doi:10.14720/aas.2021.117.3.1865 Original research article / izvirni znanstveni članek

Foliar silicate application improves the tolerance of celery grown under heat stress conditions

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Received September 08, 2020; accepted July 28, 2021.
Delo je prispelo 8. septembra 2020, sprejeto 28. julija 2021

Foliar silicate application improves the tolerance of celery grown under heat stress conditions

Abstract: Temperature rise is one of the most challenging climate change impacts that increase the intensity of heat stress. In this investigated the production of celery (*Apium graveolens* var. *rapaceum* F1 hybrid)) was tested during the late season. The experiment was carried out during the two successive summer seasons of 2019 and 2020 in Giza Governorate, Egypt. The experimental design is a split-plot, the main plots consist of three low tunnel cover treatments, and three spray treatments with three replicates in sub-main plots. Results showed that the use of white net cover gave the highest vegetative growth and yield followed by the black net. Values of plant yield were 951, 765, and 660 g/plant for white, black and without cover, respectively, in the first season. The foliar application of 3 mM of potassium silicate produced the highest vegetative growth and yield compared to the control treatment. Referring to the effect of spray foliar application of potassium silicate on yield 1.5 mM (S1), 3 mM (S2), and control were 892, 795, and 689 g/plant in the first season, respectively. The best combination that delivered the highest vegetative growth and yield was a cover low tunnel with a white net combined with S2 foliar application.

Key words: celery**;** climate measures; physical protection; vegetative growth; chemical analysis

Foliarno dodajanje silikata izboljšuje toleranco zelene, ki raste v razmerah vročinskega stresa

Izvleček: Dvig temperatrure je eden izmed največjih izzivov podnebnih sprememb, katerega učinki povečujejo jakost vročinskega stresa. V tej raziskavi je bil v zvezi s tem preučevan pridelek zelene (*Apium graveolens* var. *rapeceum* F1 hibrid) tekom pozne rastne sezone. Poskus je bil izveden v dveh zaporednih poletnih sezonah 2019 in 2020 na območju upravne enote Giza, Egipt. Poskus je bil izveden kot poskus z deljenkami, kjer so obravnavanja na glavnih ploskvah obsegale tri vrste nizke tunelske kritine in tri obravnavanja s škropljenjem s tremi ponovitvami na podploskvah. Rezultati so pokazali, da je uporaba bele mreže kot kritine dala največji prirast biomase in največji pridelek, čemur je sledila uporaba črne mreže. V prvi rastni sezoni so bili pridelki 951, 765, in 660 g/rastlino za belo, črno kritino in brez nje. V primerjavi s kontrolo je foliarno dodajanje 3 mM kalijevega silikata dalo največjo prirast biomase in največji pridelek. Glede na učinek foliarnega dodajanja kalijevega silikata (1,5 mM (S1), 3 mM (S2), in kontrola) na velikost pridelka so bile njegove vrednosti 892, 795, in 689 g/rastlino v prvi rastni sezoni. Najboljša kombinacija, ki je povzročila najboljšo rast in dala največji pridelek je bil nizek tunel pokrit z belo mrežo in s S2 foliarnim obravnavanjem.

Ključne besede: zelena**;** podnebne razmere; fizikalna zaščita; vegetativna rast; kemijska analiza

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1 INTRODUCTION

The global climate is expected to witness an increase in temperature in the range 2–4 °C by the end of 21st century (IPCC, 2007). More importantly, predictions based on global climate model analysis suggested that the tropical and subtropical regions of the world will be the worst to suffer from the forthcoming heat stress (Battisti and Naylor, 2009). Because of rising temperature, alterations in plant's phenology such as spring and autumn, phenology was noticed across different plant species (Li et al., 2014).

Improving micro-climatic conditions for horticultural plants and its influence on the plant growth and productivity were considered of the critical factors that control the need to continuous production allover the year (El-Gayar et al., 2018). Studies conducted by Zakher and Abdrabbo (2014) showed that shading could increase plant growth and productivity through moderating of the harmful effects of high air temperature during summer season for tomato plants. Plastic screen nets in the form of protected cultivation covering materials were widely used for many purposes in the horticulture sector. For example, it was used to protect crops from different farming negatively influencing factors such as heat waves, strong wind, flying insects, mamals, and birds (Al-Helal and AbdelGhany, 2010). Applying screen net regardless of its color had been proved to protect plant against environmental risks such as high air temperature, excessive solar radiation and wind, which improve microclimate for the grown crops through reduction heat, drought stresses, and moderation of extreme climatic events which led to improving crop yield and quality (Abul-Soud et al., 2014). The application of plastic net covers in crop production was a sufficient way to provide a cheap and reduced energy consuming technology than polyethylene greenhouses (Shahak, 2008). Abdrabbo et al. (2013) stated that open field treatment had a higher air temperature than white net, while black net had the lowest air temperature during summer season. Regarding the effect of cover net on relative humidity Hashem et al. (2011) stated that relative humidity increased under black net by 2–4 % compared with open field conditions. Vegetative growth parameters such as plant height, number of leaves, leaf area and productivity under white net were expressively higher than that under open field (Medany et al., 2009). Treder et al. (2016) proved that covering the greenhouses with screen net increases light scattering without affecting the light spectrum which led to increase light efficiency that reflected on increasing growth and production measures.

