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STUDIES ON STRAWBERRY PRODUCTION DURING WINTER SEASON UNDER SIWA OASIS CONDITIONS

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ABSTRACT: This experiment was conducted at the experimental farm of Siwa Oasis Research Station, Desert Research Center (Khimisa Farm), Marsa Matrouh, Egypt during two consecutive winter seasons of 2016/2017 and 2017/2018, to investigate the effect of the foliar spray of kaolin (Aluminum phyllosilicate [$Al_2Si_2O_5$ $(OH)_4$]), by concentrates at 1 and 1.5% as well as control with different protection application treatments (control, palm trees leaves siege, low tunnels covered by white shade net and low tunnels covered by black shade net) on growth, early yield and total yield of frigo strawberry transplants (Festival cv). Cultivation of strawberry under low tunnels covered by black shade net or under palm trees leaves siege produced the highest plant fresh weight, early and total yield of strawberry fruits compared with control or low tunnels covered by white shade net which gave the lowest values. Kaolin sprays at 1 % gave the best growth, early and total yield followed at 1.5 % compared to control treatments. The study summarized that, cultivation of strawberry transplants under low tunnels covered by black shade net with 1% sprays of kaolin can be succeed to protect strawberry plants and enhancement growth and yield under Siwa Oasis conditions.

Key words: Strawberry, low tunnels, shade net, kaolin, growth, yield, quality.

INTRODUCTION

Strawberry (*Fragaria* x *ananassa* Duch.) is one of the most delicious, nutritive and refreshing fruits. Where, its rich in vitamin C, manganese, potassium, folic acid, anthocyanins, and flavonoids contents which play an important role in preventing neuronal and cardiovascular diseases, even diabetes or cancer. The cultivated area of strawberry in Egypt has been rapidly expanded year after year. It was 2689 ha in 2000 and reached to 8880 ha. produced about 362639 ton, **FAO, 2018**. The increasing of cultivated area in Egypt in recent years may be due to the importance of crops for local consumption and exportation, the proper Mediterranean climate, fertile soils, and geographic location which support high production, early and profitability of such a specialty crop **(Singh *et al.*, 2007; Gomaa *et al.*, 2016 and Abd-Elgawad, 2019)**.

Although, the most strawberry production focused on some Egypt Governorates, i.e. Kalubiya, Ismailiya, Sharkiya, Behira and Menofiya **(Embaby, 2007)**, small scale production have being at some areas because demand for local produce continues to increase with the developing local food movement despite environmental conditions in this areas which commonly are less than ideal for strawberry production **(Rowley *et al.*, 2011)**. Ideal conditions for strawberry production occurred with temperatures between 20 and 26 C°. While, temperatures less than 20 C° retard the growth and development of both the strawberry plant and fruit, whereas temperatures more than 35 C° cause stop growing **(Galletta and Bringhurst, 1990)**. Also, high temperature decreased root soluble carbohydrate concentration and promoted runner formation in both mother and daughter

attached plants, enhance vegetative growth, whereas relatively lower temperatures are likely to enhance the floral response **(Kirschbaum, *et al.*, 2000 and Hegazi and Sayed 2001).** In this respect, **Hoppula and Karhu (2006)** found that, SSC, fruit firmness and fruit color were negatively correlated with the temperature during the two weeks prior to harvest but positively related with daily global radiation. Low tunnels can be used to increase temperatures for increase plant growth for strawberry **(Hegazi and Sayed 2001 and Takeuchi and Motsenbocker, 2005)**. That is typically only 40 to 50 cm tall and cover only one row or one bed of strawberries **(Galletta and Bringhurst, 1990)**, and replacing high-tunnel plastic with shade net during the warmest summer months is another method for passive manipulation of growing temperatures **(Rowley *et al.*, 2011)**. But in general, if protected culture techniques are utilized in strawberry production, care must be taken not to allow temperature to rise too high and excess shading due to cover should also be avoided to ensure the good quality of fruits (**Hoppula and Karhu, 2006)**.

The particle film is based on kaolin which is a white nonabrasive fine-grained aluminosilicate mineral that has been purified and sized, so that it easily disperses in water **Harben (1995)**. The hydrophobic kaolin particle was the first prototype of particle film technology applied to trees as dust to make the plant surfaces water repellent **(Ali, 2016)** and there has been increasing interest in the application of natural aluminosilicates in agricultural technology because it has desirable properties and a large water holding capacity as well as the unique physical and chemical properties make it particularly suitable for agricultural use **(El-Gabiery and Ata Allah., 2017)**. Many investigators used kaolin as novel biological insect and disease control material **(Reitz *et al.*, 2008 and Crooks and Prentice, 2011)**, increasing leaf water potential and decreased stomatal conductance **(Glenn *et al.*, 2010),** enhancing growth and increasing yield **(Mohadeseh *et al.*, 2013 and Soubeih *et al.*, 2017)**.

