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Irrigation management for strawberry plants (*Fragaria x ananassa* Duch.) under greenhouse conditions

Mohamed S.M. Ahmed[*] *and Doaa A.M. Gad*

Address:

Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Giza, Egypt

*Corresponding author: ***Mohamed S. M. Ahmed***, e-mail*:* abomaslama@yahoo.com

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ABSTRACT

A field experiment was conducted under greenhouse conditions in the Central Laboratory for Agricultural Climate (CLAC) Dokki, Giza governorate, during the Two winter seasons of 2018/2019 and 2019/2020. The aim of the study was investigated the response of strawberry plants to the alternative substrate mixtures such as perlite with peat moss (P+P) (1:1 v/v) and perlite with vermicompost (P+V) (3:2 v/v) as well as different irrigation levels (60%, 80% and 100%) from ETo. The experimental design was split plot in three replicates. Results obtained that, strawberry *cv.* Festival growth responded positively by using the substrate of (P+V) as well as irrigation by 100% ETo and gave the highest values of vegetative growth characteristics. Whereas, using the substrate of (P+P) and both irrigation 80% ETo and 60% ETo were less positive than the other treatment. Nutrient content of N, P, K, Ca and Mg in leaves were increased by using (P+V) substrate and 100% irrigation level. Yield and its components (no. of fruits, fruit weight, early and total yield) as well as fruit quality parameters (TSS, acidity, Taste, vitamin C and firmness) were enhanced by using (P+V) substrate and the highest irrigation level. Water use efficiency (WUE) of strawberry enhanced by using of (P+V) substrate and irrigated with 80% follows by the treatment of 60% irrigation level. The high amount of irrigation (100%) decreased the WUE. In Egypt, we can overcome the problems of strawberry production in the traditional soils by using the alternative substrates as well as a good management for irrigation water.

Keywords: Potted strawberries, Irrigation levels, substrate mixtures, WUE, fruit quality.

INTRODUCTION

Strawberry (*Fragaria x ananassa* Duch.) is one of the important export crops in Egypt which cultivated in expanded area especially, new reclaimed soils and contributes in the national income. The world production of strawberry reached to 4,516,810 tons according to 2012 statistics, Egypt ranked as the fifth producer in the world after all of USA, Mexico, Turkey, Spain (Trejo-Téllez and Gómez-Merino, 2014). The total production of strawberry fruits is increasing year after year and reached to 289.900 tons per year (FAO, 2012). In Egypt, the cultivated area of strawberry reached to 31897 Feddan in old and new reclaimed soils and the annual production reached to 544.945 tons (MALR, 2019) .On the other hand, the problem of water shortage and water quality becomes more and more important year after year, for consumption increasing and good water availability reduction (Bacci *et al*., 2003). In recent years, drought stress and water shortage is considered as a dilemma in many parts of the world, therefore, the use of greenhouses and soilless culture method is an efficient strategy under these conditions (Hesami *et al*., 2012). Water management in soilless cultivation requires more skills, technology and know-how than soil-based cultivation (Baille, 2001). The total quantities of water applied by irrigation were influenced by the climatic conditions (Kruger *et al*., 1999). Drought stress affected the accumulation of nutrients in strawberry leaves negatively so, the photosynthesis rate was decreased and reduced both of growth and yield production but led to promoted the quality of fruit such as sugar content (Perin *el al*., 2019)

Most growing media for strawberries in soilless culture are peat moss, rockwool, coir, perlite or some other mixtures. Nowadays, using mixture of peat moss and perlite is one of the mostly used substrate for production of hydroponic strawberries in developing countries (Jafarnia *et al*., 2010). Using different mixes of substrates such as coco peat, perlite, vermicompost and others had significant effects on growth and yield of strawberry cultivars (Ameri *et al*., 2012). On the other hand, using mixes of natural substrate such as rice husk, pumice and sand had a significant effect on growth and yield of strawberry especially, when mixture between rice husks and sand gave the best results (Caso et al., 2009). Perlite + FYM substrate was most effective in improving plant growth and yield parameters of strawberry plants than all other used substrate mixtures under greenhouse conditions (Mamta and Shylla, 2018). In this regard, Ameri *et al*., (2012) found that the biochemical

characteristics of strawberry fruits affected by using different substrate components such as rice hull, coco peat, vermicompost and perlite. The highest values of TSS, vitamin C and TA were obtained in vermicompost + perlite + cocopeat substrate. In addition, using of different substrate mixture for strawberry growing affected the water use efficiency and the substrate of burned rice husks mixed by organic compost gave the highest water use efficiency (Diel *et al*., 2016).

