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Studying Effect of Nano-Silicon Spraying Process on Improved Productivity of Eggplant Grown in Arid Regions and Hot Areas

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ABSTRACT

Two field investigations were carried out on the Experimental Farm of the Faculty of Agriculture and Natural Resources at Aswan University in Aswan, Egypt, in the summer of 2021 and 2022. This study primary goal is to determine whether foliar application of nano-silicon (control, 100, 200, and 300 mg/L) is effective in mitigating heat stress during the eggplant growing season in the Aswan governorate and at three transplanting dates (1st March, 15th March and 1st April) under high air temperature conditions in arid regions. The investigated included the assessment of vegetative growth performance, yield, fruit quality the pigments of photosynthetic (chlorophyll and carotenoids) and catalase enzyme activity. Results indicated that spraying of nano-silicon topically at rate (300 mg/L) generally led to significant effects in all the studied characteristics. At the same direction, 1st March transplantation showed a strong beneficial influence on every characteristic that was examined compared to another transplanting date. Moreover, combination nano-silicon at (300 mg/L) with 1st March transplantation produced significant increases in the majority of the measures examined. Nano-silicon at 300 mg/L showed significant rises in the most studied characteristics at 15th March and 1st April compared to control. In summarize up, the results indicate suggest the potential use of foliage spraying with nano-silicon particles as a compound has a lot of potential benefits for the plant to improving eggplant growth performance and production in arid regions and hot areas.

Keywords: *Solanum melongena***,** nanosilicon**,** heat stress, transplanting dates, enzymes.

INTRODUCTION

Eggplant (*Solanum melongena* L.) is a unique vegetable that grows all over the world. It belongs to the Solanaceae family and has a developed area of 1.86 million hectares and a production capacity of 51.288 million tons. According to FAO (2022) Egyptian production ranks third globally in terms of recordkeeping, accounting for 2.8 % of global production. Anthocyanin, which is abundant in eggplant may act as a counter oxidative agent to eliminate radicals Jing *et al.* (2015). Despite being a food for the warm season heat damage is frequent in eggplant seedlings Sękara *et al.* (2016). Both biotic and abiotic variables influence the growth and yield parameters of eggplants Wang *et al.* (2014).

Transplanting date was found to have a significant impact on plant output, eggplant quality and vegetative growth Salmasi *et al.* (2006). In connection to collected solar radiation throughout the crop season, the transplanting date has an impact on plant canopy development which includes plant growth the number of leaves per plant, leaf area and the age of leaves. Improperly early or late transplanting dates resulted in reductions in root and shoot growth Rinaldi and Vonella (2006).

In many domains, nanomaterial "NMs" have proven to be a useful solution to a number of creative and environmental problems Ansari and Husain (2012). Furthermore, compared to mass silicon, nano-silicon has a larger surface area, more pronounced surface reactivity, solubility and a variety of other broadly defined surface features Qados and Moftah (2015). According to Wang *et al.* (2009) molecule size is specifically thought to be possibly the most important factor influencing molecule grasp take-up and transportation into plant cells.

Furthermore, nanoparticles work with plant cells to facilitate the passage of different substances that regulate some physiological cycles and plant digestion Giraldo *et al.* (2014). Nanoparticles may accelerate seed germination and increase plant metabolism Alghuthaymi *et al.* (2015). Nano-particles, like silicon (Si) are well known for having positive effects on the physiological processes and growth of plants. Nanoparticles might lessen the biotic stress that plants experience according to Yadav *et al.* (2014). According to Teshome *et al.* (2020) climate changes have also led to increased drought, salinity, and high temperatures to increase losses in agricultural production. Because of all these issues we now have to look for other ways to reduce the effects of biotic stress and improve the quantity and quality of food that is produced. Also, Wang *et al.* (2022) mentioned that silica nanoparticles have been demonstrated to stimulate plant growth and create plant tolerance against biotic stress. Si-NPs improve supplement accessibility, stomatal conductance and water uptake which stimulate the growth of photosynthesis. Si-NPs also increase the uptake of Si which leads to the articulation of OsNAC proteins which are known to regulate pressure proline and sugar aggregation.

Elevated temperature is an outcome of global warming as reported in the fourth assessment report of IPPC (Intergovernmental Panel on Climate Change) which is the most serious concern in achieving goals of food security Hoegh-Guldberg and Bruno (2010). During different stages

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of plant growth and development, crop damages have been observed to increase by 10–15% with every degree Celsius of temperature change Upadhyaya *et al.* (2011). According to Kumar *et al.* (2011) genotype treatment period and temperature elevation (degrees) affect how much a high temperature stress inhibits plant growth. Symptoms of sun burn on plant leaves and fruit appear as burnt leaves, blemished twigs dissipated and disfigured inflorescence causing poor quality eggplant Goraya and Asthir (2016). High temperature is detrimental to plant cell membranes, osmotic balance amino acids and peptide concentrates Zinn *et al.* (2010). Most plants have developed complex systems for protection against damage some of these systems demand external stimuli or an elicitor to make resistant systems fully functional these may be plant hormones or their synthetic analogues Hasanuzzaman *et al.* (2013). The aim of study is study the effect of foliar applications of nanosilicon and different date of transplanting on eggplant growth, yield and quality.

MATERIALS AND METHODS

Locations and configuration of the experiments:

In the summer of 2021 and 2022 two field experiments were carried out at the faculty of agriculture and natural resources' experimental farm at Aswan University in Aswan, Egypt. The site's coordinates are 23°59′56″N, 32°51′36″E, with an average elevation of 85 meters above sea level. The purpose of this study was to look into the production of eggplant cv. "Classic" grown in dry regions with three transplanting date and four levels of silicon nanoparticles. CV. of eggplant genotype. "Classic" was acquired from the Ministry of Agriculture and Land Reclamation's Vegetable Breeding Department at The Agricultural Research Center's Horticulture Research Institute. Before transplanting, random soil samples (0 - 30 cm depth) from different places of the planting field were collected and some important chemical and physical properties were analyzed according to Page *et al.* (1982) and Jackson (1973). These properties are showed in Table (1).

On 1st, 15th March, and 1st April, seedlings (45day age) were transplanted on one side of the ridge at distance 0.5 m and 1.5 m width of the ridge respectively. This resulted in 5600 plants per feddan.

Table 1. Several of the experimental site's physical and chemical characteristics for the two experiment seasons (2021 and 2022)

"Property of soil" *	Seasons 2021	2022
Physical attributes		
(Clay %)	3.10	3.40
(Silt %)	0.00	0.00
(Sandy %)	96.90	96.60
(type texture)	Sandy	Sandy
Chemical attributes		
1 soil's soluble cations: One extract of water		
Ca++	3. 08	3.11
Mg++	1.04	1.07
P +	0.85	0.87
Na +	0.78	0.80
Soluble anions in one soil: one extract of water		
CO_3^{-}	0.00	0.00
HCO_3^{-}	7.21	7.26
Cl^{-}	3.60	3.69
SO_4^{-}	0.43	0.46
pH "1:1 soil suspension"	7.55	7.60
EC "dS/cm" at 25°C	0.34	0.32
N available "mg/kg soil"	128.52	129.02
P available "mg/kg soil"	8.76	9.01
K available "mg/kg soil"	176.25	169.01

*The Department of Natural Resources at Aswan University's Faculty of Agriculture and Natural Resources in Egypt conducted the analyses.

Under the conditions of the experimental site all additional agro-management procedures including fertilization, irrigation, weed control, pest and disease control, and commercial eggplant production were carried out as needed in accordance with the Egyptian Ministry of Agriculture's recommendations.