One of the most common applications for protecting plants from heat stress is foliar spraying with Si, which is approved to be a good option concerning the food productivity; consequently, using Si application was recommended as one of the acceptable practices to increase of vegetable plants productivity (Bakhat et al., 2018). Therefore, several stress factors such as heat waves, which affect vegetables and its productivity are managed by the foliar application of Si via mitigate the injurious impacts of stressors (Cooke and Leishman, 2016).

Also, Si is considered as a growth regulator, which participates in the regulation of physiological processes in plants including seed germination, stomata closure, ion uptake and transport, membrane permeability, photosynthesis and plant growth rate according to Noura et al. (2019). This research was conducted to study the effect of protection of celery plant using black and white screen net as well as three foliar applications of potassium silicate and their interactions on vegetative growth, and yield of celery during summer season.

2 MATERIALS AND METHODS

2.1 EXPERIMENTAL SITE

This study was carried out in Dokki Location, Giza Governorate, Egypt, during the summer seasons of 2019 and 2020. Dokki location is located at latitude 30.03 and longitude 31.20 with an altitude of 23 m above sea level. Describing the climate of the region; it is dry during summer season, while warm and moderate rain during winter season. The soil of the experimental site is clay soil and having bulk density 1.16 g cm^{-3}, pH in soil paste (1:2.5) 7.81, EC_e 2.39 dS m^{-1}, and field capacity 25.77 %.

2.2 EXPERIMENTAL PROCEDURE

Seedlings of celery (*Apium graveolens* L. var. *rapaceum* (Miller) Gaudin F1 hybrid) with one month from seed germination was used in the current applied study. Seeds were obtained from Takii and Co. LTD (Kyoto, Japan). Seedlings were transplanted into substrate system on 16th and 18th of March in the 2019 and 2020 seasons, respectively. The following measurements were performed for five labeled plants per replication for each treatment at the end of growing seasons: plant length, number of leaves per plant, base plant diameter, chlorophyll content as well as celery yield. Total of nitrogen (N), phosphorus (P) and potassium (K) in leaves were measured, ascorbic acid (vitamin C) and soluble sugar were measured in the fresh leaves. Experimental plots were arranged in a split plots design with three replicates. Each experimental plot contained five raised beds (4 m length x 0.8 m width). The distance between each two beds was 0.50 m.

The experimental design consists of main plots and sub-plots. The main plot is comprised of three cover treatments including white screen net, black screen net, and control (without cover). And the sub-plot contains 1.5 mM (S1), 3 mM (S2), and 0 mM (S0) of potassium silicate with S0 serving as control (sprayed with tap water). The silicate foliar applications were sprayed on the plant leaves three times, at 3, 5 and 15 weeks from cultivation, at a rate of 50 ml per plant for each. Three replicates were used in this study. Celery plants were irrigated using drippers with flow rate of 4 l h^{-1} and the distance between each two plants was 0.30 m. Chemical fertilizers $(NH_4)_2SO_4$ (20.6 % N), K_2SO_4 (48 % K_2O) and P_2O_5 (37 % P_2O_5) were injected within irrigation water system at the rate of 80, 40 and 50 kg $acre^{-1}$ respectively for fertigation purpose. The fertigation was programmed to be three times weekly, and the duration of irrigation time depended highly upon the plant needs. All treatments received the same quantity of fertilizers.

2.3 PLANT ANALYSES

Plant samples (outer leaves) were collected after six weeks from transplanting and dried in the oven at 70 °C for one day. Total nitrogen (N) in the dried leaves, digested by H_2SO_4/H_2O_2 mixture, was measured using Kjeldahl method according to the procedure described by Chapman and Pratt (1961). Total phosphorus (P) was measured using spectrophotometer according to Watanabe and Olsen (1965) and total potassium (K) in leaves was measured using flame photometer as described by Jackson (1958). Total chlorophyll was measured using chlorophyll meter SPAD-502Plus. Soluble sugar content was measured by photometer using the anthrone-sulfuric acid method (Yemm & Wills 1954). Ascorbic acid (vitamin C) was measured in the fresh leaves following 2, 6, dichlorophenol indophenol visual titration method (A.O.A.C., 1980).

2.4 CLIMATE MEASURES

Light intensity, maximum and minimum temperature as well as relative humidity were measured under different screen net cover treatments every day using digital climatic sensors. Digital thermo-hygrograph (model: TFA Dostman/Wertheim - Kat. Nr. 5002) was used to measure temperature and relative humidity. The digital thermo-hygrograph was allocated over polystyrene trays in the middle of each treatment above the level of celery plants canopy and the maximum air temperature was recorded at 13:00, while the average relative humidity was calculated by the average of maximum and minimum relative humidity every day. The average weekly maximum temperature and humidity was calculated using the daily climatic data. Light intensity was measured in each treatment daily above the celery plants canopy at mid-day (13:00) by portable Lux-meter (Model FMC- 10M). The average weekly light intensity was calculated from the measured data.