Siwa Oasis located in the northern part of the Western Desert of Egypt, at the GPS (Global Positioning System) of 29.12_N latitude and 25.29_E longitude with an elevation of 18 meter below sea level and 315 kilometers Mediterranean coast away. Siwa is characterized by very hot and dry climate conditions especially during summer and the main activity of Siwean people is agriculture which is depending on the groundwater and flood irrigation system **(Hafez, *et al.*, 2015)**. Because that Oasis is desert closed area and have irregular climate and consequently heat stress during summer season, and early fall (temperatures can be amounted to 40 C°), almost crops and vegetables productivity could be affected negatively. Because, early fall temperatures are generally super optimal for growth and production of strawberry, the cultivation of this crop consider as challenge. The aim of this study was to improve growth, yield and fruit quality of strawberry by using low tunnels shade net and kaolin foliar spray under Siwa Oasis conditions.

MATERIALS AND METHODS

Experimental site, cultivar and cultivation: The study was conducted at Siwa experimental farm station, latitude 29° 12’ N, longitude 25° 29’E and 18 meters below sea level, Marsa Matrouh Governorate, Egypt, during the two successive seasons of 2016/2017 and 2017/2018. Cold-stored bare rooted strawberry transplants (*Fragaria* X *ananassa* Duch. cv. Festival) were planted on Med of September in the first and second growing seasons. The frigo transplants were cultivated in raised beds of 10-15 cm height and 90 cm wide. The transplants were planted at 30 cm apart in both sides under drip irrigation system.

Experimental design: The experiment was conducted to investigate the effect of the foliar applications of kaolin (Aluminum phyllosilicate [$Al_2Si_2O_5$ $(OH)_4$]), by concentrates at 1 and 1.5% as well as control with different protected applications treatments (control, palm leaf siege, low tunnels covered by white shade net and low tunnels covered by black shade net) on growth, early yield and total yield of frigo transplants. Spraying of each concentration of kaolin was done at transplanting, 10, 20, 30 and 40 days after transplanting. In order to avoid interferences with different moisture levels, the same amount of water was sprayed to the control plants at a given time. Protected treatments included low tunnels 50 cm height covered by white or black shade net 63%. Palm leaf siege constructed by impale 1 meter of

palm leaf with 50-60 angel on south side of the bed. After 60 days all protected material were removed. The experimental design was split plot with 12 treatments (4 protected treatments x 3 foliar spray) with 3 replicates and the plot area was 10.5 m^2 included 70 mother plants, where, protected treatments were placed in main plot, while foliar spray occupied sub-plots.

Data recorded: Vegetative growth: A random sample of five plants of each experimental plot was taken at 90 days after transplanting for vegetative growth data. Runners number/plant, leaf area and plant fresh weight were recorded.

Chlorophyll: A portable chlorophyll meter (SPAD–502, Konica Minolta Sensing, Inc., Japan) was used to measure leaf greenness of the plants. At 90 days after transplanting, measurements were taken at four locations on each leaf, two on each side of the midrib on the youngest fully expanded leaves of randomly selected five plants per plot and then averaged.

Yield components: At the proper maturity stage, strawberry fruits were harvested (at 2–3 day intervals) during the growing seasons, counted, and weighed to record average fruit weight. The early yield/plant was determined as weights of the first four harvesting. Total yield/plant was calculated.

Fruit quality: Thirty full mature fruits were randomly collected from each treatment in the middle of the growing seasons (April) as sub samples for fruit quality. Fruit firmness (g/cm^2) was measured using Shatillon penetrometer. Soluble solid content (SSC%) was determined by using digital refractometer (Abbe Leica model). Ascorbic acid content (mg/100g few) was determined according to the methods described by **A.O.A.C. (2005)**.

Average maximum and minimum monthly temperatures during 2016/2017 and 2017/2018 seasons are shown in Table 1.

Table 1. Maximum and minimum monthly temperature

Seasons	**2016/2017 Season**				**2017/2018 Season**			
Months	Sep.	Oct.	Nov.	Dec.	Sep.	Oct.	Nov.	Dec.
Maximum (C^o)	34.3	30.6	24.6	17.2	34.1	27.7	23.1	19.8
Minimum (C^o)	21.7	18.4	15.8	11.1	21.9	19.6	15.1	12.6
Mean (C^o)	28.0	24.5	20.2	14.2	28.0	23.6	19.1	16.2

https://www.worldweatheronline.com/siwa-weather-history/matruh/eg.aspx

Statistical analysis: Data were subjected to statistical analysis according to **Thomas and Hills (1975)**. The differences among means were performed using least significant difference (LSD) at 5% level.

