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AMELIORATION PRODUCTIVITY OF POTATO CROP GROWN UNDER HIGH TEMPERATURE CONDITION SPRAYING WITH KAOLIN AND A-TOCOPHEROL

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Abstract

Two-year field experiment was conducted during 2017 and 2018 at the Experimental and Production Station of National Research Centre, El-Noubaria region, Beheira Governorate, Egypt. The aim was to study the effects of foliar spray of kaolin at levels (0, 5 10 cm^3/L) and α-tocopherol (0, 50, 100 ppm) applied singly or combined on vegetative growth, some chemical components and yield of potato. The obtained results indicated that the vigorous potato plants, i.e. plant height, number of leaves and shoots as well as fresh and dry weight of whole plant and its leaves and shoots were recorded with plants which were sprayed by the high level of kaolin followed by a treatment the spraying of kaolin at 5 cm^3/L incorporated with α-tocopherol at 50 ppm for the rest of the treatments. The highest values of chlorophyll a, chlorophyll b, chlorophylls a + b as well as carotenoids were detected when potato plants were sprayed as foliar by kaolin at the highest rate 10 cm^3/L. and there is no significant difference with treatment kaolin at 5 cm^3/L incorporated with α-tocopherol at 50 ppm. The biggest tubers yield of potato expressed as tons/fed and marketable yield and some chemical constituents recorded with plants which received the highest level of kaolin. In most cases no significant differences were realized between the spraying at kaolin high level and the spraying of kaolin at 5 cm^3/L with spraying α-tocopherol at 50 ppm. In contrast, the lowest significant values of all measured parameters were achieved when potato plants were sprayed by tap-water (checked plants).

Keywords: *Solanum tuberosum L.*, kaolin, α-tocopherol, vegetative growth and potato yield.

Introduction

Potato (*Solanum tuberosum L.*) as a member of Solanaceae family is one of the most important vegetable crops in the world, and in terms of human consumption comes in the fourth grade after wheat, rice and corn. It is rich in carbohydrate, nutrients and amino acids (Hassan 2003; Shaheen *et al.,* 2019). A lot of factors affect potato production, including cultivars, weather conditions, planting date, irrigation and nutrition. Potato plants are sensitive to climate changes especially high temperature which leading to a significant reduction in tubers quantity and quality (Abdel-Monnem, 2015). High temperature (HT) is a now major concern for crop production and approaches for sustaining high crop yields under HT stress are important agricultural goals (Hasanuzzaman, 2013). Plants were exposed to high temperatures of 40–42 °C, or transferred from daytime temperature regimes of 22 °C to 32 °C, caused a reduction in net photosynthesis. High temperature was found associated with a decrease in stomatal resistance, an increase in transpiration, and a larger difference between air and leaf temperatures (Rykaczewska, 2017).

Kaolin is a naturally occurring, chemically inert clay mineral. Kaolin particle film applications have been used to reduce negative impacts of environmental stresses on crop plants, by suppressing the diseases, and protecting the crops from high and low temperatures. The development of particle film technology and its initial applications have been reviewed (Glenn and Puterka, 2005; AbdAllah, 2019). Kaolinite is one of clay minerals with formula $Al_2Si_2O_5(OH)_5$, has chemically inert over a wide range of pH and a low exchangeable cation capacity (1-16 meq/100g) (Brown *et al.,* 2010). Gindaba and Wand (2007) reported that kaolin particle film application on apple trees was achieved vary inconsistently in its effect on leaf temperature and photosynthetic rate. While, Steiman and Bittenbender (2007) observed that kaolin spraying on glass slides reduced photo synthetically active radiation, UV transmission and the temperature of glass surface. Glenn *et al.* (2010) found that using kaolin as particle film application increased leaf water potential and decreased stomata conductance. However, kaolin at concentration of 6% in treated soybean plants decreased node number, stem height, stem diameter, number of seeds and number of pods per plant, weight of seed, biological yield, seed yield and harvest index but the number of seeds per pod was not affected (Javan *et al.*, 2013).