2.5 STATISTICAL ANALYSIS

Analysis of data was done using SAS program (SAS, 2000). The differences among means for all traits were tested for significance at 5 % level using LSD according to Waller and Duncan (1969).

2.6 ECONOMIC ANALYSIS OF APPLIED TREATMENTS

Economic analysis, after considering the cost of cover celery with screen net and potassium silicate, the incomes from celery yield was used (CIMMYT, 1988) according to the formulas:

(Net Income = value of obtained yield – annual cost of screen net and potassium silicate application).

(Relative increase in income (RII) = (net income / income of control) x 100.)

The lifetime of screen net is five years. The cost of spray application of potassium silicate was considered.

3 RESULTS AND DISCUSSION

3.1 CLIMATIC DATA

The average maximum air temperatures for the physical protection treatments showed that the use of screen net influenced maximum and minimum temperature (Figure. 1 and 2). Temperature tended to be lower under the black net cover by almost 3 °C compared to open field conditions. The white net reduced the maximum air temperature by almost 1 °C compared to ambient conditions. The minimum air temperature took the same trend, the lowest minimum air temperature was recorded under the black screen net; while the white slightly lower than the black

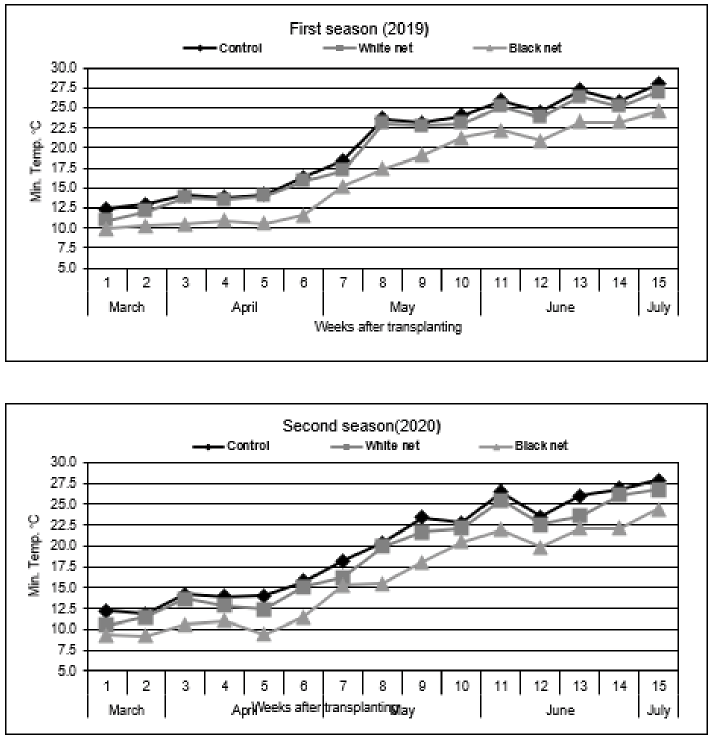

Figure 1: The minimum air temperature under black net and white net compared to the open field of the two studied seasons of 2019 and 2020

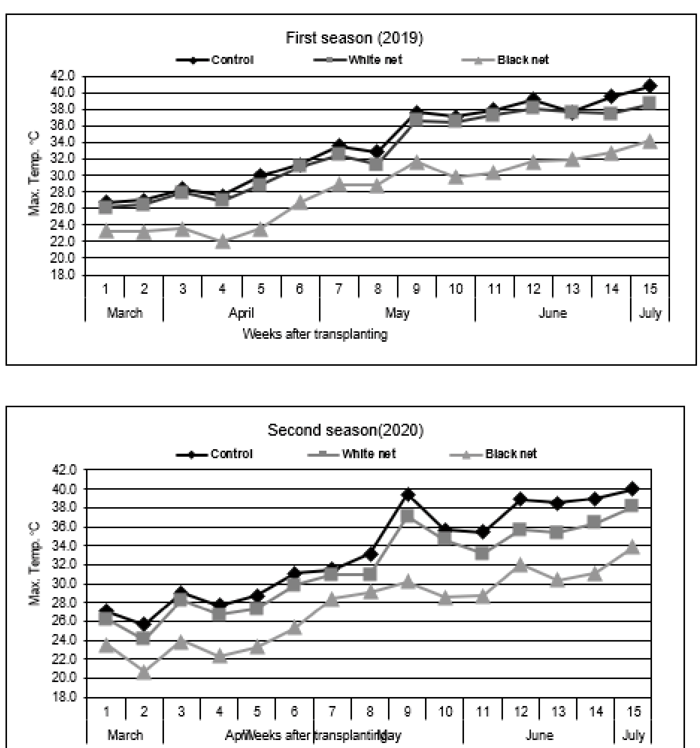

Figure 2: The maximum air temperature under black net and white net compared to the open field of the two studied seasons of 2019 and 2020

