Scientific Journal of Agricultural Sciences 3 (2): 87-104, 2021
Print (ISSN 2535-1796) / Online (ISSN 2535-180X) DOI: 10.21608/sjas.2021.81529.1118

Response of Quinoa plant grown under Drought Stress to Foliar Application with Salicylic Acid, Paclobutrazol and Algae Extract

Azza Mahmoud Ahmed Salama[1*], Engy Alaa Seleem[1], Ahmed E. Ghoniem[1] and Rabie Mohamed Abd El-Salam[2]

[1]Agricultural Botany Department, Faculty of Agriculture, Cairo University, 12613, Giza, Egypt
[2]Agronomy Department, Faculty of Agriculture, Cairo University, 12613, Giza, Egypt
*Corresponding author:: E-mail: dr_zoz@yahoo.com

Received on: 20-6-2021 **Accepted on: 11-7-2021**

ABSTRACT

The aim of this study was to evaluate the growth and productivity of quinoa grown under drought stress through using growth regulator, retardant and bio stimulant. The experiment was carried out at Agricultural Research and Experimental Station, Faculty of Agriculture, Cairo University, Giza, Egypt during two winter successive growing seasons of 2019 and 2020.The horizontal plots were devoted to two irrigation regimes [well water (80% filed capacity) and drought stress (40% filed capacity)]. The vertical plots were allocated to drought alleviating materials (salicylic acid, paclobutrazol and algae extract) in addition to control treatment (tap water). The results revealed that exogenous application of drought alleviating materials significantly enhanced growth parameters, inflorescence length, No. inflorescences plant^{-1}, No. seeds plant^{-1}, 1000-seed weight and seed yield ha^{-1} compared with untreated treatment. In addition, spraying plants with salicylic acid, paclobutrazol and algae extract at 40% field capacity (FC) exhibited a significant increase in growth and chemical characters compared with untreated plants. Foliar spray with 100 ppm salicylic acid caused positive changes in growth, yield and anatomical structure of stem and leaves of quinoa. Also, spraying plants with the aforementioned materials increased almost all macro and microelements, besides total carbohydrate percentage and crude protein in seeds. Analysis of amino acids in quinoa seeds using Amino Acid Analyzer discovered higher concentration in phenylalanine, leucine and lysine. As well as fatty acids was analysis detected higher percentages in linoleic.

KEYWORDS: quinoa, drought, salicylic, paclobutrazol, algae

1. INTRODUCTION

Quinoa plant (*Chenopodium quinoa* Willd., 2n=4x=36) belongs to family *Amaranthaceae*, originated at the Andean region, and cultivated in Peru and Bolivia (Abdallah *et al.*, 2015; Bazile *et al.*, 2016). Plant grain is an achene, a seed-like fruit, used as a pseudo-cereal (Bazile *et al.* 2016; Gámez *et al.*, 2019). Quinoa has been cultivated in Egypt since 2005, first in the south of Sinai to evaluate the opportunities of growing under harsh conditions. Recently, quinoa has great attention worldwide, it is a rich source of gluten-free protein, unsaturated fatty acids, amino acids (lysine, methionine, and threonine), vitamins and ash, the grains also contain high minerals content as sodium, calcium, and iron (Abdallah *et al.*, 2015; Ebrahim *et al.*, 2018; Gámez *et al.*, 2019). Quinoa seed has a multipurpose use; it has been used in human food as an ingredient in bread making, baby's food, and biscuits. Also, quinoa's saponin is important in the industrial uses; or it's grown as an oil seed crop (Abdallah *et al.*, 2015; El-Sadek *et al.*, 2017). Quinoa plant can grow under severe environmental conditions; drought, hyper salinity levels, forest, acid, and alkaline soil (Choukr-Allah *et al.*, 2016; Ebrahim *et al.*, 2018; Gámez *et al.*, 2019). So, it could be considered one of the best solutions to grow in arid and semi-arid regions (Abdallah *et al.*, 2015; Gámez *et al.*, 2019). Nowadays, climate change led to higher temperatures all over the world which increased by 0.74°C in the 20th century with a steadily increasing rate, associated with a decrease in precipitation rate and bad irrigation management that enhances drought problems (Lipiec *et al.*, 2013; Gámez *et al.*, 2019). Drought is one of the most deleterious abiotic stresses which severely limiting plant growth (Farooq *et al.*, 2012). Drought adversely affects most physiological processes; CO_2 uptake, chlorophyll content, and photosynthesis rate which in turn reduce plant productivity (Winnicki *et al.*, 2019; Mogazy *et al.*, 2020). One of the most important strategies to overcome the environmental stress problems is using plant growth regulators such as abscisic acid, salicylic acid (SA), paclobutrazol (PBZ) or natural extract as algae and yeast extracts, they are used to enhance plant performance under different environmental stress conditions (Nofal *et al.*, 2015; Pal *et al.*, 2016; Abdelaal *et al.*, 2020).