Strawberry is a very sensitive plant to soil borne diseases, nematodes and poor soil conditions such as salinity, over watering and poor aeration. So, this study aimed to investigate the effect of using alternative substrates either synthetic or organic instead of traditional soils. In addition, we can achieve the target by the application of good irrigation management and different irrigation levels trying to achieve high production from strawberry planted in pots.

MATERIAL AND METHODS

Experimental layout:

Field experiments were conducted under net covered greenhouse at the Central Laboratory for Agricultural Climate (CLAC), Dokki which follows the Agricultural Research Center (ARC), Giza, Egypt (30° N and 31°N). The seedlings of strawberry *(Fragaria* x *ananassa* Duch.*), cv.* Festival were transplanted on 1st October during both growing seasons of 2018/2019 and 2019/2020. The study aimed to investigate the effect of different levels of irrigation, different substrate mixtures as well as their interaction on the growth, quality and yield of strawberry plants which cultivated in pots. The experimental design was split-plot, the main factor was different levels of irrigation (60, 80 and 100%) from evapotranspiration (ETo) and distributed in the main plots whereas, the second factor was the two different substrate mixtures (perlite: peat moss, 1:1 v/v and perlite: vermicompost 3:2 v/v which distributed in sub-plots by three replicates. The total number of experimental plots were 18 plots (3 irrigation x 2 substrate x 3 replicates), each plot was included 25 pots. The used pot was 25 size with volume of 6 liters of substrate.

Experimental treatments:

Fresh strawberry seedlings were obtained from Strawberry Improvement Center, Faculty of Agric., Ain Shams University, Shoubra El-Kheima. Fresh seedlings with three to four trifoliate leaves were transplanted. Seedlings were soaked in Rhizolex fungicide solution at the rate of 2 g/l before transplanting in substrate mixer pots. A half single greenhouse area (9 m width x 25 m length) with total area 225 m^2 and covered by white net screen. The area of greenhouse divided to 5 raised beds, each one was 1 m width x 25 m length. The middle three raised beds were only used for treatments application. Pots were filled by the substrates mixtures and arranged along the raised bed. The distance between pots was 0.25 m apart. The total number of plants were 384 plants and the number of plants for plot was 64 plants. Drip irrigation system was used for water requirements of strawberry plants application during the growing season. The drippers discharge were 4 l / hr.

Irrigation requirements:

The first treatment was the different levels of irrigation such as 60, 80, and 100% of evapotranspiration (ETo) using the historical data of climatic factors which provided from meteorological station of Central Laboratory for Agricultural Climate (CLAC) and the evapotranspiration calculated by using Penman- Monteith equation, FAO 56 method, presented by Allen *et al.,* (1998) as follows:

$$ET_o = \frac{0.408\Delta\,(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34\,u_2)}$$

Where:

ETo is the daily reference evapotranspiration (mm day^{-1}), Rn is the net radiation at the crop surface (MJ m^{-2} day^{-1}), G is the soil heat flux density (MJ m^{-2} day^{-1}), T is the mean daily air temperature at 2 m height (ºC), U2 is the wind speed at 2 m height (m s^{-1}), es is the saturation vapor pressure (kPa), ea is the actual vapor pressure (kPa), Δ is the slope of vapor pressure curve (kPa $ºC^{-1}$) and γ is the psychometric constant (kPa $ºC^{-1}$).

Then irrigation requirements for strawberry plants were estimated by using next equation:

IR = (Kc * ETo * (1+LF) * IE * R* Area) / 1000

Where:

IR = Irrigation requirements (m^3/ cultivated area).

Kc = Crop coefficient (varied from 0.5 to 1.09 according to growth stage)

ETo = Reference Evapotranspiration (mm day^{-1}).

LF = Leaching Requirement (assumed 25% from total irrigation water amount).

IE = Irrigation efficiency of the trickle irrigation system (assumed 90%).

R = Reduction factor of trickle irrigation (varied from 0.3 up to 0.9 according to plant cover)

Area = the irrigated area (m^2), the area of greenhouse is 360 m^2.