In addition Kaolin spray decreased leaf temperature by increasing leaf reflectance and reducing transpiration rate more than photosynthesis in many plant species grown at high solar radiation levels (Moftah, 2005). Also the kaolin particle film product surround is labeled for reduction of heat stress and sunburn on several crops (Kahn and Damicone, 2008)

A-Tocopherol (vitamin E) is a small molecule that is synthesized in plants (Soltani *et al.*, 2012; Mokrosnop, 2014). α-Tocopherol is a strong antioxidant that assists the transport of electrons in photosystem-II protein complex, Tocopherols appear to be universal constituents of all higher plants (Bafeel and Ibrahim, 2008). El-Bassiouny *et al.* (2005) reported that foliar spray with α-tocopherol on faba bean plants induced increment in growth parameters, yield components, chlorophyll a, b and carotenoids content. Tocopherols play a role in a range of different physiological phenomena including plant growth and development, senescence, preventing lipid peroxidation and interact with the signal cascade that convey abiotic and biotic signals

(Baffel and Ibrahim, 2008; Soltani *et al.*, 2012; Orabi *et al.*, 2017). Tocopherols are believed to protect chloroplast membranes in plants from photo oxidation and help to provide an optimal environment for the photosynthetic machinery, their accumulations also occur as a response to variety of abiotic stress including high light, drought, salt and cold and may provide an additional line of protection from oxidative damage (Orabi *et al*., 2017)

The aim of this study is the mitigation of the heat stress to increase the productivity of potato by kaolin and α-tocopherol.

Material and Methods

Site Description and Plant Material

This study was carried out at the experimental station of the National Research Centre, Beheira Governorate (north of Egypt), during the two winter seasons of 2017 and 2018, to investigate the mitigation of the heat stress and increase the productivity of potato by kaolin and tocopherol. Chemical analysis and physical properties of the experimental soil are shown in Table (1):

Table 1

Physical properties							
sand		**clay**	**silt**	**texture**	**Field capacity %**	**Wilting point %**	
90.08		9.26	0.66	sandy	16.57	5.25	
Chemical analysis							
E.C. M/m	pH	Meq/L					
		Ca	Mg	Na	K	Hco_2	Cl
1.7	8.2	7.02	0.527	0.982	0.31	1.3	0.566

Potato tubers of cultivar Sponita were obtained from General Authority for Producers and Exporters of Horticulture Crops, Cairo, Egypt, were used in two seasons. The tubers were planted on the 10^{th} of February month during the two seasons on one side of ridge at distance of 25 cm between tubers and 50 cm within rows. These experiments were conducted to investigate the mitigation of the heat stress on potato with 3 levels as foliar application of each kaolin as particle film product and α-tocopherol as individually or as mixed. The normal cultural practices were used for the potato production, i.e. fertilization, irrigation, weed control as well as diseases and pest control were followed according to the recommendation of the Egyptian Ministry of Agriculture.

Plants were sprayed with Kaolin particle film as a reflective antitranspirants (ATs) (Surround WP Crop Protectant, 95% Kaolin, 5% inter ingredients, AL-Goumhoria Co. Egypt), Kaolin levels as particle film product 0, 5 cm^3/L as low level and 10 cm^3/L as high level. α-Tocopherol (vitamin E) as commercial preparation (''Vapor Gard" = 96% α- Tocopherol and 4% inert ingredients, CBC ''Europe" s. r. l, Italy) was obtained from AL-Goumhoria Co. Egypt at rate 0, 50 ppm as low level, 100 ppm as high level.

Kaolin incorporated with α-tocopherol at levels 2.5 cm^3/L kaolin + 25 ppm α-tocopherol (low level) and 5 cm^3/L kaolin + 50 ppm α-tocopherol (high level).

Experimental design:

The factorial experiment was consisting 9 treatments with three replicates. The experiment was arranged in split plot design. The three levels of application of Kaolin occupied in the main plots and the three levels of α- Tocopherol were allocated at random in the sub plots. The field data were statistically analyzed as a split plot design. All the treatments were sprayed for 3 times with 10 days interval starting at 35 days after planting date. All sprays were done in the morning using a hand pressure sprayer.

Recorded data:

A: Vegetative plant growth: A random sample of 3 plants was taken at 70 days after planting for the determination of the following characters. Plant height, Number of leaves / plant, Number of shoots / plant, Fresh weight of whole / plant and its leaves and shoots and Dry weight of whole / plant and its leaves and shoots.

B- **Photosynthetic pigments:** Total chlorophyll and carotenoids of fresh leaf tissue were calorimetrically determined according the method described by **Moran (1982).**

C- **Tuber yield:** Weight of tubers g/plant, Number of tubers / plant, Average weight of tuber g/ tuber, Average weight of tubers tons/fed., Marketable tubers yield (yield of good shapes and healthy).