Use of chemicals, except for nutrients and pesticides to manage crop yields has achieved significant progress in agricultural systems in current times. Plant growth regulators (PGRs) can be applied to gain a high yield. Salicylic acid (ortho-hydroxy benzoic acid) is a phytohormone that involves in improving plant stress tolerance, it plays a key role in regulating some the physiological processes including; transpiration, photosynthesis and nutrient uptake (Kareem *et al.*, 2017; Seleem and Taha, 2019; Abdelaal *et al.*, 2020). Exogenous application of SA improves plant growth under different biotic and abiotic stresses conditions by increasing the accumulation of osmolytes, enhances antioxidant enzymes activity, reducing Reactive Oxygen Species (ROS) generation, and increasing chlorophyll content (Youssef *et al.*, 2017; Shaki *et al.*, 2019 and Abdelaal *et al.*, 2020). Application of SA enhanced plant growth characters and chlorophyll content under abiotic stress as reported by Manzoor *et al.* (2015) on maize; Kareem *et al.* (2017) on wheat; Abdelaal *et al.* (2020) on barely; Yadav *et al.* (2020) on wheat.

Paclobutrazol (PBZ) is a plant growth regulator that belongs to triazole family; it is comprised as growth retardant, it causes inhibition of gibberellin biosynthesis, which is responsible for cell division (Tesfahun, 2018 and Xia *et al.*, 2018). PBZ has a great efficient role in resisting adverse environmental conditions (Abbasi *et al.*, 2015; Tesfahun 2018 and Cregg and Ellison-Smith, 2020). This resistance is achieved by enhancing the photosynthetic pigment content, increases osmolyte accumulation and increasing antioxidant enzymes (Abbasi *et al.*, 2015; Waqas *et al.*, 2017). As reported by Pal *et al.* (2016) foliar spray of PBZ enhanced drought tolerance of tomato plants under drought stress. Moreover, Waqas *et al.* (2017) reported that PBZ improved growth and photosynthetic pigments of quinoa plants under salt stress conditions.

Amphora coffeaeformis is a marine diatom that produces high levels of protein, carbohydrates, and lipids (Rajaram *et al.*, 2018), it contains a high amount of amino acids, β-carotene, chlorophyll, vitamins, minerals, phosphorous, iron and zinc, and antioxidants components (El-Sayed *et al.*, 2018; Mogazy, 2020). Moreover, algae extract contain high levels of plant hormones as auxins and cytokinins, so it proved to work as a natural bioactive component, which enhances plant growth and productivity (Nawar and Ibraheim, 2014; Marhoon and Abbas, 2015; Boghdady *et al.*, 2016; Enan *et al.*, 2016). Van Oosten *et al.* (2017) reported that algae extract improves plant tolerance against abiotic stress. Mogazy *et al.* (2020) found that foliar spray of Amphora extract provides a beneficial effect on growth of lupine plants under drought stress.

Thus, the aim of this study is to minimize the deleterious effects of drought stress on quinoa plant by application of SA and PBZ plant growth regulators as well as algae (Amphora) extract as an important strategy in stress resistance and to study the response of quinoa plant morphological, anatomical, yield and chemical characters to the previous treatments.

2. MATERIAL AND METHODS

2.1. Experimental Site:

Two field experiments were conducted at Agricultural Research and Experimental Station, Faculty of Agriculture, Cairo University, Giza, Egypt (30° N, 31°: 28'E with an altitude of 19 m), during two winter successive growing seasons of 2019 and 2020 to study the response of *Chenopodium quinoa* Willd. to foliar application of salicylic acid (SA), paclobutrazol (PBZ) and algae extract under drought stress (40%FC) compared with well water treatments (80%FC).