1000 = to convert from liter to cubic meter. The values of evapotranspiration (ETo) and crop coefficient (Kc) for strawberry plant is presented in **Table (1).** In addition, the estimated amount of irrigation water for different treatments is presented in **Table (2).**

Table 1. The values of evapotranspiration (ETo) and crop coefficient (Kc) of strawberry plant

Month	(ETo) mm day^{-1}	(KC)
Oct.	2.52	0.5
Nov.	1.73	0.7
Dec.	1.26	0.9
Jan.	1.52	1
Feb.	2.21	1.09
Mar.	3.35	0.9
Apr.	4.72	0.8
May	5.03	0.7
Jun.	5.71	0.7

Table 2. Estimated amount of irrigation water for strawberry plants during both growing seasons

Period	Irrigation amount (Liter/ Greenhouse area)		
	60%	**80%**	**100%**
1-15 Oct.	4088.16	5450.88	6813.60
16- 31 Oct.	5443.20	7257.60	9072.00
1-15 Nov.	4206.96	5609.28	7011.60
16- 30 Nov	4908.06	6544.08	8180.10
1-15 Dec.	4092.03	5456.04	6820.05
16- 31 Dec	4910.50	6547.33	8184.16
1-15 Jan.	6171.39	8228.52	10285.65
16-31 Jan.	6582.82	8777.09	10971.36
1-15 Feb.	9775.71	13034.28	16292.85
16- 28 Feb.	8472.28	11296.38	14120.47
1- 15 Mar.	12210.75	16281.00	20351.25
16- 30 Mar.	12210.75	16281.00	20351.25
1- 15 Apr.	15280.38	20373.84	25467.30
16- 30 Apr	15280.38	20373.84	25467.30
(1-15 May)	14273.28	19031.04	23788.80
(16-31 May)	15224.83	20299.78	25374.72
(1-15 June)	16183.35	21577.80	26972.25
(16-30 June)	16183.35	21577.80	26972.25
L / GH / season	175498	233997.568	292497
M^3 / GH / season	175.5	234.0	292.5

Nutrition of strawberry plants were applied by using the chemical nutrient solution of (El-Behairy, 1994) as shown in **Table (3),** which added with the irrigation water during the different growth stages of strawberry.

Table 3. Concentrations of nutrients in used nutrient solution (ppm)

Nutrient	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B	Mo	EC	pH
Concentration	135	33.75	225	135	45	2.7	0.75	0.375	0.113	0.188	0.009	1.5	7.2

Substrate mixtures:

The second factor was the different substrate mixtures i.e. perlite: peat moss (1:1 v/v) and perlite: vermicompost (3:2 v/v). The two substrate mixtures were analyzed, the physical and chemical properties presented in (**Table 4)**. Bulk density (BD), total pore space (TPS), water hold capacity % (WHC) and air porosity % (AP) were estimated according to (Wilson, 1983 and Raul, 1996). The pH of the potting mixtures were determined using a double distilled water suspension of each potting mixture in the ratio of 1:10 (w/v) (Inbar *et al.,* 1993) that was agitated mechanically for 2 hours and filtered through Whatman no.1 filter paper. The same solution was measured for electrical conductivity (EC dSm^{-1}) with a conductance meter that was been standardized with 0.01 and 0.1M KCl. N, P and K in the acid digested solution were determined applying Micro-Kjeldahle for N, colorimetric method

(ammonium molybdate) using spectrophotometer for P and by flame photometer for K (Chapman and Pratt, 1961).

Table 4. Physical and chemical properties of the different substrate mixtures

Substrate mixture	Physical				Chemical						
	BD (kg/l)	TPS (%)	WHC (%)	AP (%)	EC (dSm^{-1})	pH	N (%)	P_2O_5 (%)	K_2O (%)	OC (%)	C/N ratio
Perlite: Peat moss (1:1) (v/v)	0.14	65.3	52.8	12.5	0.2	5.0	1.8	0.26	0.12	45.8	25.4
Perlite: Vermicompost (3:2)(v/v)	0.33	65.4	48.7	16.8	1.3	7.4	3.5	0.75	0.95	17.5	5.0

*Bulk density = BD (kg/l), total pore space = TPS (%), water holding capacity = WHC (%) and air porosity = AP (%)

Recorded data:

Ten strawberry plants were collected from each treatment and the following parameters were measured.

Growth parameters i.e., plant height (cm), number of leaves, stem diameter (cm), total leaf area (cm^2), Plant fresh and dry weight (g/plant).

Chlorophyll content (mg / 10 g fresh weight of leaves) using Minolta Chlorophyll Meter SPAD-501 where SPAD unit mg/10gm.

Yield parameters i.e., number of fruits/plant; average fruit weight (g); early and total yield (g/plant) and total yield (kg / m^2).

Quality parameters i.e., total soluble solids TSS (%) using a hand refractometer; acidity (TA) (mg/l) of juice by titration with 0.1 N of NaOH solution using phenolphthalein indicator as described in the A.O.A.C. (1990), taste (TSS / TA) (%), total soluble solids content to total acidity ratio; vitamin C or scorbic acid (mg / 100 cm^3 juice) was determined in the fresh fruits by using the 2,6 Di-chlorophenol indophenol method described in A. O. A. C. (1990).; firmness (mg/cm^2) using Penetrometer (fruit pressure tester) mod. FT 327.