D- Chemical contents:

Potato tubers were oven dried at 70° C untill constant weight (g) was reached and the dry matter percentage was calculated as described by A. O. A. C. (1990). Total carbohydrates were determined spectro – photometrically in dry tuber tissues, using phenol sulphoric acid according to Dubois *et al.* (1956). Starch content was determined in dry tubers tissue using the method of Somogi (1952). Total nitrogen was determined using the modified micro Kjeldah method (Hanon 8910, digital) according to the procedures described by Cottenie *et al*. (1982). Phosphorus content was determined using the modified colorimetric method using spectrophotometer (Spectronic 200, Milton Roy Co., Ltd, USA) according to the procedures described by Cottenie *et al.* (1982). Potassium and calcium contents were measured using flame photometer method (JENWAY, PFP-7, ELE Instrument Co. Ltd., UK) as described by Chapman and Pratt (1982). The reaction mixture absorbance was read at 725 nm using a UV/VIS spectrophotometer. Gallic acid was used as the standard reference and total phenolic content was expressed as mg gallic acid equivalent per gram of dry weight tissue (mg GAE/g DW). Total flavonoid content was determined in absolute ethanolic extract using the aluminum chloride colorimetric method described by Chang *et al.* (2002); Mahmoud *et al.* (2019).

Statistical Analysis

Obtained data were subjected to the analysis of variance procedure and means were compared to the L.S.D.

test according to Gomez and Gomez (1984) and the least significant differences (L.S.D) test at 5% level was used to verify differences between treatments.

Results

A- Plant growth characters:

The plant growth characters (plant length, average number of leaves and shoots, as well as fresh and dry weight of potato as responded to the application of kaolin and α-tocopherol are shown in Table (2 and 3). Whereas the foliar spraying by kaolin 3 times (beginning 35 days after tuber seed at 10 days interval) at concentration within 5000 – 10000 ppm caused an enhancement in length of plant, leaves and shoot number, fresh and dry weight. On the contrary, that potato plants which applied the other compound such as α-tocopherol as antioxidant material by the same application method but at a concentration of 50 - 100 ppm it caused a depression in plant growth parameters of potato plant. From other side when mixed the above two compounds (kaolin + α-tocoperol) at rate 1:1 resulted an improvement in different values of plant growth, it were lower than applied kaolin as alone, and was more that plant which sprayed by the tocopherol. These findings were in good accordance with that data recorded in both experimental seasons 2017 and 2018.

Regarding to the effect of different levels of various materials kaolin and α-tocopherol and their mixed on potato plant in table (2 and 3) the obtain results reveals that increasing the level of using materials all plant growth characters recorded the higher values. It means that the highest plant length, average number of leaves and shoot as well as fresh and dry weight plant were noticed with plants were applied the kaolin, α-tocopherol as individual and as mixed.

Table 2 : Effect of spraying Kaolin and α-Tocopherol on plant growth characters of potato plants in the first season 2017.

Treatments		Plant length (cm)	Fresh weight g/ plant			Dry weight g/ plant			No. of	
			Leaves	shoots	Whole	Leaves	shoots	Whole	Leaves	shoots
A- Kaolin and Tocopherol										
Kaolin		65.3	302.55	152.10	454.64	37.37	18.76	56.13	59.89	4.78
α-Tocopherol		62. 9	263.49	126.92	390.41	32.61	16.05	48.66	56.78	3.67
Kaolin + α-Tocopherol		63. 6	279.43	140.46	419.88	34.26	16.79	51.06	58.11	4.22
L.S.D at 5%		**0.67**	**25.05**	**6.30**	**23.17**	**0.60**	**0.84**	**0.95**	**2.13**	**0.69**
B- Concentrations										
Control		57. 7	208.51	105.69	314.20	26.60	14.16	40.76	49.33	2.67
low		65. 9	304.42	145.60	450.02	36.06	17.84	53.90	60.89	4.78
high		68. 2	332.53	168.18	500.71	41.59	19.61	61.19	64.56	5.22
L.S.D at 5%		**1.45**	**37.96**	**10.31**	**39.35**	**1.96**	**1.01**	**2.14**	**1.49**	**0.69**
C- Kaolin and Tocopherol × Concentrations										
Kaolin	**Control**	57. 7	208.51	103.47	311.98	26.60	14.16	40.76	49.33	2.67
	low	68. 3	343.00	166.17	509.17	40.00	20.43	60.44	63.00	5.67
	high	70.0	356.13	186.65	542.79	45.51	21.67	67.19	67.33	6.00
α-Tocopherol	**Control**	57. 7	208.51	106.80	315.31	25.55	14.16	40.76	49.33	2.67
	low	67.0	300.00	143.70	443.70	39.60	17.87	55.45	61.67	4.33
	high	64.0	281.95	130.27	412.22	44.97	16.13	49.77	59.33	4.00
Kaolin + α-Tocopherol	**Control**	57. 7	208.51	106.80	315.31	25.55	14.16	40.76	49.33	2.67
	low	62.3	270.27	126.93	397.20	35.60	15.21	45.80	58.00	4.33
	high	70. 7	359.50	187.63	547.13	32.38	21.01	66.62	67.00	5.67
L.S.D at 5%		**2.52**	**N.S.**	**17.86**	**68.15**	**3.40**	**1.74**	**3.71**	**2.58**	**N.S.**

N.S. = Not significant at $p \leq 0.05$.