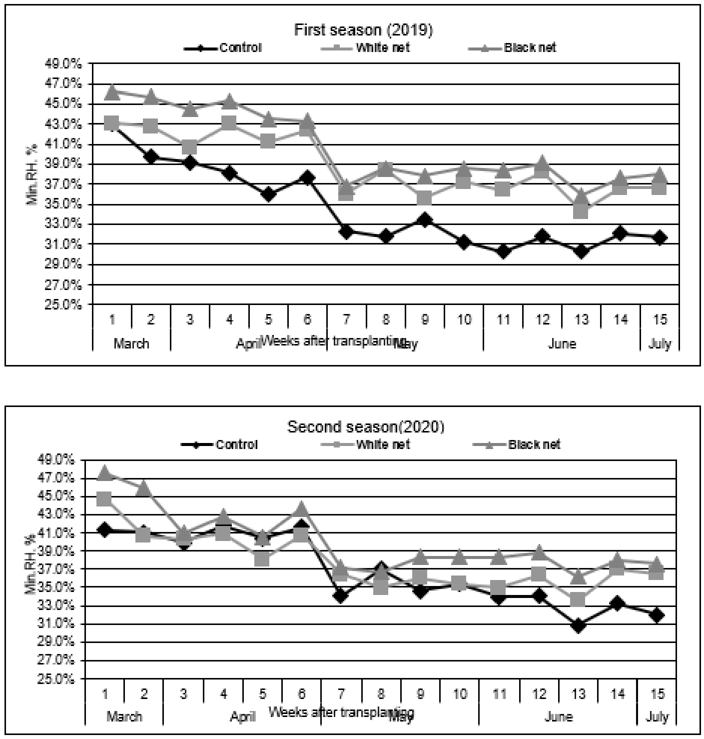

Figure 3: The minimum relative humidity under black net and white net compared to the open field of the two studied seasons of 2019 and 2020

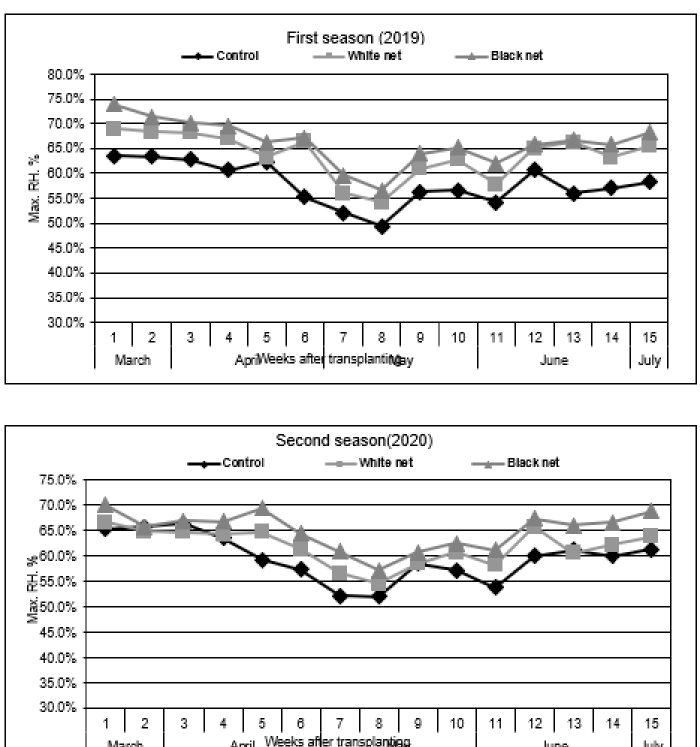

Figure 4: The maximum relative humidity under black net and white net compared to the open field of the two studied seasons of 2019 and 2020

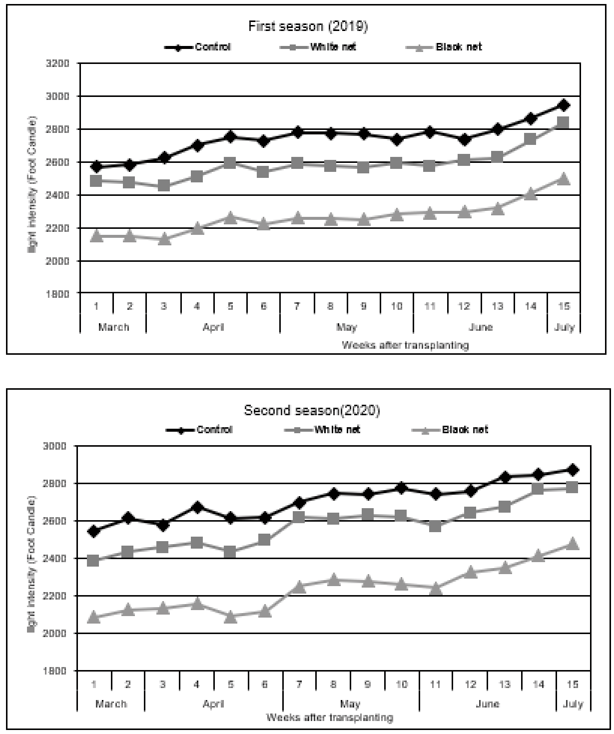

Figure 5: Light intensity under black net and white net compared to the open field of the two studied seasons of 2019 and 2020