Chemical parameters i.e., N, P, K, Ca and Mg content (%) in the dry plant samples (the fourth leaf from apical tip) on at 70° C were determined at the end of the two growing seasons. Nitrogen, phosphorous and potassium in the acid digested solution were determined applying Micro-Kjeldahle for N, colorimetric method (ammonium molybdate) using spectrophotometer for P and by flame photometer for K, Ca and Mg (Chapman and Pratt, 1961).

Water use efficiency (WUE):

Water use efficiency was calculated for fresh yield of strawberry fruits for different irrigation treatments according to Srinivas *et al*., (1989), using the following equation:

WUE = Total yield (Kg) / Total water consumption (m^3)

Statistical analysis:

The obtained data were statistically analyzed using the analysis of variance method according to Snedecor and Cochran (1980). Duncan's multiple range test at 5% level of probability was used to compare means of the treatments.

RESULTS

Growth patterns:

Data in **Table (5)** obtained that there was a significant effect of different irrigation levels on the growth parameters of strawberry plant during both growing seasons. The irrigation level of 100% of ETo gave the highest values for all measured growth parameters i.e. no. of leaves, plant height, stem diameter, fresh and dry weight of plant and total leaves area per plant followed by The level of 80% ETo. The lowest irrigation level (60% of ETo) resulted the lowest values for all measured parameters in both growing seasons. As for the effect of different substrates i.e. perlite + peat moss (P+P) and perlite + vermicompost (P+V) were also significant. No. of leaves, plant height and stem diameter gave the highest values in both growing seasons when the substrate of (P+P) was used. The other used substrate (P+V) enhanced these growth parameters i.e. plant height, leaf area and fresh and dry weight of plant. The interaction between irrigation levels and different substrates were significant in both growing seasons and the best values of growth parameters were obtained from using 100% ETo irrigation level combined with (P+P) substrate in some growth parameters such as no. of leaves, stem diameter and leaves area. The other growth parameters such as plant height and fresh and dry weight were better when we used (P+V) with the same irrigation level. On the contrary, the lowest values were obtained by using the lowest irrigation level (60% of ETo) combined with both used substrates.

Table 5. Effect of irrigation levels, mixed substrates and the interaction between them on the vegetative characteristics of strawberry during 2018/2019 and 2019/2020 seasons.

	No. of leaves / plant							
	First season				Second season			
Treatments	60% ETo	80% ETo	100% ETo	Means	60% ETo	80% ETo	100% ETo	Means
P:P (1:1)V	16.88c	25.31b	27.81a	23.33A	15.88c	24.31a	25.81a	22.00A
P:V (3:2)V	18.00c	18.44c	25.00b	20.48B	17.00c	20.91b	24.00a	20.48B
Means	17.44C	21.88B	26.41A		16.44C	22.38B	24.91A	
	Plant height (cm)							
P:P (1:1)V	17.00c	19.00b	19.88b	18.63B	15.39e	18.00d	19.63c	17.67B
P:V (3:2)V	19.50b	19.54b	22.33a	20.46A	20.50bc	21.56ab	21.83a	21.30A
Means	18.25B	19.27B	21.11A		17.95B	19.78A	20.73A	
	Stem diameter (cm)							
P:P (1:1)V	1.10f	1.38c	1.53a	1.34A	1.15e	1.32c	1.45a	1.30A
P:V (3:2)V	1.15e	1.20d	1.50b	1.28B	1.15e	1.24d	1.42b	1.27B
Means	1.13C	1.29B	1.52A		1.14C	1.28B	1.44A	
	Plant fresh weight (g)							
P:P (1:1)V	30.32d	33.37bc	34.21b	32.64B	28.29e	32.21d	35.21b	31.90B
P:V (3:2)V	33.05c	39.10a	40.08a	37.41A	34.05c	37.10a	38.80a	36.65A
Means	31.69B	36.24A	37.15A		31.17C	34.66B	37.01A	
	Plant dry weight (g)							
P:P (1:1)V	9.09d	10.31bc	10.38b	9.92B	8.72	10.59	10.88	10.06B
P:V (3:2)V	9.83c	11.57a	12.21a	11.20A	9.70c	11.57a	11.93a	11.07A
Means	946B	10.94A	11.29A		9.21B	11.08A	11.41A	
	Total leaf area / plant (cm^2)							
P:P (1:1)V	1512.63f	2558.02c	3218.60a	2429.75A	1467.81f	2507.49c	3102.87a	2359.39A
P:V (3:2)V	1516.45e	1581.24d	2607.92b	1901.87B	1558.35e	1667.00d	2678.54b	1967.96B
Means	1514.54C	2069.63B	2913.26A		1513.08C	2087.25B	2890.71A	