Table 3 : Effect of spraying Kaolin and Tocopherol on plant growth characters of potato plants in the second season 2018.

Treatments		Plant length (cm)	Fresh weight g/ plant			Dry weight g/ plant			No. of	
			Leaves	shoots	Whole	Leaves	shoots	Whole	Leaves	shoots
A- Kaolin and Tocopherol										
Kaolin		64.33	301.25	149.46	450.72	36.70	18.27	54.98	60.00	4.56
α-Tocopherol		61.89	252.42	126.12	378.54	31.18	15.15	46.33	56.44	3.11
Kaolin + α-Tocopherol		62.89	264.32	136.64	400.96	33.67	15.80	49.47	57.11	3.67
L.S.D at 5%		**1.53**	**9.75**	**4.06**	**400.96**	**0.87**	**0.79**	**0.50**	**1.40**	**0.44**
B- Concentrations										
Control		57.00	203.33	100.13	303.47	25.55	12.13	37.68	48.00	2.33
low		64.89	288.68	143.41	432.09	35.36	17.37	52.73	60.78	4.11
high		67.22	325.98	168.68	494.66	40.64	19.72	60.37	64.78	4.89
L.S.D at 5%		**1.93**	**22.48**	**3.02**	**21.48**	**0.76**	**0.52**	**0.87**	**1.70**	**0.69**
C- Kaolin and Tocopherol × Concentrations										
Kaolin	**Control**	57.00	203.33	100.13	303.47	25.55	12.13	37.68	48.00	2.33
	low	66.67	338.60	161.25	499.85	39.60	20.35	59.95	64.00	5.33
	high	69.33	361.83	187.00	548.84	44.97	22.34	67.31	68.00	6.00

α-Tocopherol	**Control**	57.00	203.33	100.13	303.47	25.55	12.13	37.68	48.00	2.33
	low	65.67	292.61	145.38	438.00	35.60	17.60	53.20	61.33	4.00
	high	63.00	261.30	132.85	394.15	32.38	15.73	48.12	60.00	3.00
Kaolin + α-Tocopherol	**Control**	57.00	203.33	100.13	303.47	25.55	12.13	37.68	48.00	2.33
	low	62.33	234.82	123.60	358.42	30.88	14.17	45.05	57.00	3.00
	high	69.33	354.80	186.20	541.00	44.58	21.10	65.68	66.33	5.67
L.S.D at 5%		**3.35**	**38.94**	**5.22**	**37.20**	**1.32**	**0.90**	**1.51**	**2.95**	**1.20**

N.S. = Not significant at p≤0.05.

As general it could be concluded that the application of this materials caused an increasing in all plant growth characters. These results are in complete similar in both seasons.

The interaction between the antiheat stress materials with the different levels had a significant effect in all plant growth parameters in two seasons expect average of fresh weight of first season. Whereas kaolin and α-tocopherol as alone and or as mixed at higher rate gained the higher valves of plant growth parameters if comported with plants don't received any materials. Also the obtained data noticed that using kaolin alone and as mixed with tocopherol at higher rate (5000 ppm kaolin + 500 ppm α-tocopherol) recorded the best plant growth of potato plant if comported with other treatments.

B- Leaves pigments:

Effect of some anti-heat stress materials (kaolin, α-tocopherol) and their interaction on total pigments of potato plants are presented in Table (4) during the two seasons 2017 and 2018. Spraying potato plants by kaolin 3 times beginning 35 days after seeding with 10 days intervals gained the highest values of chlorophyll a, b and carotenoids contents. On contrary that plants which received the second martial i,e, tocopherol gained the lowest values of total pigments and its different fraction. Moreover, with mixed the two anti-stress materials together resulted lower values than that plants applied kaolin but more than that plants supplied tocopherol as individual application. The statistical analysis for the collected data reveals that differences within different ant stress material were great enough to reach the % level of significant. This findings were completely similar for the two seasons.

Concerning to the response of potato plants to the application of various levels of the ant stress materials, the data of table (4) indicates that under the recent study the chlorophyll a and chlorophyll b and carotenoid pigment recorded an increase with increasing the level of application. It means that don't received any materials resulted the lowest values but that plants which sprayed by the highest levels of this materials gained the highest pigment values. These results held well in both seasons.