RESULTS AND DISCUSSION

Plant growth: The effect of protected instrument treatments and kaolin foliar spray on runners number, leaf area, leaf total chlorophyll content and plant fresh weight are shown in Table (2).

All growth characters significantly affected by protected instruments, runners number and plant fresh weight were significantly affected by kaolin treatments, while the effect of interaction was not significant in both seasons.

White and black shade net produced the highest number of runners in the first and second season, respectively followed by palm tree leaves treatment compared with control (without protection) treatment which gave the lowest runners number in both seasons. Black net produced the highest significant leaf area and lowest significant total chlorophyll content of leaves compared with other treatments in both seasons. Control treatment gave the lowest leaf area, while palm trees leaves followed by control treatment gave the highest leaf total chlorophyll content in both seasons. Also, palm trees leaves treatment produced the highest significant plant fresh weight followed by black net, while control treatment gave the lowest value followed by white net in both seasons.

Regarding kaolin foliar spray treatments, kaolin at 1 % significantly increased runners number and plant fresh weight followed by 1.5 % compared with control treatment which gave the lowest values in both seasons. The simulative effect of kaolin at 1 and 1.5 % as foliar application on growth may be due to that kaolin as a reflecting material (anti-transpirent) reduce the absorption of radiant energy thereby reduce leaf temperature and thus transpiration rate **(Glenn *et al.*, 2003)**. Increasing growth characters of strawberry plants with protected instrument treatments especially palm trees leaves or black net shading may be due to moderate the micro climates within plants which resulted in this protected material. These results are agreed with Galletta **and Bringhurst (1990)**. Although, **high** temperature promoted runner formation in both mother and daughter attached plants, enhance vegetative growth **(Kirschbaum, *et al.*, 2000 and Hegazi and Sayed 2001)**. Control treatment (without protection) under study conditions decreased runners number and this may attribute to excessive high temperature (as shown in Table 1) which resulted in decreasing growth, whereas temperatures more than 35 ˚C cause stop growing **(Galletta and Bringhurst, 1990)**. Also, decreasing the negative impact of high temperature by kaolin are similar with finding by **(Mohadeseh *et al.*, 2013 and Soubeih *et al.*, 2017)**.

Table 2. Effect of protected instruments, kaolin foliar spray and interaction between them on runner number, leaf area, total chlorophyll and plant fresh weight of strawberry at 90 days after transplanting during 2016/2017 and 2017/2018 seasons

Treatments		Number of runners		Leaf area (cm^2)		Total chlorophyll content (SPAD)		Plant fresh weight (g)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Protected instruments									
Black net		3.50	3.61	59.74	59.45	36.35	37.83	34.19	31.97
White net		3.75	3.47	56.63	56.41	39.67	41.24	31.39	28.71
Palm leaf		3.57	3.36	53.98	53.55	42.00	42.31	34.71	32.15
Control		3.16	3.26	47.71	47.71	41.70	41.43	28.92	26.41
LSD at 0.05		**0.10**	**0.11**	**1.71**	**1.34**	**1.40**	**0.55**	**1.63**	**1.04**
Kaolin concentrate									
Kaolin at 1.5%		3.49	3.45	55.52	56.15	39.99	39.82	32.16	29.70
Kaolin at 1%		3.60	3.51	53.99	55.36	40.63	39.59	34.13	31.71
Control (water)		3.39	3.32	54.05	54.34	40.67	38.94	30.62	28.04
LSD at 0.05		**0.15**	**0.08**	**N.S**	**N.S**	**N.S**	**N.S**	**0.76**	**0.90**
The interaction									
	Kaolin at 1.5%	3.41	3.66	61.96	60.97	35.64	38.31	33.31	31.42
Black net	**Kaolin at 1%**	3.69	3.69	60.26	59.68	37.00	38.34	36.34	34.12
	Control (water)	3.40	3.47	57.02	57.72	36.41	36.83	32.91	30.36
	Kaolin at 1.5%	3.81	3.53	57.18	58.75	38.24	41.57	31.83	29.05
White net	**Kaolin at 1%**	3.84	3.54	56.20	55.35	39.66	41.49	33.24	30.71
	Control (water)	3.60	3.36	56.52	55.11	41.10	41.66	29.09	26.37
	Kaolin at 1.5%	3.62	3.36	54.59	53.99	42.25	42.06	34.76	32.19
Palm leaf	**Kaolin at 1%**	3.68	3.46	53.01	53.56	42.81	42.22	36.60	34.04
	Control (water)	3.42	3.25	54.35	53.10	42.93	40.64	32.79	30.23
	Kaolin at 1.5%	3.14	3.25	48.33	46.88	41.81	35.35	28.75	26.13
Control	**Kaolin at 1%**	3.20	3.35	46.50	48.84	42.03	35.31	30.34	27.91
	Control (water)	3.14	3.19	48.31	47.41	41.25	35.64	27.68	25.18
LSD at 0.05		**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**