Chemical contents:

Concerning the response of chemical contents of strawberry leaves for different irrigation levels and cultivated substrates, data in **Table (6)** show that all tested chemical parameters such as chlorophyll, N, P, K, Ca and Mg content in leaf were affected significantly. Data illustrated that increasing the irrigation water level led to increasing the fore mentioned characteristics values. Chlorophyll and nutrient contents in leaf were increased when the 100% ETo irrigation level was applied for pots in both growing seasons followed by (80% of ETo). While the lowest values were recorded with irrigation at 60% of ETo in both growing seasons. On the other hand, the previous characteristics were affected by the both used substrates mixtures, the substrate which consists of perlite and vermicompost (P+V) enhanced the chemical concentration in leaves compared with (P+P) substrate mixture. In addition, the interaction between irrigation levels and different substrates obtained a significant differences. The using of irrigation at 100% of ETo combined with (P+V) substrate gave the highest values of previous characteristics. On the contrary, the lowest values were obtained by using 60% ETo irrigation level combined with (P+P) substrate in both growing seasons.

Table 6. Effect of different irrigation levels, mixed substrates and their interaction on the chemical characteristics of strawberry during 2018/2019 and 2019/2020 seasons.

	Leaf chlorophyll concentration (SPAD)							
	First season				Second season			
Treatments	60% ETo	80% ETo	100% ETo	Means	60% ETo	80% ETo	100% ETo	Means
P:P (1:1)V	48.33d	50.75c	51.48c	50.18B	49.32d	50.88c	52.40c	50.87B
P:V (3:2)V	54.85b	57.28a	58.26a	56.80A	55.34b	55.73	58.09	56.38A
Means	51.59B	54.02A	54.87A		52.33B	53.31B	55.25A	
	N (%)							
P:P (1:1)V	1.83f	2.10e	2.19d	2.04B	1.85f	2.11e	2.22d	2.06B
P:V (3:2)V	2.46c	2.51b	2.80a	2.59A	2.47c	2.50b	2.80a	2.59A
Means	2.15C	2.31B	2.50A		2.16C	2.31B	2.51A	
	P (%)							
P:P (1:1)V	0.862f	0.891e	0.938c	0.897B	0.867f	0.895e	0.942c	0.901B
P:V (3:2)V	0.906d	0.957b	0.996a	0.953A	0.915d	0.960b	0.995a	0.957A
Means	0.884C	0.924B	0.967A		0.891C	0.928B	0.969A	

Table 6 (continoued)								
	K (%)							
P:P (1:1)V	1.97e	2.17d	2.47b	2.20B	1.98e	2.22d	2.49b	2.23B
P:V (3:2)V	2.19d	2.36c	2.72a	2.42A	2.21d	2.32c	2.68a	2.40A
Means	2.08C	2.27B	2.60A		2.10C	2.27B	2.59A	
	Ca (%)							
P:P (1:1)V	0.627f	0.950d	1.247b	0.941B	0.567f	0.883d	1.223b	0.891B
P:V (3:2)V	0.713e	0.967c	1.323a	1.001A	0.667e	0.927c	1.323a	0.972A
Means	0.670C	0.958B	1.285A		0.617C	0.905B	1.273A	
	Mg (%)							
P:P (1:1)V	0.317f	0.363d	0.457b	0.379B	0.303f	0.370d	0.457b	0.377B
P:V (3:2)V	0.353e	0.383c	0.483a	0.407A	0.337e	0.397c	0.480a	0.404A
Means	0.335C	0.373B	0.470A		0.320C	0.383B	0.468A	

Fruit quality:

Data in **Table (7)** present the influence of irrigation levels and different substrates on some fruit quality parameters i.e. acidity (TA), total soluble solids (TSS), taste (TSS / TA), firmness and vitamin C content. Concerning the acidity, irrigation level had a significant effect on acidity and the highest values were obtained by applying 80% ETo irrigation level. On the other hand, using (P+P) was better than using (P+V) substrate. The interaction between 80% irrigation and (P+P) substrate gave the highest values for acidity. Regarding TSS, data revealed that the highest values of TSS resulted from using 100% ETo irrigation level and the lowest values obtained when we used the lowest irrigation level, 60% ETo in both growing seasons. On the contrary, there were no significant effect between both of used substrates on TSS values. The highest values of TSS resulted from irrigation level of 100% combined with both substrates and the lowest values obtained from using 60% irrigation level with both substrates. Concerning the fruit taste, the irrigation level of 100% ETo gave the highest values of taste as well as using the (P+V) substrate in both growing seasons. The interaction between irrigation level and used substrate was significant. Using 100% irrigation level with (P+V) substrate was better than using the others irrigation levels (80% and 60%) combined with (P+P) substrate. Fruit firmness and vitamin C content were affected by irrigation level and gave the highest values when we use the highest level of irrigation water (100%), whereas, gave the lowest values under the lowest irrigation level (60%). Regarding of used substrates, using the substrate of (P+P) gave the highest values of firmness and vitamin C in both growing seasons. On the contrary, using the low level of irrigation water (60%) with (P+V) substrate obtained the lowest values of firmness and vitamin C content in both growing seasons.

Table 7. Effect of different irrigation levels, mixed substrates and their interaction on the fruits quality of strawberry.

	Acidity (TA) (%)							
	First season				Second season			
Treatments	60% ETo	80% ETo	100% ETo	Means	60% ETo	80% ETo	100% ETo	Means
P:P (1:1)V	0.390c	0.541a	0.335e	0.422A	0.415c	0.532a	0.411d	0.453A
P:V (3:2)V	0.342d	0.446b	0.285f	0.358B	0.377e	0.469b	0.368f	0.405B
Means	0.366B	0.494A	0.310C		0.396B	0.501A	0.390C	
	TSS (%)							
P:P (1:1)V	7.48d	8.38c	9.09a	8.32A	7.17d	7.87c	9.08a	8.04A
P:V (3:2)V	7.69d	9.10b	9.41a	8.73A	7.58d	8.35b	9.61a	8.52A
Means	7.58C	8.74B	9.25A		7.38C	8.11B	9.35A	
	Taste (TSS/TA)							
P:P (1:1)V	19.18c	15.50d	27.14b	20.60B	17.27c	14.78d	22.09b	18.05B
P:V (3:2)V	22.48b	20.41b	33.03a	25.30A	20.10b	17.81c	26.13a	21.35A
Means	20.83B	17.95C	30.08A		18.69B	16.30B	24.11A	
	Firmness (mg/cm^2)							
P:P (1:1)V	250.00c	275.00a	275.00a	266.67A	269.75c	295.13a	296.13a	287.00A
P:V (3:2)V	250.00c	250.00c	263.00b	254.33B	267.75d	269.75c	282.30b	273.27B
Means	250.00C	262.50B	269.00A		268.75C	282.44B	289.22A	
	Vitamin C (mg/ 100g F.W)							
P:P (1:1)V	73.16c	90.00a	84.67b	82.61A	74.49c	91.75a	87.28b	84.51A
P:V (3:2)V	68.49d	68.49d	71.85c	69.61B	69.20e	71.20d	74.41c	71.61B
Means	70.83B	79.24A	78.26A		71.85B	81.48A	80.85A	

Yield and its components:

The presented data in **Table (8)** obtained that the irrigation amount as well as the type of substrate affected in the strawberry yield and its components i.e. number of fruit, average fruit weight, early yield and total yield in both growing seasons. The highest amount of irrigation (100% ETo) enhanced all yield components and gave the highest values. Whereas, irrigation at 60 % ETo recorded the lowest values of all yield components. On the other hand, the type of substrate affected in fruit yield and all measured components. In this concern, the mixture of perlite and vermicompost (P+V) gave the highest yield compared with another substrate (P+P) mixture in both growing seasons. The best combination was using 100 % ETo irrigation level with the substrate of perlite and vermicompost (P+V).

Table 8. Effect of irrigation levels, mixed substrates and their interaction on the yield and its components and WUE of strawberry during 2018/2019 and 2019/2020 seasons.