Table 4 : Effect of spraying Kaolin and α-Tocopherol on Leaf pigments contents of potato plants in two seasons 2017-2018.

Treatments		**Leaf pigments mg/g fresh weight**							
		Chlorophyll a mg/g F. W		**Chlorophyll b mg/g F. W**		**Total Chlorophyll mg/g F. W**		**Carotonoids mg/g F. W**	
		2017	2018	2017	2018	2017	2018	2017	2018
A- Kaolin and Tocopherol									
Kaolin		1.62	1.68	0.67	0.67	2.29	2.35	1.49	1.55
α-Tocopherol		1.49	1.55	0.52	0.52	2.01	2.07	1.45	1.46
Kaolin + Tocopherol		1.54	1.57	0.61	0.57	2.15	2.14	1.40	1.48
L.S.D at 5%		**0.09**	**0.02**	**0.38**	**0.33**	**0.11**	**0.03**	**0.04**	**0.03**
B- Concentrations									
Control		1.30	1.35	0.38	0.33	1.68	1.68	1.15	1.23
low		1.56	1.65	0.64	0.65	2.20	2.30	1.56	1.57
high		1.79	1.80	0.78	0.79	2.57	2.59	1.63	1.68
L.S.D at 5%		**0.10**	**0.03**	**0.11**	**0.02**	**0.12**	**0.04**	**0.05**	**0.09**
C- Kaolin and Tocopherol × Concentrations									
Kaolin	**Control**	1.30	1.35	0.38	0.33	1.68	1.68	1.15	1.23
	low	1.67	1.78	0.79	0.81	2.46	2.59	1.65	1.67
	high	1.89	1.91	0.84	0.88	2.73	2.79	1.67	1.74
α-Tocopherol	**Control**	1.30	1.35	0.38	0.33	1.68	1.68	1.15	1.23
	low	1.61	1.66	0.60	0.64	2.21	2.30	1.64	1.58
	high	1.57	1.64	0.58	0.60	2.15	2.23	1.57	1.55
Kaolin + α-Tocopherol	**Control**	1.30	1.35	0.33	0.33	1.68	1.68	1.15	1.23
	low	1.39	1.50	0.64	0.51	1.92	2.01	1.39	1.46
	high	1.93	1.86	0.60	0.88	2.84	2.74	1.66	1.75
L.S.D at 5%		**0.18**	**0.04**	**0.19**	**0.04**	**0.20**	**0.07**	**0.09**	**0.15**

The interaction effects between the two studies factors on the total leaves pigment of potato plants are showed in table (4), as a general the application of kaolin as anti-stress and using as mixture with α-tocopherol resulted the highest pigment contents when used at a high level compared with other levels, as a general that plants which sprayed by α-tocopherlol resulted an enhancement in total pigments and its fraction if compared with control treatment. Also the obtained data indicate that the differences within the interaction treatment were statistically significant in both seasons.

C- Total tuber yield and its properties

Presented data in Table (5) showed that the foliar application of potato plants with some anti-heat stress materials i.e. kaolin, α-tocopherol and mixture within two materials caused significant effect on tubers weight as g/ plant, tubers yield tons/fed, as well as marketable yield ton/ fed. During two seasons. However, that plants which applied with kaolin as anti-stress material obtained the heaviest tubers yield 1533 and 1525 g/plant, 8.3 and 8.0 tubers / plant and 12.35 and 12.44 tons/ fed. And marketable 10.48 and 10.63 tons/fed respectively in two seasons 2017 and 2018. On the contrary that plants which received α-tocopherol gave the lowest tuber yield. However, mixed kaolin with α-tocopherol as 1:1 resulted the lower tuber yield if compared with using kaolin alone, also more tubers yield if compared with α-tocopherol as individual. The above findings are completely similar in both two seasons.

Concerning the response of tuber properties as effected by ant stress materials, the obtained data Cleary indicate that the same pattern of increase was followed which above written. It could be abstracted that the foliar by kaolin resulted the best tubers yield with a good tubers properties.

Application of kaolin or α-tocopherol as individual or mixed with a various levels of them caused a significant effect on total tubers yield of potato on contrary the lowest values were associated with no anti stress martials using (control treatment) but the total tubers yield were obtained with spraying the high level of this materials followed in descending order when the low levels were used. These were true for all criteria of potato yield i.e. tubers yield /plants or tubers yield /fedin. By other meaning using high level of this materials had an increase in total tuber yield as ton fed. amounted by 13.8 and 14 in 2017 and 2018 seasons respectively compared with 8.10 and 8.13 ton /fed, for the same respective that plants no received an antistress materials.