considering the minimum temperature (about 0.5 °C), which is lower compared to open field conditions. The same trend of maximum and minimum temperature was obtained during both seasons. The maximum relative humidity took another trend; the open field had the lowest relative humidity during both seasons. Black net cover had the highest average maximum and minimum relative humidity followed by the white net cover during the two studied seasons (Figure. 3). Relatively, humidity under the black net cover was higher by 3 – 5 % than open field. Maximum average weekly light intensity under different physical protection treatments showed that open field conditions recorded the highest light intensity followed by the white net cover while the black net screen net had the lowest light intensity during both seasons (Figure. 4). The obtained results of the low temperature under physical protection treatments according to the observation, achieved lower interception of sun radiation rays under screen cover than ambient conditions. Use of screen net especially black nets penetrated light intensity and increase relative humidity by 2-5 %. Similar results were reported by Al-Helal and Abdel-Ghany (2010) and Abdrabbo et al. (2013) who indicated that covering the plants with black or white net led to the reduction of the temperature because of the lessening of the radiation via reflection or absorption by covered materials. Formerly addressed by Shahak et al. (2008) that using screen net led to decrease in air temperature around the cultivated plants in comparison with open field. In conclusion, the lowest recorded maximum temperature was achieved by black net

3.2 VEGETATIVE GROWTH

The effect of different net covers on celery vegetative growth characteristics, *i.e.,* plant height, number of leaves per plant, base of plant diameter and chlorophyll content, were presented in Table 1 and 2. Data showed that using black net cover significantly increased the celery plant height, followed by a white net cover, while the lowest plant height was obtained without applying net cover, during the two studied seasons. Number of leaves per plant, base plant diameter and chlorophyll took different trends, the highest values were obtained by white net cover followed by black net procedure. The lowest number of leaves per plant, base of plant diameter and chlorophyll were obtained by open field.

Regarding the foliar application using two concentrations of potassium silicate, the highest plant height was obtained by S2 treatment followed by S1. The lowest plant height was obtained by control. Number of leaves per plant, base of plant diameter and chlorophyll took the same trend.

Regarding the interaction between different net covers and foliar application of potassium silicate, data illustrated that the highest plant height were obtained by black net cover combined with S2 foliar application. Number of leaves per plant, base of plant diameter and chlorophyll took another trend. The highest values were obtained by covering with white net combined with S2 foliar application. The lowest vegetative growth of celery plants was obtained by open field treatment combined with control. The same results were obtained by Tubana and Heckman (2015) who stated that application of silicon led to decrease the harmful effects of heat waves and then enhancing the plant growth and productivity. The same result was confirmed by Bakhat et al. (2018), they concluded that application of silicon compound as foliar application led to enhancement of plant growth and improving the ability of plants to combat the abiotic stresses such as heat waves. On the other hand, the protection of celery plants from high temperature using black net led to increase the plant height due to low light intensity under the tunnel, which led to improvement of the plant elongation. Using white net led to decrease the stress from exposure to direct sun radiation without reducing the light intensity such as black net, which also led to increasing the reception of plant leaves to daylight and increasing photosynthesis and then the enhancement of plant growth parameter such as number of leaves and plant diameter (Medany et al., 2009). Moreover, use of screen net led to reduction of the daylight intensity but increasing the light usage efficiency due to sun rays scattered when penetrate the screen later, which led to achieve the sun rays a new angels that led to reach for all plant leaves and then increases the total plant photosynthesis (Abul-soud et al., 2014). The screen net could also increase solar radiation scattering up to 50 %; that enhanced plant growth. On the other hand, dark net reduced radiation reaching crops canopy (Shahak et al., 2004). Low light inten-

Table 1: Different efficiencies of different net covers on celery vegetative growth characteristics during the first growing season of 2019