2.2. Experimental design and treatments:

The experiment was laid out in a strip-plot design in randomized complete blocks arrangement with three replications. The horizontal plots were devoted to two water regimes [well water (80%FC) and drought stress (40%FC)]. Each irrigation treatment was thoroughly separated from each other by deep channels to prevent water leaching between different treatments in terms of high isolation. Soil moisture content in different treatments was measured by tensiometers under a flooding irrigation system and the field capacity was calculated. The vertical plots were allocated to drought alleviating materials (salicylic acid, paclobutrazol and algae extract) in addition to control treatment. Each plot consisted of eight ridges. The ridge was four meters long, 70 cm apart and 25 cm between hills on one side of the ridge. A composite soil samples at depth of 30 cm were collected (Table 1) from the site of the experiment during 2019 and 2020 seasons at time of sowing to examine the mechanical and chemical properties of soil according to standard methods outlined by Jackson (1973).

2.2.1. Cultural practices:

In both seasons the previous summer crop was maize. Quinoa seeds were acquired from Agricultural Research Centre Giza, Egypt, and planted by hand at a seed rate of 12kg ha^{-1} on 3 December 2019 in the 1st season and 5 December 2020 in the 2nd season. Thinning till two plants were left per hill was conducted before the first irrigation (20 days after planting). Before starting water regime treatments, the plants were irrigated up to 100% soil field capacity conditions, after 20 days

Table 1. Soil mechanical and chemical properties (0-30 cm depth) during 2019 and 2020 growing seasons of quinoa.

Soil properties	Season 2019	Season 2020
Mechanical analysis (%):		
Clay	32.1	33.1
Silt	31.5	32.4
Fine Sand	33.4	31.2
Coarse Sand	3.1	3.3
Texture	**Clay loam**	**Clay loam**
Chemical analysis:		
pH (paste extract)	7.81	7.79
EC (dS/m)	1.81	1.89
Organic matter (%)	2.41	2.19
Total calcium carbonate (%)	3.53	3.71
Available nitrogen (mg/kg)	37.3	39. 8
Available phosphorus (mg/kg)	8.97	9.13
Available potassium (mg/kg)	243	231

when the plants established, we applied the treatments.

Salicylic acid was obtained from Soil and Water and Environment Research Institute, Agriculture Research Center (ARC) were applied as a solution of 1 l/fed at concentration of 100 ppm. Paclobutrazol applied at concentration of 20 ppm and algae extract (*Amphora coffeaeformis*) was produced at Algal Biotechnology Unit, National Research Centre with a final capacity of $75m^3$ (El-Sayed *et al*., 2018) with concentration of 1mm/L. A constant volume of drought alleviating materials (salicylic acid, paclobutrazol and algae extract) were sprayed by a hand sprayer twice early in the morning on the leaves after 50 days from planting and two weeks later in both seasons.

2.2.2. Morphological characters:

Ten plants were taken from the outer four ridges at 90 days after sowing to determine growth attributes which included: plant height (cm), stem diameter (cm), number of internodes/plant, number of branches/plant, number of leaves / plant, shoot fresh and dry weight/plant (g).

2.2.3. Yield and yield components:

Harvesting took place on 1st week of July in 2019 and 2020. In both seasons, five representative hills (10 plants $plot^{-1}$) were randomly chosen from the outer four ridges and threshed to determine some yield components. Yield components included: inflorescence length, inflorescence diameter, No. inflorescences/plant, No. seeds/plant, 1000-seed weight. The inner four ridges of each plot were hand harvested to determine seed yield in kilogram $plot^{-1}$ and transformed to kilogram ha^{-1}.

2.2.4. Anatomical investigation:

Specimens were taken from the 5th internodes of stem from plant tip and its corresponding leaf at the end of vegetative growth (90 days). The specimens fixed in formalin-acetic acid alcohol (FAA) solution (50 ml 95 % ethyl alcohol + 10 ml formalin + 5 ml glacial acetic acid + 35 ml distilled water), gradually dehydrated in a tert-butyl alcohol (TBA), and were cut on a rotary microtome at a thickness of 20 µm, finally stained with double crystal violet/erythrosine combination (Nassar and El-Sahhar, 1998). Measurements were done using a micrometer eyepiece and average of 10 readings were calculated. The selected sections were examined and photographed using a light microscope (Model BX51; Olympus Optical)

2.2.5. Chemical analysis:

Determination of N, P, K, Mg and Ca were subjected in mature seeds of the 2nd season and calculated as percentage of dry weight. Total nitrogen content of the seeds was determined according to Helrich (1990). Phosphorus was determined according to Jackson (1973). Potassium concentrations were determined using the flame photometer apparatus (CORNING M 410, Germany). Concentrations of Mg and Ca were determined using atomic absorption spectrophotometer (Pye Unicam, model SP-1900, US). Total carbohydrates in plant herbs were determined according to Helrich (1990). Crude protein was determined by multiplied nitrogen content of seeds by 6.25 (Anon., 1990). Amino acids were extracted according to Csomos and Simon-Sarkadi (2002) and Shalabia (2011) and measured using Amino Acid Analyzer (AAA 400 INGOS Ltd) at Faculty of Agriculture, Cairo University Research Park (CURP). Fatty acids analysis was prepared according to A.O.A.C. (2000) and Vogel (1975), respectively. Determination of fatty acids by GLC described by farag *et al*. (1981).