Table (5) indicates that interaction treatments between using different anti stress with various levels had statistical significant effects on tubers number and weights per plant, tuber volume, total tubers yield and its marketable yield during the two seasons. It could be stated that using kaolin as individual or mixed with α-tocopherol at rate 1:1 by the high level resulted an increase in tubers yield as weight /plant and ton /fed, compared at applied α-tocopherol as individual. The obtained results showed that using the low level recorded the best values if compared with using the high level. The above mention data are a complete similar in both seasons. Finally the presented data clearly indicated that the heaviest tubers yield as expressed by weight /plant number/ plant, weight per fed and marketable yield of these parameters were recorded with that potato plants received kaolin as anti-stress material.

Table 5 : Effect of spraying Kaolin and α-Tocopherol Total tuber yield and its properties of potato plants in the two seasons 2017-2018.

Treatments		Tubers/ plant				Tubers properties				Total yield ton/fed,		Total marketable yield ton/fed.	
		Wt. g		No.		diameter		Average Wt. g					
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
A- Kaolin and Tocopherol													
Kaolin		1533	1555	8.3	8.0	6.6	6. 8	183	194	12.35	12.44	10.48	10.63
α-Tocopherol		1385	1382	7.0	6. 8	5.9	6.0	197	203	11.19	11.06	9.27	9.27
Kaolin + Tocopherol		1447	1446	7.2	7.0	6.2	6.1	202	209	11.60	11.57	9.79	9.76
L.S.D at 5%		**77.1**	**100.1**	**0.50**	**0.50**	**0.12**	**0.37**	**N.S.**	**N.S.**	**0.40**	**0.67**	**0.37**	**0.48**
B- Concentrations													
Control		1007	1016	5. 7	5.3	4.8	4.3	179	191	8.10	8.13	6.46	6.53
low		1629	1617	7. 9	7. 6	6.6	6.7	210	217	13.01	12.94	11.09	10.99
high		17300	1750	9.0	8. 9	7.4	7.8	194	198	13.80	14.00	12.00	12.13
L.S.D at 5%		**51.0**	**72.8**	**0.61**	**0.55**	**0.49**	**0.39**	**19.1**	**16.8**	**1.41**	**1.58**	**1.38**	**1.61**
C- Kaolin and Tocopherol × Concentrations													
Kaolin	**Control**	1007	1016	5. 7	5.3	4.8	4.3	179	191	8.10	8.13	6.46	6.53
	low	1765	1779	9.3	9.0	7.0	7.2	189	197	14.12	14.24	12.12	12.24
	high	1828	1870	10.0	9. 7	8.0	8.8	182	193	14.63	14.96	12.87	13.12
α-Tocopherol	**Control**	1007	1016	5. 7	5.3	4.8	4.3	179	191	8.10	8.13	6.46	6.53
	low	1610	1600	8.0	7. 7	6.9	7.3	201	210	12.88	12.80.	11.04	10.96
	high	1540	1530	7.33	7. 3	6.1	6.3	210	209	12.32	12.24	10.32	10.32
Kaolin + α-Tocopherol	**Control**	1007	1016	5. 7	5. 3	4.8	4.3	179	191	8.10	8.13	6.46	6.53
	low	1513	1473	6. 3	6.0	5.8	5. 7	240	245	12.11	11.78	10.12	9.79
	high	1821	1850	9. 7	9. 7	8.0	8.3	188	191	14.57	14.80	12.81	12.96
L.S.D at 5%		**88.4**	**126.28**	**1.05**	**0.96**	**0.84**	**0.68**	**N.S.**	**N.S.**	**1.71**	**1.10**	**1.80**	**1.12**

N.S. = Not significant at $p \leq 0.05$.

D- Nutritional values:

As shown in Tables (6 and 7) the results indicated that potato plants which treated with kaolin material as foliar spraying gained the significant highest nutritional values (N, P, K, total carbohydrates, starch. Phenols and flavonoids) if compared with that plants which treated by α-tocopherol as individual or if mixed with kaolin 1:1as volume. On the contrary the lowest nutritional values were estimated with that plant which received α-tocopherol as individual. These finding were in good similar in both two seasons.

Regarding to the response of potato plants to the different concentration of the anti-stress materials, the collected data reveals that the highest significant nutritional values as mention above were recorded with that plants which received the higher concentration if compared with the lower one or the control treatment. However, the lowest nutritional values were found with the plants no treated (control). These results held well in the two seasons.