Meteorological data:

The meteorological data of the pilot site during the current study period are placed in Table (2) which shows the climatic data of Aswan province according to the National Oceanic and Atmospheric Administration (NOAA). The highest temperature was 52°C in July and the lowest standard temperature was -2.4°C in January.

Table 2. The maximum, minimum and average air temperatures per week during the two seasons of 2021and 2022

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Year
Record high °C	35.4	38.6	44.1	46.2	48.6	50.7	52.0	49.0	52.0
Mean daily maximum °C	23.2	25.8	30.4	35.6	39.6	41.7	41.8	41.8	34.3
Daily mean °C	16.4	18.7	22.8	28.1	32.1	34.5	35.2	35.1	27.1
Mean daily minimum °C	10.1	11.8	15.6	20.2	24.7	26.8	27.9	27.8	20.1
Record low °C	−2.3	3.9	5.1	7.9	13.5	18.8	20.1	20.1	−2.4
Average rainfall mm	0.1	0.0	0.5	0.3	0.1	0.0	0.0	0.0	2.0
Average rainy days (≥ 1 mm)	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.4
Average relative humidity (%)	41	33	25	20	18	17	19	22	26.4
Average dew point °C	1.4	0.1	0.0	0.6	2.3	3.2	5.8	7.3	3.5
Mean monthly sunshine hours	298.1	281.2	321.5	316.3	346.9	363.3	374.7	359.7	3,862.9

The design and methods of experimental

1. Nano-silicon treatment

The four concentrations of silicon nanoparticles that were applied as "control, 100, 200, and 300 mg/L" were sprayed four times; at 20, 35, 50 and 65 days after transplanting. Distilled water was sprinkled on the control plants. Every foliar spraying was done to thoroughly coat the entire plant's foliage so that it would run off early in the morning.

Producing silica nanoparticles

To remove soil and contaminants the collected sugar cane husks were first cleaned with tap water. They were then dried in a broiler for twenty-four hours at sixty ˚C. Finally, they were burned for six hours at six hundred ˚C in an electric heater with no treatment. It was possible to synthesize silica nanoparticles "SiNPs" according to the convention Ghorbani *et al.* (2015). Formation of silica nano-particles Five grams of extracted silica from sugar cane husks was dispersed in 500 milliliters of 0.5M NaOH solution and heated to 100 °C for four hours while vigorously mixed to dissolve the silica and create sodium silicate.

2.Time of transplanting treatments

In order to investigate the effects of heat stress and transplanting date on the quality and yield of eggplants, seedlings were transplanted three times on 1st March, 15th March and 1st April. Twelve treatments "three transplanting date and four levels of silicon nanoparticle concentration" were used in the experiment. A strip plots design with three replications. Transplanted date treatments were arranged in horizontal plots while foliar applications with nanoparticles were assigned in vertical plots. Every sub-plot had three ridges, each measuring 4 m in length and 1.50 m in breadth, for a total plot size of 18 m^2.

Collecting experimental data

1. Characteristics of vegetative growth and root system:

Following an 85-day after transplanting five plants per from each replicate were selected at random for the purpose of recording the following growth attributes: plant height (cm), plant fresh weight (g), number of branches, root length (cm) and root weight (g). Additionally, leaf dry weight (g) was measured at 70˚ C in an electrical oven until the weight remained consistent.

2. Yield and physical fruit characters

The fruits were harvested when they reached consumer maturity twice a week during the harvesting season for a total of twenty picking times. Average fruit weight (g), number of fruit per plant, total fruit (kg/plant) and total yield (ton/fed.) were calculated. Fruit length (cm), fruit diameter (cm) and fruit shape index were calculated using the formula below:

$$\textbf{Shape index} = \frac{\textbf{Fruit length}}{\textbf{Fruit diameter}}$$

3. Structure of chemicals:

A. The pigments that are photosynthetic

Following 75 days of transplanting, the amount of chlorophyll a, b, total chlorophyll a + b and carotenoids in the leaf was measured using a spectrocolorimeter starting with the fifth leaf from the growing tip as per Lichtenthaler's (1987) description.

B. Catalase activities:

1. Making the enzyme extract

Liquid N_2 was used to finely grind 0.5 g of leaves, which were subsequently homogenized in 5 ml of 100 mM potassium phosphate buffer (pH 7.8) that contained 0.1 g of polyvinyl pyrrolidone and 0.1 mM ethylendiamine tetraacetic acid. After centrifuging the homogenate for 10 minutes at 4 °C at 18000 rpm, the supernatants were collected and used in the catalase (CAT) and guaiacol peroxidase (POD) tests. The enzyme activities were measured colorimetrically at 20 °C using a Unico UV-2100 spectrophotometer. Units/mg protein was used to express the particular activity. Utilizing a standard curve made of bovine serum albumin, the Lowery *et al.* (1951) method was used to estimate the protein concentration in the enzyme extract.

2. Catalase measures (unit mg^{-1} $protein^{-1}$):

Enzyme activity followed Chance and Maehly's (1995) technique. The catalase activity was measured using a reaction solution that contained 0.1 mL of gum solution, pH 7, 5.9 mM hydrogen peroxide and 50 mM phosphate buffer. The sample was added to start the reaction and after 20 seconds the absorbance at 240 nm was measured. An absorbance variation of 0.01 units/ min was indicative of one unit of catalase enzyme activity.

C. Contents of the N, P, K and Si leaves:

The techniques outlined by Okalebo *et al.* (2002), Pregl (1945), Murphy and Riley (1962) and APHA (1992) were utilized to determine it in plant tissues.

4. Analyzing data with statistics

All of the gathered data was statistically assessed using the MSTAT-C tool which Bricker (1991) created. After data were subjected to analysis of variance procedures, means were compared using the L. S. D. test at the 0.05 level of probability in accordance with Snedecor and Cochroni (1973).

RESULTS AND DISCUSSION

Characteristics of vegetative growth and root system

The data in Table 3 makes it clear that all plant growth increased in the early transplanting dates, with the initial transplanting date, or 1st March, showing a faster rate of growth than the transplanting dates of 15th March and 1st April, which correspond with rising temperatures. These outcomes are consistent with Faiz *et al.* (2024). The optimum time to transplant is on the 1st March since sunburned leaves and dispersed twigs are a sign of sunburn on plant leaves in late planting date Goraya and Asthir (2016). Plant cell membranes, osmotic equilibrium and concentrations of amino acids and peptides are all negatively impacted by high temperatures Zinn *et al.* (2010). Heat stress accelerates transpiration because it gives water molecules energy to escape from the leaf surface; hence, fast water loss from the plant surface causes the organ to become dehydrated Mazorra *et al.* (2002). Moreover, heat stress inhibits eggplant plant growth Li *et al.* (2011).

In (Table 3) the foliar spray of 300 mg/l nanosilicon produced the highest significant mean value of the studied vegetative growth characters, such as plant height, number of branches per plant, fresh foliage, dry weights, root length and root weight. The application of nanoparticles as biostimulants, nanofertilizers can help to promote growth and it has been highlighted as an essential strategy to control the negative effects of abiotic stress. These results are demonstrated by those obtained by Gonzalo Tortella (2023) on eggplant and Eman *et al.* (2022) on tomatoes. These outcomes are attributable to the fact that nanoparticles (NP_S) can act as miracle cures by targeting particular cellular organelles in plants and releasing their content to improve overall plant growth and the characteristics of (NP_S) particles include pore size, particle morphology, chemical properties, and concentration Ma *et al.* (2010). Furthermore, nanoparticles work with plant cells to facilitate the passage of different substances that regulate some physiological cycles and plant digestion Giraldo *et al.* (2014). The fresh and dry weight of chickpea roots are enhanced by nanoparticles, according to research by Farhana *et al.* (2022).