Treatment		Plant height (cm)	Number of leaves cm	Base plant diameter SPAD	chlorophyll g/plant	Yield (g)
			Net covers treatment			
black		59.3	68.8	4.05	30.6	765
white		47.1	73.8	5.01	36.2	951
control		39.5	56.6	3.72	45.2	660
LSD $_{5\%}$		3.07	2.37	0.37	2.42	5.82
			Potassium Silicate treatment			
S0		35.8	55.9	3.33	42.5	689
S1		49.3	68.5	4.53	36.0	795
S2		60.8	74.8	4.92	33.5	892
LSD $_{5\%}$		4.18	2.03	0.146	1.05	4.84
			Interaction between cover net and slilicate spray			
black	S0	42.0	58.7	3.66	33.5	653
	S1	59.7	68.4	4.22	31.8	718
	S2	76.1	79.3	4.27	26.4	925
white	S0	33.4	66.9	3.90	42.8	863
	S1	48.9	72.3	5.41	29.6	988
	S2	59.1	82.1	5.70	36.3	1003
control	S0	32.0	41.9	2.42	51.2	553
	S1	39.3	64.9	3.96	46.7	680
	S2	47.1	63.0	4.77	37.8	748
LSD $_{5\%}$		1.95	2.19	0.256	2.47	7.03

S0 (sprayed with tap water), S1 (1.5 mM of potassium silicate), S2 (3 mM of potassium silicate), SPAD (Unit for determines the amount of chlorophyll present by measuring absorbance two wavelength regions), LSD 5% (Significance at 5 % level)

Table 2: Different efficiencies of different net covers on celery vegetative growth characteristics during the second growing season of 2020

Treatment		Plant height (cm)	Number of leaves cm	plant diameter SPAD	chlorophyll g/plant	Yield (g)
				Net covers treatment		
black		61.0	67.7	5.19	26.9	808
white		56.6	76.4	5.55	34.4	912
control		41.6	49.8	3.50	38.3	677
LSD $_{5\%}$		2.75	3.42	0.26	2.35	6.04
				Potassium Silicate treatment		
S0		50.4	60.3	4.19	35.8	674
S1		52.8	61.3	4.86	34.4	798
S2		55.9	72.3	5.19	29.5	924
LSD $_{5\%}$		1.792	1.032	0.253	1.985	5.07
			Interaction between cover net and slilicate spray			
black	S0	56.0	63.0	4.89	27.5	723
	S1	60.3	69.4	5.11	28.4	830
	S2	66.7	70.6	5.56	24.9	870
white	S0	54.7	70.6	5.44	36.5	740
	S1	56.7	76.4	5.43	35.4	933
	S2	58.3	82.3	5.78	31.4	1063
control	S0	40.7	47.3	2.22	43.3	560
	S1	41.3	37.9	4.04	39.5	630
	S2	42.7	64.2	4.22	32.2	840
LSD $_{5\%}$		1.03	1.84	0.209	1.83	6.93

S0 (sprayed with tap water), S1 (1.5 mM of potassium silicate), S2 (3 mM of potassium silicate), LSD 5 % (Significance at 5 % level)

sity under black net resulting from netting affected the micro-climatic conditions and reduce the plant growth especially in the winter season because of low light intensity (Hashem et al., 2011). Furthermore, silicon application increased the chlorophyll content of plant leaf and enhanced the antioxidant system in plants that were exposed to abiotic stress which led to better photosynthesis (Al-aghabary et al., 2004)

3.3 CELERY YIELD

Presented data in Table (1 and 2) shows that there were significant effects considering the used cover on celery plants wither it is the black or white screen net, the celery yield was improved during both seasons. The indicated data from using white net coverage led to increasing in celery yield significantly; secondly came the black net coverage, while the lowest mass of celery was obtained by control treatment.

Effect of foliar application treatments of potassium silicate on celery yield was significantly noticeable during both seasons. The high concentration of potassium silicate (S2) treatment gave the highest celery yield followed by low concentration of potassium silicate (S1). The lowest celery yield was obtained by control treatment during both seasons.

Concerning the interaction effect of screen net coverage and foliar application of potassium silicate, it was statistically significant; the highest celery yield was obtained by white net cover combined with S2 foliar application during the two season followed by black screen net cover combined with S2 foliar application. The lowest celery yield was obtained by control (without cover) treatment combined by without foliar application. The same results were obtained by Piotr et al. (2009) who mentioned that using cover screen led to enhance celery stalks quality, however the dark screen cover decreased dry matter content and obtained yield. Zakher and Abdrabbo (2014) studied the growing vegetable crops during the summer using shading net; shading led to decrease air temperature, which reduces plant growth and lower yield percentage. Another study was conducted considering the production of celery during summer season by using screen net; the results indicated that white screen net led to increasing the plant growth, celery quality and productivity (Siwek et al., 2009). As of the effect of silicon, it enhanced plant tolerance during summer season. Bakhat et al. (2018) reveled that silicon improved plant growth and productivity under abiotic stresses conditions. Cooke and Leishman (2016) had the same results under heat waves stresses compared to plants without silicon foliar application. Moreover, foliar application of potassium silicate led to the increase of potassium concentration in celery leaves under different screen net coverage; Potassium (K) is necessary for the function of all living cells and is thus present in all plant tissues. K is a vital element for plant growth and productivity as well as the quality of produced vegetables (Marschner, 2012). Shen et al. (2009) concluded that foliar application by silicon compound led to relieve of high-temperature stress in vegetables. In addition, silicon application protects cultivated vegetables against the ultraviolet-B radiation by increasing photosynthesis and antioxidant levels. High level of ultraviolet-B radiation produces a wide physiological damage to plants, which had been implanted during summer season.