The interaction treatments within the two studies factors effected on the N, P, K, total carbohydrates, starch, phenols and flavonoids during two seasons are shown in Table (6 and 7). As a general it could be stated that under different ant heat stress materials (kaolin, α-tocopherol and the mixture between them) if sprayed with the higher concentration gained an increase in all nutritional values. Moreover, that potato plants which sprayed with kaolin at higher concentration gained the highest chemical compounded. On contrary that plants no treated with ant stress materials recorded the lowest nutritional values. The results were completely similar in two seasons.

Table 6 : Effect of spraying Kaolin and α-Tocopherol on nutritional values of potato plants in the first season 2017.

Treatments		N %	P %	K %	Carbohydrate %	starch %	Phenols mg/g dw	Flavonoids mg/dw
A- Kaolin and Tocopherol								
Kaolin		1.66	0.61	3.33	60.45	53.90	40.42	12.78
Tocopherol		1.53	0.59	3.25	57.65	49.85	37.47	11.67
Kaolin + Tocopherol		1.55	0.59	3.23	58.58	51.29	38.38	12.00
L.S.D at 5%		**0.03**	**0.01**	**0.02**	**0.86**	**1.23**	**1.47**	**0.40**
B- Concentrations								
Control		1.33	0.53	2.43	50.06	40.08	30.07	9.33
low		1.66	0.62	3.63	61.23	55.43	41.21	12.89
high		1.75	0.65	3.75	65.38	59.53	44.99	14.22
L.S.D at 5%		**0.02**	**0.01**	**0.10**	**0.84**	**0.93**	**1.31**	**0.75**
C- Kaolin and Tocopherol × Concentrations								
Kaolin	**Control**	1.33	0.53	2.43	50.06	40.08	30.07	9.33
	low	1.80	0.65	3.75	64.12	59.55	44.27	14.00
	high	1.85	0.66	3.83	67.15	62.08	46.93	15.00
α-Tocopherol	**Control**	1.33	0.53	2.43	50.06	40.08	30.07	9.33
	low	1.64	0.62	3.65	61.28	54.36	40.17	12.67
	high	1.61	0.63	3.67	61.62	55.12	42.17	13.00
Kaolin + Tocopherol	**Control**	1.33	0.53	2.43	50.06	40.08	30.07	9.33
	low	1.53	0.59	3.50	58.29	52.39	39.19	12.00
	high	1.79	0.66	3.77	67.38	61.39	45.87	14.67
L.S.D at 5%		0.04	**0.02**	**N.S.**	**1.46**	**1.61**	**2.27**	**1.30**

N.S. = Not significant at *p≤0.05.*

Table 7 : Effect of spraying Kaolin and α-Tocopherol on nutritional values of potato plants in the second season 2018.

Treatments		N %	P %	K %	Carbohydrate %	starch %	Phenols mg/g dw	Flavonoids mg/dw
A- Kaolin and Tocopherol								
Kaolin		1.68	0.65	3.38	62.45	56.62	42.53	13.80
α-Tocopherol		1.50	0.55	3.20	57.65	52.66	39.10	11.84
Kaolin + α-Tocopherol		1.55	0.59	3.23	59.58	52.47	39.88	12.77
L.S.D at 5%		**0.03**	**0.01**	**0.02**	**0.78**	**0.65**	**2.25**	**0.21**
B- Concentrations								
Control		1.30	0.54	3.25	48.50	41.68	32.00	10.78
low		1.68	0.61	2.40	61.89	57.63	43.06	13.53
high		1.78	0.65	3.64	65.70	61.43	46.77	15.00
L.S.D at 5%		**0.11**	**0.03**	**0.11**	**0.95**	**1.11**	**2.82**	**1.03**
C- Kaolin and Tocopherol × Concentrations								
Kaolin	**Control**	1.30	0.54	2.40	48.50	41.68	32.00	10.07
	low	1.82	0.66	3.77	65.31	60.70	46.77	15.00
	high	1.89	0.67	3.84	67.78	64.47	48.53	16.33
α-Tocopherol	**Control**	1.30	0.54	2.40	48.50	41.68	32.00	11.13
	low	1.66	0.61	3.60	61.05	57.51	42.40	13.43
	high	1.62	0.61	3.69	62.06	58.78	44.50	13.67
Kaolin + Tocopherol	**Control**	1.30	0.54	2.40	48.50	41.68	32.00	11.13
	low	1.56	0.57	3.53	59.32	54.67	40.00	12.17
	high	1.84	0.66	3.80	67.25	61.05	47.27	15.00
L.S.D at 5%		**N.S.**	**N.S.**	**N.S.**	**1.65**	**1.92**	**N.S.**	**1.78**