Significant variations were seen in all vegetative development parameters when the quantities of nanosilicon particles and transplanting time were analyzed in eggplant plant studies. When compared to the control, 1st March eggplant plants that were sprayed with 300 mgl^{-1} nanosilicon showed the highest significant mean values for all plant growth characters in both growing seasons. However, the plants treated with a different concentration of nanosilicon showed improved growth characteristics when transplanted on 15th March and 1st April. These findings can be attributed to improve photosynthetic proficiency maintenance, which is further enhanced by optimal stomatal conductance Jia *et al.* (2021). SilicaNPs immediately affect plant growth, which makes them highly promising for agriculture El-Ashry (2022). According to Zainab (2016) on tomatoes, the gene expression patterns linked to exposure to N-SFi indicated that N-Si might play a role in the plant's reaction to stress, indicating that N-Si could be helpful in enhancing plants' stress tolerance. According to a review by Wang *et al.* (2022) silica nanoparticles have been demonstrated to support plant growth in the face of stress.

Table 3. Effect of transplanting dates and foliar application of nano-silicon particles on eggplant vegetative growth characters and root system during summer seasons of 2021and 2022.

Treatments		Plant height (cm)		plant fresh weight (g)		No. of branch/plant		plant dry weight (g)		Root length cm		Root weight g/plant	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Transplanting date													
1st March		81.28	79.20	427.1	423.8	7.927	7.230	59.82	59.95	27.49	24.93	145.9	141.5
15th March		78.47	75.75	409.5	405.3	7.527	6.806	57.36	57.32	25.44	23.14	134.8	129.2
1st April		68.58	66.20	348.6	346.3	5.510	4.652	48.82	48.98	21.84	19.50	118.2	114.6
L.S.d.0.05		0.90	1.49	4.96	2.7	0.300	0.320	0.69	0.39	0.38	0.38	3.3	2.2
Nano-Si particles "NSp" (mg/L)													
Control		60.70	58.05	271.7	269.6	5.803	4.832	38.06	38.13	20.61	17.84	101.7	97.1
100 mg/L		72.10	69.82	392.5	389.4	6.471	5.824	54.98	55.09	24.25	21.44	126.9	121.4
200 mg/L		83.64	80.69	448.9	445.7	7.603	6.729	62.87	63.04	26.52	23.69	142.2	138.9
300 mg/L		88.00	86.29	467.1	462.4	8.073	7.531	65.42	65.40	28.30	27.12	161.0	156.3
L.S.d.0.05		1.00	1.82	3.4	7.6	0.520	0.690	0.48	1.07	0.65	0.80	5.3	4.3
(Transplanting date) X (NSp mg/L)													
1st March	Control	63.18	60.78	286.6	285.3	6.227	5.073	40.15	40.35	23.05	20.17	112.1	108.4
	100 mg/L	76.25	74.04	418.9	414.7	7.427	6.717	58.67	58.65	26.36	23.83	138.0	131.2
	200 mg/L	91.50	88.80	482.4	479.6	8.927	8.347	67.56	67.84	28.59	25.94	153.7	148.9
	300 mg/L	94.18	93.15	520.5	515.7	9.127	8.783	72.90	72.94	31.94	29.78	179.8	177.4
15th March	Control	60.67	58.05	272.7	270.4	5.757	5.110	38.20	38.24	20.87	17.71	99.5	94.8
	100 mg/L	72.54	70.19	401.3	397.4	6.787	6.143	56.21	56.21	25.35	22.35	131.5	127.1
	200 mg/L	89.27	86.11	479.5	475.0	8.637	7.647	67.16	67.18	27.61	25.04	145.1	141.1
	300 mg/L	91.40	88.64	484.5	478.3	8.927	8.323	67.86	67.66	27.91	27.43	163.0	153.6
1st April	Control	58.25	55.31	255.9	253.0	5.427	4.313	35.85	35.79	17.90	15.63	93.4	88.2
	100 mg/L	67.50	65.24	357.3	356.3	5.200	4.613	50.05	50.40	21.05	18.13	111.1	105.9
	200 mg/L	70.14	67.17	384.8	382.5	5.247	4.193	53.89	54.10	23.37	20.07	127.9	126.8
	300 mg/L	78.41	77.08	396.2	393.2	6.167	5.487	55.49	55.62	25.04	24.14	140.3	137.8
L.S.d.0.05		1.00	1.99	9.9	5.5	0.550	0.637	1.39	0.77	0.75	0.76	6.7	4.3

Yield and physical fruit characters

Tables (4 and 5) also indicates that transplanting date exerted profound and significant effects on fruit length (cm), fruit diameter (cm), average fruit weight (g), total fruit yield (kg/plant) and total yield (ton/fed.) characters in both growing seasons. Transplanting date significantly increase all yield and physical fruit characters but the shape index significantly increased in first season only and insignificantly increased in the second season respectively. The optimal transplanting date was on1st March as opposed to March 15th and 1st April when high temperatures were experienced and decreased all yield and physical fruit characters. Data in (Table 2) showed that after February ends the temperature was rises quickly. According to Li *et al.* (2011) heat stress reduces productivity and has an impact on fruit quality and indicated that the ideal temperature range for eggplant species is between 22 and 30 ºC. Thus, the transplanting date on 1st March is within the appropriate temperature for the transplanting of eggplants which improves yields and its components compared with the dates of 15th March and 1st April when the temperature increased and the yield declined. These results are consistent with what the Faiz *et al.* (2024) found in eggplant yield when transplantation at 1st March compared to the lowest yield at 1st April.

Data in (Tables 4 and 5) showed that the spray with nanosilicon levels improved and significantly effects on fruit length, fruit diameter, shape index, average fruit weight kg/plant and total fruit yield ton/fed. during both seasons. The greatest dosage of 300 mg/L nanosilicon treatment significantly increased all yield parameters. The current study suggest that the increased of vegetative development parameters as previously reported (Table 3) may have contributed to the increased eggplant fruit production with spray by 300 mg/L nano-silicon compared to control. Additionally, these increases might be related to the function of nano-silicon in reducing heat stress effects. These results are consistent with those of studies conducted by Eman *et al.* (2022) on tomato and Avdeenko and Avdeenko (2022) on eggplant enhancement of fruit quality by nano-silicon. According to research by Marodin *et al.* (2014) nanoparticles differ from their bulk form in that they are smaller (less than 100 nm) and have a larger surface area which allows them to more readily enter plants and take part in their metabolisms.

Furthermore, the spraying plants which transplanted in1st March,15th March and 1st April with the maximum concentration of nano-silicon at (300 mg/L) led to a significant increase in fruit length (cm), fruit diameter (cm), average fruit weight (g), total fruit yield (kg/plant) and total yield (ton/fed.) characters in both seasons comparing to control. The best interaction was spraying with nano-silicon (300 mg/L) on transplanting date at 1st March. These findings are in harmony with those obtained by Helal *et al.* (2022) who reported that Si nanoparticles were planted at normal sowing dates and late sowing dates (heat stress) and that these treatments significantly reduced the observed decline in yield and the heat stress intensity index value at late sowing dates as well as enhanced wheat yield quality. Accordingly, it is possible that the increased fruit yield per plant, total fruit yield per plant, and average fruit weight in this study are caused by the nano silicon which is one of the elements that helps plants become more resistant to heat stress Saber *et al.* (2021).

Table 4. Effect of transplanting dates and foliar application of nano-silicon particles on eggplant physical fruit characters during summer seasons of 2021and 2022.