	Number of fruits per plant							
	First season				**Second season**			
	60% ETo	80% ETo	100% ETo	Means	60% ETo	80% ETo	100% ETo	Means
P:P (1:1)V	16.66e	22.23d	25.48c	21.45B	19.89e	24.73d	27.17c	23.93B
P:V (3:2)V	24.02cd	30.27b	36.72a	30.33A	26.13cd	35.49b	37.69a	33.10A
Means	20.34C	26.25B	31.10A		23.01C	30.11B	32.43A	
	Total yield per plant (g)							
P:P (1:1)V	374.44f	541.02e	622.49c	512.65B	448.00f	608.09e	700.86c	585.65B
P:V (3:2)V	584.72d	818.40b	956.86a	786.66A	664.90d	881.65b	1028.15a	858.23A
Means	479.58C	679.71B	789.67A		556.45C	744.87B	864.51A	
	Average fruit weight per plant							
P:P (1:1)V	22.51d	24.37c	24.46b	23.78B	22.55f	24.61d	25.86b	24.34B
P:V (3:2)V	24.38b	27.06a	26.07a	25.84A	25.48c	24.86b	27.31a	25.88A
Means	23.44B	25.72A	25.27A		24.02B	24.74B	26.59A	
	Early yield per plant (g)							
P:P (1:1)V	93.61f	135.26e	155.62c	128.16B	112.00f	152.02e	175.22c	146.41B
P:V (3:2)V	146.18d	204.60b	239.21a	196.66A	166.23d	220.41b	257.04a	214.56A
Means	119.90C	169.93B	197.42A		139.11C	186.22B	216.13A	
	Total yield (kg / m^2)							
P:P (1:1)V	5.99f	8.66d	9.96c	8.20B	7.17f	9.73d	11.21c	9.37B
P:V (3:2)V	9.36c	13.09b	15.31a	12.59A	10.64c	14.11b	16.45a	13.73A
Means	7.67C	10.88B	12.63A		8.90C	11.92B	13.83A	
	WUE (Kg / m^3)							
P:P (1:1)V	6.8c	7.3c	6.8d	7.0B	8.0c	8.1c	7.5d	7.9B
P:V (3:2)V	10.8a	11.1a	10.6b	10.8A	12.0a	12.0a	11.3b	11.7A
Means	8.8B	9.2A	8.7B		10.0A	10.0A	9.4B	

Water use efficiency (WUE):

Water use efficiency (WUE) is a correlation between the fruit production and water use amount throughout the growing season. Data in Table 8 demonstrated how strawberry WUE values were influenced by various applied amounts of irrigation. In this regard, the median level of irrigation (80% ETo) produced the highest value of WUE, followed by the application of the least amount of water (60% ETo). The application of 100% ETo irrigation level gave the lowest values of WUE. Therefore, if the great production is my goal, I will use the highest irrigation level; but if the water is a limited factor in the production, I will use the median irrigation amount. On the other hand, the substrate mixture affected the WUE of strawberry and the substrate of perlite and vermicompost gave the highest values of WUE compared with another substrate of perlite and peat moss. The application of middle irrigation regime (80% ETo) combined with the substrate of perlite and vermicompost is recommended to use as an alternative cultivated media for strawberry and gave the highest value of water use efficiency in both growing seasons.

DISCUSSION

Strawberry is an important export crop in Egypt. Nowadays, a wide range of Egyptian soils suffering from some production prevention issues such as soil salinity, nematodes, soil borne diseases as well as water scarcity. Because of strawberry is very sensitive plant to fore mentioned issues, this study tried to solve the problem of strawberry production by using alternative soil and manage the irrigation process during different stages of plant. Growth parameters of strawberry enhanced by using the irrigation level of 100% ETo as well as both substrates

which provide the suitable conditions for root absorption for water and nutrients. These results are matched with those of (Baille, 2001, Ameri *et al*., 2012 and Perin *el al*., 2019).

Nutrients were more concentrated in the plants which had sufficient amount of irrigation water as well as using the vermicompost in cultivation media. Water is a vital factor in plant growth and enhancing the solubility of nutrients to be available for plant absorption and helps nutrient element like calcium to transfer into the plant by transpiration stream. In addition, physical and chemical properties of this mixture which contained some of available nutrients adsorbed on the substrate particles and the balance between water capacity and aeration which provides in the root zone of strawberry plant. On the contrary, the peat moss that is a main component of another substrate has a high water holding capacity and make a bad aeration condition surrounding the root system of strawberry plant especially in the high dose of irrigation water because of the root system of strawberry is very sensitive to over watering as well as salinity. These results are in agreement with those of (Baille, 2001; Perin *el al*., 2019).

The quality of strawberry fruits affected by irrigation level and the mixture of used substrate. The fruit taste is a ratio between TSS and TA, I think this parameter is somewhat complicated because it depends on the sense of the human who eat this fruit. Anyway, the suitable fruit taste will be defer from one person to another. This conflict of the quality parameters maybe because of all quality parameters in the fruit depend on the metabolism process and the last one affected by many factors in plant and different growth conditions such as climate, nutrition, watering, soil fertility or substrate. So, there are no static trend of those biological parameters. These results is matching with those of Ameri *et al*., (2012). The increments of yield parameters may be due to the effect of suitable available water in plant growth and photosynthesis process was more efficient. Nutrient elements are transferring and absorbed better when the amount of water is sufficient. Besides, the enhancement of yield of fruits occurred in the substrate which have a balance among water, air and nutrients as well as organic matter in the vermicompost. In the contrary, peat moss included substrate led to increase the portion of water instead air which led to unsuitable condition for root absorption of nutrients as well as bad respiration environment. These results are matched with those of (Baille, 2001; Ameri *et al*., 2012 and Perin *el al*., 2019).