3.4 CHEMICAL ANALYSIS OF CELERY OUTER LEAF

Table 3 and 4 shows that the concentration of N, P,

Table 3: Different efficiencies of different net covers on chemical analysis of celery outer leaf during the first growing season of 2019

Treatment		N	P	K	Soluble sugars content	Vitamin C
%		%	%	$mg.kg^{-1}$ fresh	mg / 100g fresh	
				Net covers treatment		
black		1.49	0.27	3.11	6.59	2.52
white		1.78	0.39	3.80	6.97	2.86
control		1.85	0.49	4.48	8.23	3.44
$LSD_{5\%}$		0.11	0.08	0.26	0.39	0.22
				Potassium Silicate treatment		
S0		1.95	0.44	3.30	8.05	3.28
S1		1.62	0.36	3.63	7.20	2.92
S2		1.55	0.34	4.45	6.53	2.62
$LSD_{5\%}$		0.07	0.03	0.19	0.66	0.15
				Interaction between cover net and slilicate spray		
black	S0	1.88	0.32	2.70	7.72	2.98
	S1	1.30	0.24	2.90	6.59	2.64
	S2	1.29	0.23	3.73	5.46	1.93
white	S0	1.84	0.46	3.57	7.30	2.96
	S1	1.86	0.37	3.54	6.93	2.80
	S2	1.63	0.34	4.29	6.67	2.81
control	S0	2.13	0.54	3.65	9.13	3.89
	S1	1.70	0.47	4.46	8.08	3.31
	S2	1.72	0.46	5.33	7.47	3.11
$LSD_{5\%}$		0.06	0.04	0.38	0.21	0.15

S0 (sprayed with tap water), S1 (1.5 mM of potassium silicate), S2 (3 mM of potassium silicate), N (Nitrogen), P (phosphorous), K (potassium). $LSD_{5\%}$ (Significance at 5 % level

K, soluble sugar content and vitamin C in celery leaves cultivated under the tested treatments during the two studied seasons. It indicated that, in general, the treatment of covered celery plants was sufficient to give high values of the studied macronutrient percentages N, P and K as well as soluble sugar content and vitamin C in the celery leaf. Plants that were covered by white net gave the lowest N, P, K, soluble sugar content and vitamin C, while the highest values were obtained by control treatment; due to effect of heat stress for plants at ambient conditions which reduced the photosynthesis and metabolism, leading to storing the nutrient in the plant tissues (Abul-Soud et al., 2014 and Zakher and Abdrabbo, 2014).

On the other hand, the appropriate microclimate under white and black screen net led to enhancement of the plant primary metabolism and then improves the ability of plant roots to absorb water and fertilizer from soil without stress which led to the enhancement of growth parameters (Hashem et al., 2011; Medany et al., 2009).

Regarding the using of potassium silicate foliar application treatments, data in Table 3 and 4 indicated that using 3.0 mM of potassium silicate increased K percentage in celery leaf more than the other treatments. N and P took another trend, as the control treatment had the highest percentages in celery's outer leaves. It may be due to the role of potassium silicate in improving the ability of plants to combat the stresses during summer and enhancing the machinery and metabolism, which reflected on increasing plant mass making dilution effect of nutrients in its tissues (Abd El-Rahman et al., 2018 and Zakher and Abdrabbo, 2014).

Table 4: Different efficiencies of different net covers on chemical analysis of celery outer leaf during the second growing season of 2020

Treatment		N	P	K	Soluble sugars content	Vitamin C
				$mg.kg^{-1}$		
%		%	%	fresh	mg / 100g fresh	
				Net covers treatment		
black		1.41	0.29	3.74	6.18	2.59
white		1.70	0.36	4.47	7.44	3.17
control		1.90	0.37	5.04	8.30	3.45
$LSD_{5\%}$		0.16	0.06	0.29	0.40	0.12
				Potassium Silicate treatment		
S0		1.90	0.39	3.73	8.42	3.52
S1		1.65	0.34	4.41	7.31	3.08
S2		1.46	0.29	5.10	6.19	2.61
$LSD_{5\%}$		0.13	0.03	0.56	0.93	0.22
				Interaction between cover net and slilicate spray		
black	S0	1.76	0.36	3.08	7.68	3.24
	S1	1.16	0.27	3.49	5.76	2.41
	S2	1.31	0.23	4.66	5.10	2.12
white	S0	1.75	0.39	4.02	7.98	3.38
	S1	1.83	0.35	4.59	7.65	3.27
	S2	1.53	0.33	4.80	6.68	2.86
control	S0	2.20	0.41	4.11	9.59	3.95
	S1	1.95	0.40	5.16	8.52	3.56
	S2	1.55	0.32	5.84	6.78	2.85
$LSD_{5\%}$		0.07	0.03	0.204	0.11	0.11