Treatments		Fruit length (cm)		Fruit diameter (cm)		Shape index	
		2021	2022	2021	2022	2021	2022
Transplanting date							
1st March		16.20	15.66	25.54	25.44	0.635	0.615
15th March		15.83	15.30	24.98	24.41	0.634	0.625
1st April		14.57	14.15	23.45	22.55	0.621	0.629
L.S.d.0.05		0.13	0.62	0.69	0.56	0.004	n.s
Nano-Si particles "NSp" (mg/L)							
Control		13.88	13.33	23.04	22.17	0.603	0.604
100 mg/L		15.36	14.69	24.27	23.58	0.634	0.624
200 mg/L		16.28	15.59	25.16	25.04	0.648	0.623
300 mg/L		16.62	16.47	26.17	25.74	0.636	0.640
L.S.d.0.05		0.15	0.83	0.90	0.71	0.0038	0.0021
(Transplanting date) X (NSp mg/L)							
1st March	Control	14.49	13.83	23.62	23.19	0.614	0.597
	100 mg/L	15.89	15.39	24.83	24.90	0.642	0.618
	200 mg/L	16.89	16.03	26.09	26.18	0.649	0.612
	300 mg/L	17.53	17.37	27.63	27.47	0.636	0.632
15th March	Control	14.49	13.73	23.80	23.40	0.610	0.586
	100 mg/L	15.57	14.64	24.28	23.25	0.642	0.632
	200 mg/L	16.46	15.93	25.31	25.10	0.651	0.635
	300 mg/L	16.81	16.75	26.52	25.90	0.635	0.647
1st April	Control	12.66	12.44	21.69	19.93	0.585	0.628
	100 mg/L	14.62	14.05	23.69	22.60	0.618	0.624
	200 mg/L	15.48	14.82	24.08	23.82	0.644	0.623
	300 mg/L	15.51	15.28	24.36	23.86	0.638	0.641
L.S.d.0.05		0.27	0.16	1.34	n.s	0.009	n.s

Table 5. Effect of transplanting dates and foliar application of nano-silicon particles on eggplant yield characters during summer seasons of 2021and 2022.

Treatments		Average fruit weight (g)		No. of fruit /plant		Total fruit yield (kg/plant)		Total yield ton/fed	
		2021	2022	2021	2022	2021	2022	2021	2022
Transplanting date									
1 March		267.6	291.3	13.24	11.47	3.596	3.393	20.13	19.00
15 March		248.5	266.2	12.69	11.03	3.206	2.955	17.81	16.55
1 April		218.3	227.2	11.50	9.86	2.537	2.262	14.21	12.67
L.S.d.0.05		2.14	8.91	0.226	0.373	0.0528	0.0755	0.386	0.422
Nano-Si particles "NSp" (mg/L)									
Control		200.5	219.8	10.72	8.87	2.197	1.947	12.11	10.90
100 mg/L		237.3	260.1	12.31	10.26	2.927	2.666	16.39	14.93
200 mg/L		255.9	269.7	13.21	11.52	3.392	3.121	18.99	17.48
300 mg/L		285.5	296.6	13.67	12.49	3.936	3.747	22.04	20.98
L.S.d.0.05		2.76	24.15	0.176	0.899	0.0532	0.0972	0.273	0.543
(Transplanting date) X (NSp mg/L)									
1st March	Control	210.4	248.3	11.42	8.987	2.401	2.219	13.45	12.43
	100 mg/L	247.4	278.9	12.89	10.77	3.189	2.991	17.86	16.75
	200 mg/L	284.0	306.5	13.82	11.96	3.924	3.665	21.98	20.52
	300 mg/L	328.5	331.4	14.82	14.17	4.867	4.696	27.26	26.30
15th March	Control	211.4	230.9	11.16	9.333	2.467	2.130	13.22	11.93
	100 mg/L	242.8	266.6	12.5	10.39	3.034	2.759	16.99	15.45
	200 mg/L	254.1	268.2	13.39	11.85	3.402	3.179	19.05	17.80
	300 mg/L	285.5	299.2	13.74	12.55	3.921	3.754	21.96	21.02
1st April	Control	179.6	180.3	9.59	8.303	1.722	1.492	9.64	8.36
	100 mg/L	221.6	234.8	11.55	9.617	2.559	2.247	14.33	12.59
	200 mg/L	229.5	234.3	12.41	10.74	2.848	2.518	15.95	14.10
	300 mg/L	242.6	259.1	12.44	10.76	3.019	2.790	16.90	15.62
L.S.d.0.05		4.28	4.31	0.452	0.747	0.1057	0.1511	0.773	0.844

Structure of chemicals:

A. The pigments those are photosynthetic

Data in Table 6 presents the effects of nano-silicon, transplanting date along with their interaction on photosynthetic characters as chlorophyll a, b, total chlorophyll (a+b) and carotenoids **(**mg/g fresh weight) during both seasons.

Table 6 illustrates the impact of varying levels of transplanting date on various eggplant photosynthetic pigments during the 2021 and 2022.This includes measurements chlorophyll a, b, total chlorophyll (a + b) and carotenoids (mg/g fresh weight) content. The findings indicate that the 1st March significantly enhanced all photosynthetic pigments parameters in the first and second season respectively. The findings aligned with those obtained by Faiz *et al.* (2024) who reported that these stress-tolerant eggplant genotypes in the first transplantation in March showed maximal chlorophyll concentrations. It is well known that plant chlorophyll pigment is essential to many metabolic processes during abiotic stress. Evaluation of chlorophyll is thought to be a helpful method for determining how environmental conditions affect plants. Reduced growth low stress tolerance and a fall in plant productivity are all strongly correlated with chlorophyll degradation Kalaji (2018). According to Sami Hannachi *et al.* (2022) all eggplant cultivars showed a trend toward a decrease in plant pigments when exposed to heat stress. Carotenoids use their powerful antioxidant capacity to play a critical role in inhibiting photooxidation Tripathi *et al.* (2022). Depending on the eggplant cultivar the degree of chloroplast impairment may account for this. Chlorophyll content declines have been linked to many stressors in numerous species including tomato by Raja *et al.* (2020). Carotenoids' ability to defend the body makes them more vulnerable to deterioration in stressful situations which can lead to cellular damage and pigment obstruction. Heat-induced generation of reactive oxygen species (ROS) damages DNA and chlorophyll a and b Sharma *et al.* (2012).

Additionally, spraying of nanosilicon concentration boosted photosynthetic pigments. (300 mg/L) of nano-silicon produced the greatest mean values for eggplant photosynthetic pigments in both seasons including chlorophyll a, b, total chlorophyll (a + b) and carotenoids (mg/g fresh weight). These results are consistent with those of Saber Avestan *et al.* (2019), who found that strawberry plants treated with 100 mg/L of nano-silicon dioxide were better able to sustain the levels of carotenoid and chlorophyll in their epicuticular tissues. Similarly, Haghighi and Pessarakli (2013) showed that mesophyll conductance a component of photosynthesis was enhanced by nano Si particles. Because silica nanoparticles directly affect plant growth they offer enormous agricultural potential El-Ashry *et al.* (2022). According to Priyanka Dhakate *et al.* (2022) silicon nanoforms are said to promote photosynthetic rate enhancement.

Table 6 displays the interaction influences of transplantation date and levels of nanosilicon concentration NSp (mg/L) on various photosynthetic pigments characteristics during both the 2021 and 2022 growth seasons. All previously mentioned parameters exhibited significant increases with the successive rise in transplanting date levels at each concentration of nano-silicon levels. Particularly, the combination of 1st March and 300 mg/L nano-silicon resulted in the highest significant mean values for chlorophyll a, b, total chlorophyll (a + b) and carotenoids (mg/g fresh weight) then followed by the interaction of 300 mg/L nano-silicon with 15th March then with 1st April compared to the control in both seasons. In contrast, during both seasons the untreated plants showed the lowest mean values. Haghighi and Pessarakli (2013) have proposed that plants growing under stressed situations may benefit from higher photosynthetic rate, which is another benefit of nano-silicon.

