88	0.161	2.03
Modified tunnel		3.38	0.196	1.76	2.91	0.173	1.55
F. test		NS	NS	NS	NS	NS	NS
	Soil	2.42b	0.157b	2.23a	2.1b	0.138b	1.96a
	Perlite	3.29ab	0.163b	1.93ab	2.83ab	0.144b	1.71ab
	Peat	3.33ab	0.253a	2.13ab	2.86ab	0.223a	1.87ab
	Peat: perlite	3.64a	0.234a	1.69b	3.13a	0.206a	1.49b
	Peat: vermicn	3.71a	0.170b	2.20ab	3.19a	0.150b	1.94ab
	Peat: vermic: perlite	3.81a	0.161b	2.00ab	3.28a	0.142b	1.76ab
F. test		*	**	*	*	**	*
Traditional tunnel	Soil	2.32	0.17d	2.33ab	2.00	0.14c	2.05ab
	Perlite	2.73	0.16d	2.49a	2.35	0.14c	2.19a
	Peat	3.50	0.18cd	2.55a	3.01	0.16bc	2.24a
	Peat: perlite	3.43	0.17d	2.25abc	2.95	0.15c	1.98abc
	Peat: vermicn	3.64	0.14d	1.69d	3.13	0.13c	1.49c
	Peat: vermic: perlite	4.48	0.28ab	2.51a	3.85	0.25a	2.21a
Modified tunnel	Soil	2.52	0.15d	2.13a-d	2.17	0.13c	1.87abc
	Perlite	3.85	0.31a	0.90e	3.31	0.28a	0.79d
	Peat	3.15	0.16d	1.85bcd	2.71	0.14c	1.63bc
	Peat: perlite	3.85	0.15d	1.75cd	3.31	0.13c	1.54c
	Peat: vermicn	3.78	0.18cd	2.19a-d	3.25	0.16bc	1.93abc
	Peat: vermic: perlite	3.15	0.23bc	1.75cd	2.71	0.20b	1.54c
F. test		NS	**	**	NS	**	**

**,* and NS indicate significant differences at $P < 0.01$, $P < 0.05$ and not significant, respectively according to F test. Values having the same alphabetical letter within each column are not significantly different at the 5% level, according to Duncan's test.

The interaction between temperature modification and growth substrates had a highly significant effect on P and K% in leaves in both seasons. The plants grown under modified tunnel with perlite substrate had the highest P content in strawberry leaves in both seasons. While, the highest value of K leaves content was obtained from plants grown in peat:vermic:perlite or peat substrate under traditional tunnel in both seasons.

It could be concluded that the best results of vegetative growth characters, fruit yield and its components and leaf chemical analysis of strawberry plants were obtained from those grown in peat under temperature modified tunnel.

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تأثير تعديل درجة الحرارة وبيئة النمو على الإنتاجية وجودة ثمار نباتات الفراولة النامية تحت الانفاق البلاستيكية العالية

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أجريت تجربتان تحت الانفاق البلاستيكية العالية خلال موسمي 2014/2013 و 2015/2014 على نباتات الفراولة صنف Carmelo بموقع الزراعة المحمية – كلية الزراعة – جامعة كفر الشيخ بهدف دراسة تأثير تعديل درجة الحرارة وبيئة نمو النباتات (الزراعة الارضية، البرليت، البيتموس، البيتموس+البرليت، البيتموس+الفيرميكوليت والبيتموس+البرليت+الفيرميكوليت) والتفاعل بينهما على صفات النمو الخضري، والانتاجية، جودة المحصول والتحليل الكيماوي للأوراق. أوضحت النتائج أن النباتات النامية فى الصوبة ذات درجة الحرارة المعدلة اعطت اعلى قيم لعدد الأوراق ، عدد التيجان ، درجة اللون الأخضر ، المساحة الورقية ،وزن المحصول المبكر والكلي لكل نبات ولكل م^2 ، متوسط وزن الثمرة ، السكريات المختزلة والغير مختزلة و الحموضة مقارنة بتلك النامية تحت الأنفاق البلاستيكية التقليدية.

اعطت النباتات النامية فى بيئة البيتموس زيادة في عدد الأوراق، عدد التيجان، المساحة الورقية لكل نبات، عدد ووزن الثمار للمحصول المبكر ومحتوى الأوراق من الفسفور، بينما أعطت بيئة البرليت زيادة في درجة اللون الأخضر الكلي. إنتجت بيئة البيتموس: الفرميوكيوليت اعلى عدد ووزن ومتوسط وزن لثمار المحصول الكلي، فى حين ان اعلى محتوى للاوراق من النيتروجين كان من النباتات النامية فى بيئة البيتموس+البرليت+الفيرميكوليت وكذا بيئة البيتموس+الفيرميكوليت مقارنة الزراعة الارضية والتى اعطت اعلى محتوى للاوراق من البوتاسيوم. أعطى التفاعل المشترك بين معاملة تعديل درجة الحرارة والبيتموس كبيئة نمو للنباتات اعلى القيم لعدد الأوراق، المساحة الورقية لكل نبات بعد 90 يوم، عدد التيجان لكل نبات بعد 60 يوم من الشتل، المحصول مبكر لكل نبات، متوسط وزن الثمرة لكل من المحصول المبكر والكلى في كلا الموسمين، المحصول الكلى لكل نبات ومتر مربع فى الموسم الثانى فقط، السكريات الكلية والمختزلة والحموضة فى كلا الموسمين. اعطت النباتات النامية داخل الانفاق ذات درجة الحرارة المعدلة والبرليت كبيئة نمو اعلى محتوى للاوراق من الفوسفور فى كلا الموسمين مقارنة بتلك النامية داخل الانفاق البلاستيكية التقليدية والبرليت كبيئة نمو والتى اعطت اعلى محتوى للاوراق من البوتاسيوم. اعطت النباتات النامية سواء فى بيئة البيتموس+البرليت+الفيرميكوليت او البيتموس+الفيرميكوليت وداخل الانفاق التقليدية اعلى محتوى للاوراق من اللون الاخضر.