Yield and its component

Data presented in Table (3) showed that, average fruit weight, early and total yield of strawberry were significantly affected by both treatments of protection instrument and kaolin foliar spray, while interaction effect was not significant in both seasons. Black net and palm trees leaves gave the highest average fruit weight in the first and second seasons respectively, followed by white net compared with control treatment which gave the lowest average fruit weight in both seasons. Also, black net and palm trees leaves produced the highest early and total yield compared with control (without protection) treatment which gave the lowest value followed by whit net treatment in both seasons. Regarding kaolin foliar spray treatments, sprays of kaolin at 1 % significantly enhanced average fruit weight, early and total yield compared with control and kaolin at 1.5 % which gave the lowest values in this respect in both seasons. Many investigators used kaolin as novel biological insect and disease control material **(Reitz *et al.*, 2008 and Crooks and Prentice, 2011)**, increasing leaf water potential and decreased stomatal conductance **(Glenn *et al.*, 2010)**, enhancing growth and increasing yield **(Mohadeseh *et al.*, 2013 and Soubeih *et al*., 2017)**.

Increment of strawberry yield when protection instrument has been used refer to enhancement strawberry growth as mothers and early daughter runner formation and consequently enhancement early and total yield. Moreover, black shade net or palm trees leaves treatment considered a suitable method for passive manipulation of high excessive temperatures **(Rowley *et al.*, 2011)**. As reported by many researchers that**,** low tunnels can be used to increase temperatures for increase plant growth for strawberry **(Hegazi and Sayed 2001 and Takeuchi and Motsenbocker, 2005)**, replacing high-tunnel plastic with shade net during the warmest summer months is successive method for passive manipulation of growing temperatures **(Rowley *et al.*, 2011)**. And consequently, don't allow temperature to rise too high and in the same time the excess shading due to cover should also be avoided to ensure high yield and good quality of fruits (**Hoppula and Karhu, 2006)**.

Table 3. Effect of protected instruments, kaolin foliar spray and the interaction between them on average fruit weight, early yield and total yield of strawberry during 2016/2017 and 2017/2018 seasons

Treatments		Average fruit weight (g)		Early yield (kg/fad.)		Total yield (kg/fad.)	
		1st	2nd	1st	2nd	1st	2nd
Protected instruments							
Black net		12.56	12.41	440.2	439.0	8593	8289
White net		11.61	11.46	351.5	324.2	7436	7491
Palm leaf		12.23	12.54	446.5	447.9	8538	8444
Control		11.44	11.33	348.1	315.1	7192	7323
LSD at 0.05		**0.12**	**0.15**	**22.1**	**10.7**	**150**	**222**
Kaolin concentrate							
Kaolin at 1.5%		11.83	11.91	395.6	376.9	7893	7850
Kaolin at 1%		12.24	12.20	414.0	397.3	8090	8061
Control (water)		11.82	11.70	380.2	370.5	7836	7750
LSD at 0.05		**0.13**	**0.10**	**14.1**	**9.2**	**112**	**130**
The interaction							
Black net	**Kaolin at 1.5%**	12.25	12.42	431.5	428.8	8511	8236
	Kaolin at 1%	12.70	12.64	464.4	449.7	8795	8371
	Control (water)	12.73	12.18	424.8	438.6	8474	8259
White net	**Kaolin at 1.5%**	11.60	11.44	348.4	322.2	7383	7382
	Kaolin at 1%	12.08	11.73	369.0	336.2	7562	7870
	Control (water)	11.16	11.21	337.2	314.1	7362	7222
Palm leaf	**Kaolin at 1.5%**	12.02	12.53	458.7	441.6	8517	8409
	Kaolin at 1%	12.45	12.82	464.0	470.4	8700	8556
	Control (water)	12.23	12.27	416.9	431.8	8396	8368
Control	**Kaolin at 1.5%**	11.43	11.24	343.7	315.0	7162	7372
	Kaolin at 1%	11.74	11.61	358.8	332.9	7304	7447
	Control (water)	11.16	11.13	341.8	297.5	7110	7149
LSD at 0.05		**0.26**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**

Fad. (faddan) = 4200 m^2 = 0.42 ha.