Table 6. Effect of transplanting dates and foliar application of nano-silicon particles on eggplant pigments photosynthetic during summer seasons of 2021and 2022.

Treatments		Chlorophyll a		Chlorophyll b		Total chlorophyll (a+b)		Carotenoids mg/g fresh weight	
		2021	2022	2021	2022	2021	2022	2021	2022
Transplanting date									
1 March		1.694	1.669	0.713	0.736	2.407	2.404	0.815	0.790
15 March		1.389	1.390	0.620	0.623	2.008	2.012	0.744	0.719
1 April		1.174	1.137	0.454	0.493	1.627	1.630	0.675	0.640
L.S.d.0.05		0.071	0.065	0.027	0.031	0.091	0.076	0.037	0.029
Nano-Si particles "NSp"(mg/L)									
Control		0.897	1.043	0.444	0.426	1.341	1.460	0.547	0.522
100 mg/L		1.265	1.250	0.581	0.597	1.846	1.840	0.660	0.636
200 mg/L		1.650	1.542	0.634	0.700	2.284	2.240	0.848	0.817
300 mg/L		1.864	1.760	0.722	0.745	2.585	2.505	0.922	0.901
L.S.d.0.05		0.083	0.071	0.032	0.037	0.120	0.096	0.041	0.035
(Transplanting date) X (NSp mg/L)									
1st March	Control	1.152	1.275	0.542	0.496	1.694	1.771	0.593	0.568
	100 mg/L	1.643	1.479	0.691	0.724	2.334	2.203	0.714	0.682
	200 mg/L	1.810	1.787	0.761	0.818	2.571	2.605	0.915	0.885
	300 mg/L	2.172	2.135	0.858	0.904	3.030	3.039	1.036	1.061
15th March	Control	0.864	1.140	0.499	0.514	1.363	1.654	0.556	0.535
	100 mg/L	1.302	1.249	0.601	0.596	1.903	1.845	0.659	0.638
	200 mg/L	1.620	1.482	0.651	0.680	2.271	2.162	0.858	0.830
	300 mg/L	1.770	1.690	0.727	0.700	2.497	2.390	0.901	0.871
1st April	Control	0.676	0.716	0.292	0.267	0.968	0.983	0.492	0.464
	100 mg/L	0.850	1.023	0.451	0.471	1.301	1.494	0.608	0.587
	200 mg/L	1.521	1.357	0.491	0.603	2.012	1.960	0.770	0.737
	300 mg/L	1.650	1.455	0.580	0.631	2.230	2.086	0.829	0.772
L.S.d.0.05		0.096	0.084	0.051	0.067	0.132	0.105	0.073	0.054

B. Activity of catalase enzyme

The result in Table 7 displays reveal that the 1st April (46.2 °C) led to significant increases in catalase enzyme (unit mg^{-1} protein) in eggplant compared to another transplanting date levels in 1st March and 15th March. These findings are consistent with those of Faiz *et al.* (2024) who observed that the catalase (CAT) enzyme activity on eggplant increased considerably during the third transplanting or1st April. According to Hira *et al.* (2020) when heat stress (45°C) occurs in eggplant, catalase's antioxidant activity increases in all genotypes.

The primary effects of nanosilicon on the activity of catalyze enzyme are shown in Table 7. The parameters cited showed a considerable decrease in values in plants treated with nanosilicon. The plants that were left untreated had the highest value while the lowest were obtained from treatment with 300 mg/L. These outcomes align with similar results reported by Mahmoud and Sweaty (2020) showed that "SiNPs" significantly enhanced tomato plant enzymatic detoxification systems, with this effect being more obvious in the roots than the shoots.

The findings in (Table 7) make it evident that the parameters indicated were strongly impacted by the application of silicon nanoparticle concentration with transplant date in both seasons. During both seasons, the application of 300 mg/L and various transplanting date had the lowest values when compared to the control treatments. According to Gonzalo Tortella *et al.* (2023) nanosilicon has been identified as a crucial instrument for managing the negative consequences of abiotic stress. Tripathi *et al.* (2022) found that the nanoparticles have also demonstrated the capacity to be employed as inducers of the manufacture of phytohormones controlling plant development and metabolism under biotic stress and reactive oxygen species (ROS) suppression in plants is summed up by their transcriptional regulation of stress-related genes which promotes plant growth and development. They primarily mitigate the stress response by inducing the regulation of the plant antioxidant systems and endogenous plant hormones. Additionally, the chemical and morphological instruction of leaves and roots is crucial for the uptake and translocation of nanoparticles into the plant system, once inside the system the nanoparticles can modify physiological, biochemical and morphological characteristics to enhance the plant's ability to withstand biotic stress Sun *et al.* (2021)

. Contents of the N, P, K, and Si leaves

Data presented in Table 7 cleared that the chemical constituents of eggplant influenced by transplanting dates and concentration of nano-silicon particles along with their combinations during 2021 and 2022.

Based on Table 7 data findings the transplanting date of 1st March produced the greatest mean values for the chemical ingredients of eggplant such as N, P, K, and Si (%). Showed the lowest significant mean values in both seasons when compared to control plants.

Data illustrated in Table 7 there is a direct proportionate link between the concentrations of nanosilicon particularly at 300 mg/L during both seasons and the chemical composition of leaves N, P, K and Si%. Spraying eggplant with 300 mg/L of nanosilicon showed increased mean values of N, P, K and Si% contents in their leaves during both research seasons. As mentioned to studies by Tondey *et al.* (2021) on potatoes nanotechnologies are very useful in agriculture and can even increase plant nutrition. Consequently to Mahmoud and Sweaty (2020) SiNPs raised the amount of Si in tomato plants' roots and shoots. Moreover, Sonali and Jeong (2014) demonstrated that silicon foliar spraying has been demonstrated to improve plant leaf quality and reduce nutritional imbalance in plants. Priyanka Dhakate *et al.* (2022) reported that silicon nanoforms are said to increase nutritional intake.

In order to, the combination of the transplanting date levels and different nano-silicon particles concentration brought about a significant increase in chemical composition of leaves N, P, K and Si% content.

The combination of the highest concentrations of nanosilicon particles at 300 mg/L with 1st March transplanting eggplant brought about a significant increase leaf N, P, K and Si content compared to unsprayed plants. Moreover, the interaction between nanosilicon particles at 300 mg/L with other transplanting date 15th March and 1st April present positive increasing in leaf N, P, K and Si content compared to control. These findings are consistent with research on sage plants conducted by Mahmoud and Sweaty (2020) which showed that the addition of (n-Si) improved the nutritional value of potatoes after stress. According to Eman *et al.* (2022) foliar treatment of nano-silicon under stress resulted in significantly greater leaf mineral contents N, P, and K in commercial tomato varieties.

Table 7. Effect of transplanting dates and foliar application of nano-silicon particles on eggplant catalase enzyme activity and chemical characters during summer seasons of 2021and 2022.