N.S. = Not significant at *p≤0.05.*

Discussion

Although the planting date is approximately 30 days later than the appropriate date the obtained data proved that foliar treatments of kaolin as individual or as mixed with α-tocopherol (1:1 v/v) significantly improved the plant growth characters during the two seasons 2017 and 2018. These results were in agreement with those obtained by Soubeih *et al.*, 2017 on potato, Javan *et al.*, 2013 on soybean and Glenn 2012 on grape. It could be explained that kaolin spraying increase fresh and dry weight of potato plant may be due to sprayed kaolin made anti transpiration particle film on plant leaves led to increase free water in plant tissues in turn increase plant fresh weight. Whereas, Glem *et al.*, 2010 found that kaolin spray increased leaf water potential and lowered stomatal conductance. The alteration of reflected light is the result of the ability of the particle film of kaolin to reflect IR, and ultraviolet radiation. Reflection of IR by kaolin can reduce canopy temperature as much as 5 C, which will reduce potential transpiration (Glenn 2016; Steiman and Bittenbender 2007)

On the contrary Javan *et al.*, 2013 indicated that sparing kaolin decreased node number, stem height and diameter of soybean plants. Support this hypothesis that dry foliage weight chlorophyll content accumulated dry weight in plant tissue were decreased significantly in the same sample. This agree with findings by AbdAllah (2019) mentioned that kaolin spraying reduced photo synthetically active radiation and UV transmission. As generally, the data obtained showed that all vegetative growth measurements were significantly increased when applied kaolin at rate 1 cm^3/L. the results may be due to the role of kaolin as clay minerals can enhance plant growth. Also it has chemically inert over a wide range of pH and a low exchangeable cation capacity (1-16 meq/100g). Moreover, Kaolin particle film applications have been used to reduce negative impacts of environmental stresses on crop plants, to suppress diseases, and to protect crops from insect pests. The development of particle film technology and its initial applications have been reviewed (Brian and John, 2008). Also, kaolin reduced leaf surface temperature and improved fruit maturation and quality of apple (Wünsche *et al.,* 2004). And reduced leaf surface temperature and increased Co_2 assimilation rates in olive (Rousso *et al.,* 2010). In tomato, kaolin application reduced the number of sunburned fruits, exhibited protective properties against insect attack (Cantore *et al.,* 2009) and influenced the physiological response to salinity (Bouri *et al.* 2014).

Concerning to foliar spraying of tocopherol recent findings have demonstrated that it can affect important physiological processes such as germination, export of photoassimilates, growth and leaf senescence, beyond their antioxidant function in photosynthetic membrane and role in plant response to abiotic stresses. The role of tocopherol in other important physiological processes remain however still very poorly understood. α-Tocopherol is a strong antioxidant that assists the transport of electrons in photosystem -II protein complex (Semida, 2016). El-Bassiouny *et al.* (2005) reported that foliar spray with α-tocopherol on faba bean plants induced increase in growth parameters, yield components, chlorophyll a, b and carotenoids content. Tocopherols play a role in a range of different physiological phenomena including plant growth and development, senescence, preventing lipid peroxidation and to interact with the signal cascade that convey abiotic and biotic signals (Baffel and Ibrahim, 2008; Soltani *et al.*, 2012). El-Quesni *et al.* (2009) reported that application of α-tocopherol increased fresh weight of shoots and roots in *Hibiscus rosa sineses* L. plants. The same trend in *Calendula officinalis* L. plants by (Soltani *et al.*, 2012). The promotive effect of α-tocopherol on growth and biochemical traits beside protection under stress was reported by El-Quesni *et al.* (2009) and Orabi *et al.* (2017).

Conclusion

From the above mention results it could be concluded that when delaying the cultivation of potatoes and exposure to high temperatures, plants can be sprayed with kaolin (3 times beginning 35 days after tuber seed at 10 days interval) at concentration 10000 ppm (10cm^3/L) or Kaolin incorporated with α-tocopherol at levels 5 cm^3/L kaolin + 50 ppm α-tocopherol, for improving the vegetative growth of potato plants, yield and nutritional quality. Further, its use can be promising and useful as a good agricultural practice for crop production under newly reclaimed sandy soil conditions.

Competing interest statement

The authors declare no conflict of interest.

Disclosure

Author contribution statement

Sami Hosni Mahmoud: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Ahmed M. El-Tanahy and Sameh. M. El-Sawy: Conceived and designed the experiments; Analyzed and interpreted the data

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