Fruits quality

The effect of protection instruments and kaolin foliar spray treatments on fruit firmness, soluble solids content and ascorbic acid (vit. c) in fruits are shown in Table (4).

Protection instruments have a significant effect on fruit firmness, S.S.C and ascorbic acid (vit.c) content in both seasons while, kaolin treatments have a significant effect on S.S.C in both seasons and fruit firmness in the second season. On the other hand, effect of kaolin on ascorbic acid (vit. c), fruit firmness in the first season and all interactions were not significant.

Black shade net produced the highest significant fruit firmness and soluble solids content followed by palm trees leaves compared with control (without protection) treatment which gave the lowest values followed by white shade net in both seasons. Palm trees leaves or control treatment and palm trees leaves treatment only gave the highest ascorbic acid (vit. c) compared with both shade net treatments, or both of them plus control in the first and second seasons, respectively. Sprays of 1% kaolin slightly enhanced S.S.C compared with 1.5% or control treatment in both seasons. Moreover, the same treatment significantly increased fruit firmness in the second season compared with other treatments. These results indicated that, relatively lower temperatures are likely to enhance the floral response **(Kirschbaum, *et al.*, 2000 and Hegazi and Sayed 2001).** In this respect, **Hoppula and Karhu (2006)** found that, SSC, fruit firmness and fruit color were negatively correlated with the temperature during the period prior to harvest, but positively related with daily global radiation. In the same time excess shading may be have a negative effect on strawberry fruits quality, similar results were reported by **Hoppula and Karhu (2006)**.

Table 4. Effect of protected instruments, kaolin foliar spray and interaction between them on fruit firmness, soluble solids content and L. ascorbic acid of strawberry during 016/2017 and 2017/2018 seasons

Treatments		Fruit firmness (g/cm^2)		S.S.C (%)		Ascorbic acid content (mg/100 g f.w.)	
		1st	2nd	1st	2nd	1st	2nd
Protected instruments							
Black net		271.8	250.8	8.56	8.27	57.28	61.87
White net		251.7	235.5	8.27	7.61	60.62	64.75
Palm leaf		266.3	254.1	8.32	7.64	65.46	68.87
Control		240.3	237.6	8.13	7.44	66.43	63.99
LSD at 0.05		**6.8**	**3.1**	**0.05**	**0.06**	**2.89**	**1.52**
Kaolin concentrate							
Kaolin at 1.5%		256.8	246.0	8.27	7.75	61.69	62.19
Kaolin at 1%		260.3	249.3	8.38	7.83	62.44	62.79
Control (water)		255.5	238.2	8.31	7.65	63.22	62.13
LSD at 0.05		**N.S**	**3.8**	**0.05**	**0.05**	**N.S**	**N.S**
The interaction							
Black net	**Kaolin at 1.5%**	269.1	252.0	8.50	8.28	56.71	61.44
	Kaolin at 1%	271.8	256.7	8.66	8.40	57.45	62.51
	Control (water)	274.7	243.6	8.51	8.14	57.70	61.67
White net	**Kaolin at 1.5%**	252.3	234.0	8.21	7.64	59.48	63.93
	Kaolin at 1%	257.8	241.5	8.32	7.70	60.67	65.56
	Control (water)	244.9	231.1	8.27	7.48	61.70	64.75
Palm leaf	**Kaolin at 1.5%**	265.4	256.0	8.30	7.62	63.97	69.42
	Kaolin at 1%	266.8	262.2	8.38	7.71	66.11	68.44
	Control (water)	266.5	244.2	8.28	7.58	66.32	68.76
Control	**Kaolin at 1.5%**	240.3	242.1	8.08	7.44	66.62	63.99
	Kaolin at 1%	244.8	236.7	8.14	7.51	65.53	64.64
	Control (water)	235.9	234.0	8.17	7.38	67.16	63.33
LSD at 0.05		**N.S**	**N.S**	**N.S**	**N.S**	**N.S**	**N.S**

Conclusion

This study recommended that, strawberry growth, yield and fruit quality improved under protection treatments especially, low tunnels covered by black shade net or under palm trees leaves siege. But these instruments can be replaced with high tunnels covering by black shade net to facilitate agricultural practices during growing season. In addition, kaolin foliar sprays with low concentration may be useful in this respect.

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