S0 (sprayed with tap water), S1 (1.5 mM of potassium silicate), S2 (3 mM of potassium silicate), N (Nitrogen), P (phosphorous), K (potassium). $LSD_{5\%}$ (Significance at 5 % level)

Table 5: Economic analysis for using cover net and potassium silicate during the first growing season of 2019

Cover	Potassium Silicate	Avge. yield kg/plant	Yield Ton/ Acre	Grass in-come Acre	Cover cost *L. E/ Acre	Annual cover cost *L. E/ Acre	Applied Potassium Silicate cost Liter/ Acre	Potassium Silicate cost Cost/ Acre	Spray cost *LE/ Acre	Total treat-ments cost *LE	Net in-come *L. E/ GH	Incremental income *L. E / GH
Black net	S0	653	15.7	31320	21000	4200	0	0	150	4350	26970	600
	S1	718	17.2	34440	21000	4200	3	360	150	4710	29730	3360
	S2	925	22.2	44400	21000	4200	6	720	0	4920	39480	13110
White net	S0	863	20.7	41400	21000	4200	0	0	150	4350	37050	10680
	S1	988	23.7	47400	21000	4200	3	360	150	4710	42690	16320
	S2	1003	24.1	48120	21000	4200	6	720	0	4920	43200	16830
control	S0	553	13.3	26520	0	0	0	0	150	150	26370	0
	S1	680	16.3	32640	0	0	3	360	150	510	32130	5760
	S2	748	17.9	35880	0	0	6	720	0	720	35160	8790

Average price 2 LE/ kg
cover cost 5 LE/ m^2
The greenhouse applied by one acre net cover
Potassium Silicate cost 120 L.E/Liter
Average currency change rate = (1 USD = 16 L.E.)

Table 6: Economic analysis for using cover net and potassium silicate during the second growing season of 2020

Cover	Potassium Silicate	Avge. yield kg/plant	Yield Ton/ Acre	Grass income Acre	Cover cost L. E/ Acre	Annual cover cost L. E/ Acre	Applied Potassium Silicate cost Liter/ Acre	Potassium Silicate cost Cost/ Acre	Spray cost LE/ Acre	Total treat-ments cost LE	Net income L. E/ GH	Incremental income L. E / GH
Black net	S0	723	17.4	34720	21000	4200	0	0	150	4350	30370	3640
	S1	830	19.9	39840	21000	4200	3	360	150	4710	35130	8400
	S2	870	20.9	41760	21000	4200	6	720	0	4920	36840	10110
White net	S0	740	17.8	35520	21000	4200	0	0	150	4350	31170	4440
	S1	933	22.4	44800	21000	4200	3	360	150	4710	40090	13360
	S2	1063	25.5	51040	21000	4200	6	720	0	4920	46120	19390
control	S0	560	13.4	26880	0	0	0	0	150	150	26730	0
	S1	630	15.1	30240	0	0	3	360	150	510	29730	3000
	S2	840	20.2	40320	0	0	6	720	0	720	39600	12870

Average price 2 LE/ kg
cover cost 5 LE/ m^2
The greenhouse applied by one acre net cover
Potassium Silicate cost 120 L.E/Liter
Average currency change rate = (1 USD = 16 L.E.)

3.5 ECONOMIC ANALYSIS

Cost of using nets for protect celery plants were 21000 Egyptian pound (L.E.) per acre, for white or black nets during the two studied seasons (Tables 5 and 6). We consider a lifetime for the cover screen net of 5 years then the annual cost of covering with net was 4200 L.E. The cost of spray potassium silicate was also considered in this analysis. The other costs of production were not considered such as labor, inputs, irrigation, etc., because these are the same for the tested treatments (under white and black screen net as well as open field) on one acre of celery. Compared to control, the benefits (total gross profit) of using the different treatments were higher than cultivate in open field. White net combined with application of potassium silicate S2 was superior in yield of two years, comparing with the other treatments during both seasons; the white net combined with S1 came in the second order; the lowest values was obtained by open field treatment combined with absent potassium silicate application. Regarding the relative increase in income compared to control treatment; the white net with S1 and S2 gave the highest values; use of potassium silicate S2 came in the third option. The lowest relative increase in income was obtained by without screen cover combined with absent potassium silicate treatment. From the above we can conclude that using of physical or chemical protection led to the improvement of the profitability of celery during the early season compared to the control treatment.

4. CONCLUSIONS

This research provided evidence on how to produce winter leafy crops such as celery plants during the early summer season providing high quality production by applying the required physical and chemical protection for plants. The results showed that using of screen net coverage increased plant growth and provided high quality yield compared to the situation without appropriate coverage. Also, the acquired results gave a recommendation for the usage of potassium silicate as foliar application for plant protection from heat waves. This study confirmed that silicon has a beneficial effect of foliar application. Using white screen net combined by foliar application of potassium silicate 3 mM gave the highest yield of celery and enhanced the vegetative growth and yield during the late season.

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