Treatments		Catalase (unit mg^{-1} protein)		N %		P %		K %		Si %	
		2021	2022	2021	2022	2021	2022	2021	2021	2021	2022
Transplanting date											
1 March		47.57	49.30	2.598	2.536	0.387	0.352	2.728	2.598	2.508	2.446
15 March		54.43	55.39	2.340	2.276	0.329	0.311	2.470	2.340	2.250	2.186
1 April		61.99	64.19	2.119	2.001	0.301	0.276	2.249	2.120	2.029	1.911
L.S.d.0.05		1.37	1.33	0.091	0.087	0.028	0.026	0.097	0.092	0.096	0.084
Nano-Si particles "NSp"(mg/L)											
Control		71.04	74.33	1.381	1.317	0.299	0.274	1.511	1.381	1.291	1.227
100 mg/L		57.38	62.22	2.378	2.246	0.313	0.288	2.508	2.378	2.288	2.156
200 mg/L		50.80	50.89	2.727	2.644	0.348	0.318	2.857	2.727	2.637	2.554
300 mg/L		39.43	37.73	2.923	2.877	0.395	0.372	3.053	2.924	2.833	2.787
L.S.d.0.05		1.45	1.41	0.111	0.098	0.032	0.028	0.117	0.112	0.121	0.117
(Transplanting date) X (NSp mg/L)											
1st March	Control	63.85	70.77	1.540	1.483	0.329	0.304	1.670	1.540	1.450	1.393
	100 mg/L	51.94	54.37	2.580	2.513	0.350	0.327	2.710	2.580	2.490	2.423
	200 mg/L	44.07	42.28	2.950	2.883	0.392	0.342	3.080	2.950	2.860	2.793
	300 mg/L	30.41	29.75	3.320	3.263	0.477	0.435	3.450	3.320	3.230	3.173
15th March	Control	70.25	74.26	1.380	1.323	0.291	0.266	1.510	1.380	1.290	1.233
	100 mg/L	57.52	59.97	2.390	2.263	0.307	0.280	2.520	2.390	2.300	2.173
	200 mg/L	50.63	49.74	2.750	2.703	0.337	0.324	2.880	2.750	2.660	2.613
	300 mg/L	39.32	37.56	2.840	2.813	0.381	0.374	2.970	2.840	2.750	2.723
1st April	Control	79.03	77.96	1.223	1.143	0.277	0.251	1.353	1.223	1.133	1.053
	100 mg/L	62.67	72.30	2.163	1.960	0.284	0.258	2.293	2.163	2.073	1.870
	200 mg/L	57.71	60.63	2.480	2.347	0.315	0.287	2.610	2.480	2.390	2.257
	300 mg/L	48.56	45.87	2.610	2.553	0.328	0.308	2.740	2.613	2.520	2.463
L.S.d.0.05		1.53	1.47	0.121	0.117	0.046	0.042	0.119	0.114	0.131	0.121

CONCLUSION

According to this study, foliar spraying 300 mg/L of nano-Si particles could improve the quality and production of eggplant plants grown in arid climates and hot areas. Additionally, when compared to other evaluated treatment 1st March transplanting produced the highest production and quality, particularly when treated with nanosilicon particles at a dose of 300 mg/L. Treatment with nano-Si particles also reduced the effect of heat on the planting dates of 15th March and 1st April and achieved a significant increase in production and all other yield traits compared to the control. Before recommending this combination for commercial use on a broad scale, however, on-farm experiments with eggplant producers should be conducted.

In brief, the results highlight the encouraging possibilities of nanosilicon and stress the need to investigate environmentally suitable substitutes for sustainable farming methods in difficult settings.

REFERENCES

Alghuthaymi, M. A.; Almoammar, H.; Rai, M.; Said-Galiev, E. and Abd-Elsalam, K. A. (2015). Myconanoparticles: synthesis and their role in phytopathogens management. Biotechnol Biotechnol Equip., 29(2):221–236.

Ansari, S. A. and Husain, Q. (2012). Potential applications of enzymes immobilized on/in nano materials: a review. Biotechnol. Adv. 30: 512-523.

APHA. (1992). Standard Methods for Examination of Water and Wastewater. 18th Edition. American Public Health Association. Washington DC.

Avdeenko, S. S. and A. P. Avdeenko (2022). Changes in some indicators of growth, development and quality of eggplant in unheated greenhouses when using nanosilicon. IOP Conf. Series: Earth and Environmental Science 979 – 012074 IOP Publishing. doi:10.1088/1755-1315/979/1/012074

Bricker, B. (1991). MSTATC: A Micro Computer Program from the Design Management and Analysis of Agronomic Research Experiments. Michigan State University, USA.

Chance, B.; Maehly, A. C. (1955). Assay of catalase and peroxidase. Methods in Enzymology, vol. 2: 764-775. http:// dx.doi.org/10.1016/S0076-6879(55)02300-8.

El-Ashry, R.M.; El-Saadony, M.T.; El-Sobki, A.E.A.; El-Tahan, A.M.; Al-Otaibi, S.; El-Shehawi, A.M.; Saad, A.M.; Elshaer, N. (2022): Biological silicon nanoparticles maximize the efficiency of nematicides against biotic stress induced by Meloidogyne incognita in eggplant. Saudi J. Biol. Sci., 29, 920–932. [CrossRef]

Eman, G. Sayed; Abdel Wahab, M. Mahmoud; Mohamed, M. El-Mogy; Mahmoud, A. A. Ali; Mahmoud, A. M. Fahmy and Ghada, A. Tawfic (2022): The Effective Role of Nano-Silicon Application in Improving the Productivity and Quality of Grafted Tomato Grown under Salinity Stress. Horticulturae 8, 293.https:// doi. org/10.3390/horticulturae8040293https://www.mdpi. com/journal/horticulturae

Faiz, H. O. Khan; I. Ali; T. Hussainc, S. T.; Haider, T. Siddique, M. Liaquat, A. Noor, R. W. Khan, S. Ashraf, S. Rashid, A. Noreen, S. Asghar, Q. S. Anjum (2024). Foliar application of triacontanol ameliorates heat stress through regulation of the antioxidant defense system and improves yield of eggplant. Brazilian Journal of Biology, vol. 84, e253696 | https://doi.org/10.1590/1519-6984.253696

Fan, N.; Zhao, C.; Yue, L.; Ji, H.; Wang, X.; Xiao, Z.; Rasmann, S.; Wang, Z. (2022). Nanosilicon alters oxidative stress and defence reactions in plants: A meta-analysis, mechanism and perspective. Environ. Sci. Nano, 9: 3742–3755. [CrossRef].

FAO (2022): Global information system on water and agriculture. Food and agriculture organization; Rome, Italy.

Farhana; Munis, M. F. H.; Alamer, K.H.; Althobaiti, A.T.; Kamal, A.; Liaquat, F.; Haroon, U.; Ahmed, J.; Chaudhary, H.J.; Attia, H. (2022). ZnO Nanoparticle-Mediated Seed Priming Induces Biochemical and Antioxidant Changes in Chickpea to Alleviate Fusarium Wilt. J. Fungi, 8, 753. [CrossRef]

Ghorbani, F.; Sanati, A. M. and Maleki, Maryam (2015). Production of Silica Nanoparticles from Rice Husk as Agricultural Waste by Environmental Friendly Technique. Environmental Studies of Persian Gulf 2(1): 56-65.

Giraldo, J. P.; Landry, M. P.; Mcnicholas, T. P.; Jverson, N. M.; Boghossian, A. A.; Reuel, N. F.; Hilmer, A. J.; Sen, F.; Brew, J. A. and Strano, M. S. (2014). Plant nanobionics approach to augment photosynthesis and biochemical sensing. Nat. Mater. 13, 400-408.

Gonzalo T. Olga, R. Joana C. P., Paola F., Bianca de Melo S., Martín A. F., Adalberto B. and Amedea B. S. (2023): Nanoparticles as a Promising Strategy to Mitigate Biotic Stress in Agriculture. Antibiotics, 12,338. https://doi.org/10.3390/antibiotics12020338 https:// www. mdpi.com/journal/antibiotics

Goraya, G.K. and Asthir, B. (2016): Magnificent role of intracellular reactive oxygen species production and its scavenging encompasses downstream processes. Journal of Plant Biology, vol. 59, no. 3: 215-222. http://dx.doi.org/10.1007/s12374- 016-0057-9.