Water use efficiency (WUE) is a ratio between total yield production and total amount of water consumption. So as amount of water decreased as WUE values increased. In addition, the suitability of substrate for growth and productivity because of the balance between oxygen and water as well as the availability of nutrients. These results are in agreement with those of Baille, 2001 and Diel *et a*l., 2016

CONCLUSION

Strawberry is an important exported crop in Egypt. In the same time it is very sensitive for water salinity and soil borne diseases in the traditional soil. So, this study aimed to produce the strawberry by using an alternative cultivated media instead of using soil fumigation. Soil fumigation treatment is very expensive and unsustainable for soil use and harmful on human health. Irrigation management for potted cultivated strawberry is so important to give the suitable amount of water in the optimum time. In this concern the treatment of middle amount gave acceptant production and high water use efficiency. On the other hand, using the suitable mixture of alternative cultivated substrate like perlite combined with vermicompost gave the highest production of strawberry fruits. We can recommend that using the irrigation level of 80% from evapotranspiration combined with perlite and vermicompost substrate is the suitable conditions for strawberry production in pots instead of traditional soil.

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إدارة الري لنباتات الفراولة المنزرعة تحت ظروف البيوت المحمية

محمد سعيد محمد أحمد* ، دعاء أبو بكر محمد جاد

المعمل المركزي للمناخ الزراعي، مركز البحوث الزراعية، الجيزة

* بريد المؤلف المراسل:abomaslama@yahoo.com

أجريت تجربة حقلية تحت ظروف البيوت المحمية بالمعمل المركزي للمناخ الزراعي بالدقي بمحافظة الجيزة خلال موسمي الشتاء 2019/2018 و 2020/2019. كان الهدف من الدراسة هو معرفة مدي استجابة نباتات الفراولة للزراعة في البيئات البديلة للتربة وهي البرليت مع البيت موس بنسبة (1:1) حجماً أو البرليت مع الفيرميكمبوست بنسبة (3:2) حجماً، وكذلك استجابة النباتات لمستويات الري المختلفة وهي (60٪ و 80٪ و 100٪) من قيمة البخر نتح المرجعي. وكان تصميم التجربة هو قطع منشقة مرة واحدة في ثلاث مكررات. أوضحت النتائج أنه كان هناك تأثير إيجابي علي نمو صنف الفراولة فستيفال عند استخدام بيئة الزراعة المتكونة من خليط البرليت والفيرميكمبوست وكذلك الري بمعدل 100٪ من البخر نتح المرجعي، حيث أعطت أعلى قيم في خصائص النمو الخضري. في حين كان استخدام بيئة الزراعة المتكونة من خليط البرليت والبيت موس والري بمعدل 80% أو 60% من البخر نتح المرجعي أقل إيجابية من المعاملة الأخرى. زاد محتوي الأوراق من عناصر النيتروجين، الفوسفور، البوتاسيوم، الكالسيوم والماغنسيوم عند استخدام بيئة الزراعة من البرليت والفيرميكمبوست والري بمعدل 100% من البخر نتح المرجعي. تحسنت جميع صفات المحصول ومكوناته وهي (عدد الثمار، متوسط وزن الثمار، المحصول المبكر والكلي) وكذلك صفات الجودة وهي (نسبة المواد الصلبة الذائبة، الحموضة، التذوق، فيتامين سي والصلابة) عند استخدام بيئة الزراعة المتكونة من البرليت والفيرميكمبوست مع استخدام معدل الري الأعلي. زادت قيمة كفاءة استخدام الماء للفراولة عند استخدام بيئة النمو المتكونة من البرليت والفيرميكمبوست مع معدل الري 80% من البخر نتح المرجعي ثم استخدام معدل الري 60% من البخر نتح المرجعي. في حين كانت أقل قيمة لكفاءة استخدام الماء في معدل الري 100% من البخر نتح المرجعي. من الممكن التغلب على مشاكل إنتاج الفراولة في الأراضي المصرية التقليدية باستخدام بيئات زراعية بديلة بالإضافة إلى الإدارة الجيدة لمياه الري.

الكلمات الإفتتاحية: الفراولة في الأصص، معدلات الري، خلطات البيئات، كفاءة استخدام الماء، جودة الثمار