Faiza, H. O. Khanb, I. Alic, T. Hussainc, S. T. Haiderd, T. Siddiquee, M. Liaquatf, A. Noord, R. W. Khang, S. Ashrafh, S. Rashida, A. Noreeni, S. Asgharj, Q. S. Anjuma (2024). Foliar application of triacontanol ameliorates heat stress through regulation of the antioxidant defense system and improves yield of eggplant. Brazilian Journal of Biology, vol. 84, e253696 | https://doi.org/10.1590/1519-6984.253696.

Haghighi, M. and Pessarakli, M. (2013). Influence of silicon and nano-silicon on salinity tolerance of cherry tomatoes (*Solanum lycopersicum* L.) at early growth stage. Sci. Hortic. 161: 111–117. [CrossRef]

HasanuzzamanA, M., Nahar, K., Alam, M.M., Roychowdhury, R. and Fujita, M., (2013). Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants. International J. of Molecular Sciences, vol. 14, no. 5: 9643-9684. http://dx.doi.org/ 10.3390/ ijms 14059643. PMid:23644891.

Helal, M. N. M.; H. I. Khattab, M.M. Emam, G. Niedbała, T. Wojciechowski, I. Hammami, N. M. Alabdallah, D. B. Darwish, M. M. El-Mogy and H. M. Hassan (2022). Improving Yield Components and Desirable Eating Quality of Two Wheat Genotypes Using Si and NanoSi Particles under Heat Stress. Plants, 11, 1819. https://doi.org/10.3390/plants11141819 https:// www. mdpi.com/journal/plants

Hira F., Choudhary M., Rashad W. and Rashid A. (2020). Morphological, Physiological and biochemical responses of eggplant (*Solanum melongena* L.) seedling to heat stress. Pak. J. Agri. Sci., Vol. 57(2), 371-380;ISSN (Print) 0552-9034, ISSN (Online) 2076-0906. DOI: 10.21162/PAKJAS/20.9433. http:// www.pakjas.com.pk

Hoegh-Guldberg, O. and Bruno, J.F. (2010). The impact of climate change on the world's marine ecosystems. Science, vol. 328, no. 5985:1523-1528. http://dx. doi.org/10.1126/science.1189930. PMid:20558709.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice Hall of India. New Delhi. pp. 498.

Jia, X.; Mao, K.; Wang, Y.; Jia, X.; Huo, L.; X.; Che, R.; Gong, X. and Ma, F. (2021). Overexpression MdATG8i improves water use efficiency in transgenic apple modulating photosynthesis, osmotic balance, and autophagy activity under moderate water deficit. Hortic. Res. 8:1-15.

Jing, P., Qian, B., Zhao, S., Qi, X., YE, L., Giusti, M.M. and Wang, X. (2015). Effect of glycosylation patterns of Chinese eggplant anthocyanins and other derivatives on antioxidant effectiveness in human colon cell lines.Food Chemistry, vol. 172: 183-189. http://dx. doi.org/10.1016/j.foodchem.2014.08.100. PMid: 25442541.

Kalaji, H.M.; Rastogi, A.; Živčák, M.; Brestic, M.; Daszkowska-Golec, A.; Sitko, K.; Alsharafa, K.Y.; Lotfi, R.; Stypiński, P.; Samborska, I.A. (2018). Prompt chlorophyll fuorescence as a tool for crop phenotyping: An example of barley landraces exposed to various abiotic stress factors. Photosynthetica , 56, 953–961. [Google Scholar] [CrossRef]

Kumar, S., R. Kaur, N. Kaur, K. Bhandhari, N. Kaushal, K. Gupta, T.S. Bains and H. Nayyar. (2011). Heat-stress induced inhibition in growth and chlorosis in mungbean (*Phaseolusaureus Roxb.*) is partly mitigated by ascorbic acid application and is related to reduction in oxidative stress. Acta Physiol. Plant.33:1861-1864.

Li, Y., Z. Li, Z. Li, S. Luo and B. Sun. (2011). Effects of heat stress on gene expression in eggplant (*Solanum melongena* L.) seedlings. Afr. J. Biotechnol. 10: 18078-18084.

Lichtenthaler, H. K. (1987). Chlorophyll and carotenoids pigments of photosynthetic biomembranes. Methods Enzymols. 148: 350-382.

Lowry, O. H.; Rosebrough, N. J.; Farr, A. L. and Randall. R. J. (1951). Protein measurement with the Fohn phenol reagent J. Bio. Chem. 193: 265-275.

Ma, G.X. J.; Lee, Y. Deng and A. Kolmakov (2010). Interaction between engineered nano particles (ENPS) and plants phytotoxicity, uptake and accumulation. Sci. Total Environ.4008 (16): 3053-3061.

Mahmoud, A. W. M.; Sweaty, H.M. (2020). Comparison between commercial and nano-NPk in presence of nano- ze-polite on sage plant yield and its components under water stress. Agriculture 66, 24–39. [CrossRef]

Marodin ,J.C.; J.T.V. Resende; R.G.F. Morales; MLS Silva; A.G Galvao and D.S. Zanin(2014). Yield of tomato fruits in relation to silicon sources and rates. Hortic. Bras. 32: 220-224.

Mazorra, L.M., M. Nunez, E. Echerarria, F. Coll and M.J. Sanchez- Blanco. (2002). Influence of brassinosteriods and antioxidant enzymes activity in tomato under different temperatures. Plant Biol. 45:593-596.

Murphy, J. and J. P. Riely (1962). A modified single solution method for determination of phosphate in natural waters. Anal. Chim. Acta. 29: 31-36.

Okalebo, J. R., Cuthua, K.W. and P. J. Woomer (2002). Laboratory methods of soil and plant analysis- A working manual. TSBF- CIAT and SACRED Africa, Nairobi, Kenya. Pp. 128.

Page, A.L., Miller, R.H., and D.R. Keeney (1982). Methods of soil analyses. Part 2. Chemical and microbiological properties. American Society of Agronomy Inc.; Soil Science Society of America Inc., Madison, WI.

Pregl, E. (1945). Quantitative organic micro analysis. 4th Ed. J. Chundril, London.

Priyanka, D.; Nidhi, K.; Gaurav, R.; Priyanka, R.; Anupriya, B.; Aakriti, S.; Laveena, K.; Akanksha, S.; Sangeeta, P.; Devendra, K. C.; Nawal, K. D.; Shivesh, S.; Vijay, P. S.; Shivendra, S., Renato; G., Jose, P.; Rupesh, D.; Durgesh, K. T. (2022). Silicon nanoforms in crop improvement and stress management. Chemosphere volume 305, 135156. https://doi.org/ 10.1016/ j. chemosphere. 135165Get rights and content.

Qados, A. M. A.; Moftah, A. E. (2015). Influence of silicon and nano-silicon on germination, growth, and yield of faba bean (*Vicia faba* L.) under salt stress conditions. J. Exp. Agric. Int. 5(6): 509-524.

Raja, V.; Qadir, S.U.; Alyemeni, M.N.; Ahmad, P. (2020) Impact of drought and heat stress individually and in combination on physio-biochemical parameters, antioxidant responses, and gene expression in *Solanum lycopersicum*. 3 Biotech, 10, 208. [Google Scholar] [CrossRef] [PubMed]

Rinaldi, M. and Vonella, A.V. (2006). The response of autumn and spring sown sugar beet (*Beta vulgaris* L.) to irrigation in southern Italy. Water and radiation use efficiency field Crops Research, 95 (2-3): 103-14.

Saber, A., M. Ghasemnezhad, M. Esfahani and C. S. Byrt (2019). Application of Nano-Silicon Dioxide Improves Salt Stress Tolerance in Strawberry Plants. Agronomy, 9, 246; doi:10.3390/agronomy9050246 www.mdpi.com/journal/agronomy

Saber, N.E.; Abdel-Rahman, M.M.; Mabrouk, M.E.; Eldebawy, E.M.; Ismail, G.S. (2021). Silicon. Alleviates Cadmium Toxicity in *Triticum aestivum* L. Plants by Modulating Antioxidants, Nutrient Uptake and Gene Expression. Egypt. J. Bot., 62, 319–336.

Salmasi, S., Ghassemi, G. and Moghbelli, S. (2006). Effect of sowing date and limited irrigation on the seed yield and quality of dill (*Anethum Graveolens* L.), Turk. J. Agric. Fori., 30: 281-286.

Sami, H.; Angelo S.; Mohd, A. and Lassaad M. (2022). Single and Associated Effects of Drought and Heat Stresses on Physiological, Biochemical and Antioxidant Machinery of Four Eggplant Cultivars. Plants 11(18), 2404; https://doi.org/10.3390/plants11182404

Sekara, A., Baczek-Kwinta, R., Gaweda, M., Kalisz, A., Pokluda, R. and Jezinsky, A., (2016). Sequential abiotic stress applied to juvenile eggplant modifies the seedlings parameters, plant ontogeny and yield. Horticultural Science, vol. 43, no. 3: 149-157. http://dx.doi.org/10.17221/162/2015-HORTSCI.

Sharma, P., Jha, A.B., Dubey, R.S. and Pessarakli, M., (2012). Reactive oxygen species, oxidative damage, and antioxidative defense mechanism in plants under stressful conditions. Le Journal de Botanique, 217037. http://dx.doi. org/10.1155/2012/217037.

Snedecor, G.W. and W.G. Cochroni (1973). Statistical methods (sixthed.) Iowa state Univ.press, U.S.A.

Sonali, J. and B. R. Jeong (2014). Silicon: The Most Under-appreciated Element in Horticultural Crops. Trends in Horticultural Research, 4: 1-19.

Sun, H.; Jiang, S.; Jiang, C.;Wu, C.; Gao, M.;Wang, Q. A (2021). Review of root exudates and rhizosphere microbiome for crop production. Environ. Sci. Pollut. Res., 28, 54497–54510. [CrossRef].

Teshome, D.T.; Zharare, G.E.; Naidoo, S. (2020). The Threat of the Combined Effect of Biotic and Abiotic Stress Factors in Forestry Under a Changing Climate. Front. Plant Sci., 11, 601009. [CrossRef] [PubMed]

Tondey, M.; Kalia, A.; Singh, A.; Dheri, G.S.; Taggar, M.S.; Nepovimova, E.; Krejcar, O.; Kuca, K. (2021). Seed Priming and Coating by Nano-Scale Zinc Oxide Particles Improved Vegetative Growth, Yield and Quality of Fodder Maize (Zea mays). Agronomy, 11, 729. [CrossRef]

Tripathi, D.; Singh, M. Pandey-Rai, S. (2022). Crosstalk of nanoparticles and phytohormones regulate plant growth and metabolism under abiotic and biotic stress. Plant Stress, 6, 100107. [CrossRef]

Upadhyaya, H.D., N. Dronavalli, C.L.L. Gowda and S. Singh. (2011). Identification and evaluation of chickpea germplasm for tolerance to heat stress. Crop Sci. 51:2079-2094.

Wang, L.; Ning, C.; Pan, T.; Cai, K. (2022). Role of Silica Nanoparticles in Abiotic and Biotic Stress Tolerance in Plants: A Review. Int. J. Mol. Sci., 23, 1947. [CrossRef]

Wang, L.; Wang, Z.; Xu, Y.; Joo, Kim, S. K.; Xue, Z.; Wang, Z. and Chong, Z. and Chong K. (2009). OsGSR1 is involved in crosstalk between gibberellins and brassionsteroids in rice. Plant J., 57: 498-510.

Wang, M. C.; Wu, Z.; Cheng, H. Meng, M. Zhang and H. Zhang. (2014). Soil chemical property changes in eggplant/garlic relay intercropping systems under continuous cropping. PloS one. 9:110-140.

Yadav, T.; Mungray, A. A,; Mungray, A. K. (2014). Fabricated nanoparticles. Rev Env Contam Toxicol., 230:83–110.

Zainab, M. Almutairi (2016). Effect of nano-silicon application on the expression of salt tolerance genes in germinating tomato ('*Solanum lycopersicum*' L.) seedlings under salt stress. Plant Omics, Vol. 9, No. 1: 106-114.

Zinn, K.E., Tunc-Ozdemir, M. and Harper, J.F., (2010). Temperature stress and plant sexual reproduction: uncovering the weakest links.Journal of Experimental Botany, vol. 61, no. 7: 1959- 1968. http://dx.doi. org/10.1093/jxb/erq053. PMid:20351019.

دراسة تأثير عملية الرش بالنانو سيليكون على تحسين إنتاجية الباذنجان المزروع في المناطق الجافة والحارة تحت مواعيد زراعة مختلفة

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الملخص

إجريت تجربتان حقليتان في المزرعة البحثية لكلية الزراعة والموارد الطبيعية - جامعة أسوان – محافظة أسوان - مصر، في صيف 2021 – 2022، والهدف الأساسي لهذه الدراسة هو تحديد ما إذا كان الرش الورقى للنانو سيليكون بتركيزات (كنترول، 100، 200، 300 ملجم/لتر) فعال في تخفيف الإجهاد الحراري خلال موسم نمو الباذنجان في محافظة أسوان فى الزراعات الصيفية، وذلك في ثلاثة مواعيد زراعة مختلفة حيث اجرى الشتل فى (1 مارس، 15 مارس، 1 أبريل) تحت ظروف درجات حرارة الهواء المرتفعة في المناطق القاحلة. شملت الدراسة تقييم الصفات الاتية (النمو الخضري – المحصول - جودة الثمار - الكلوروفيل والكاروتينات - نشاط إنزيم الكاتلاز - النسبة المئوية للنيتروجين والفوسفور والبوتاسيوم والسيليكون بالاوراق). أشارت النتائج إلى أن رش اوراق الباذنجان بجزيئات النانو سيليكون بمعدل (300 ملجم/لتر) أدى عموماً إلى زيادات معنوية واضحة في جميع الصفات المدروسة.كما أظهر الشتل فى موعد 1 مارس تأثيرًا معنويا على كل الصفات موضع الدراسة مقارنة بمواعيد الزراعة الاخرى. علاوة على ذلك، كانت افضل المعاملات هى التفاعل بين النانو سيليكون بتركيز (300 ملجم/لتر) مع موعد الشتل فى 1 مارس والتى ادت إلى زيادات معنوية قوية بكل الصفات التى تم دراستها مقارنة بالكنترول. وايضا أظهر التفاعل بين النانو سيليكون بتركيز (300 ملجم/لتر) تحسناً معنوياً في معظم الصفات المدروسة عند رش النباتات التى شتلت فى 15 مارس و1 أبريل مقارنة بالكنترول. وخلاصة القول: ان النتائج تشير إلى إمكانية استخدام الرش الورقى لجزيئات النانو سيليكون كمركب له الكثير من الفوائد المحتملة للنباتات لتحسين نمو الباذنجان وإنتاجه في المناطق الجافة و الحارة تحت مواعيد زراعة مختلفة.