2.3. Data analysis:

Test of normality distribution was carried out for field data (growth, yield and yield components characters) according to Shapiro and Wilk, method (1965), by using SPSS v. 17.0 (2008) computer package. Also, data were tested for violation of assumptions underlying the combined analysis of variance by separately analyzing each season and then combined analysis across the two seasons was performed if homogeneity (Bartlet test) was insignificant. Collected field data were subjected to analysis of variance according to Steel *et al*. (1997). Treatment means, at a probability level of 0.05 were compared based on least significant difference (LSD). Finally, all statistical analysis was carried out using "MSTAT-C" program 1991.

3. RESULTS AND DISCUSSION

3.1. Morphological characters

Data in Table (2) indicated that the drought stress (40% FC) decreased plant height and stem diameter, by 5.5 and 14.1%, respectively, as compared with control (80% FC). Moreover, number of internodes, branches and leaves/plant decreased by 13.6, 6.7 and 21.4%, respectively, in control plants. Similarly, shoot fresh and dry weights were decreased significantly by 16.9 and 4.6%, respectively compared with control. Data presented in Table (2) showed that plant height, stem diameter, number of internodes/stem, number of branches and number of leaves/plant, shoot fresh and dry weight of quinoa plants were significantly affected by application of salicylic acid, paclobutrazol and algae extract wheather under normal or drought conditions compared with untreated plants.

Results revealed that foliar spray with salicylic acid had the most significant increase on all growth parameters of plants at 80% FC in comparison with either control or all other treatments in combined data across seasons. The maximum plant height recorded at 143.5 cm, being 38.9% more than control, also stem diameter recorded 1.8 cm, being 87.6% over control. Moreover, number of internodes, branches and leaves / plant, they were increased by 35.4, 48.6 and 200.5%, respectively more than control.

Table 2. Effect of salicylic acid, paclobutrazol and algae extract on morphological characteristics of quinoa plant under two water regimes(combined data over 2019 and 2020 seasons).

Treatments		Plant height (cm)	Stem diameter	No. internodes / plant	No. branches / plant	No. leaves / plant	Shoot F.W (g)	Shoot D.W (g)
Irrigation (A)	**Drought alleviating materials (B)**							
Well water (80% FC)	**Control**	109.33	1.13	42.50	18.33	134.00	167.33	26.82
	Salicylic acid 100 ppm	143.50	1.82	49.70	26.75	316.50	682.95	114.26
	Paclobutrazol 20 ppm	130.87	1.50	45.00	13.25	203.00	327.25	47.81
	Algae extract 1mm/l	140.25	1.60	45.00	15.75	161.25	286.63	44.45
Mean		**130.98**	**1.51**	**45.55**	**18.52**	**203.68**	**366.04**	**58.33**
Drought (40% FC)	**Control**	103.30	0.97	36.70	17.00	105.33	138.92	25.58
	Salicylic acid 100 ppm	138.30	1.30	46.00	23.00	146.30	328.60	67.00
	Paclobutrazol 20 ppm	128.00	1.10	44.00	19.00	133.30	286.45	62.30
	Algae extract 1mm/l	133.00	1.20	45.00	21.00	131.70	270.50	34.60
Mean		**125.65**	**1.14**	**42.92**	**20.00**	**129.15**	**256.11**	**47.37**
Means of drought alleviating materials (B)	**Control**	106.32	1.05	39.60	17.67	119.67	153.13	26.20
	Salicylic acid 100 ppm	140.90	1.56	47.85	24.88	231.40	505.78	90.63
	Paclobutrazol 20 ppm	129.44	1.30	44.50	16.13	168.15	306.85	55.06
	Algae extract 1mm/l	136.63	1.40	45.00	18.38	146.48	278.57	39.53
F test	**A**	*	**	**	**	**	**	**
LSD at $_{0.05}$	**B**	**0.49**	**0.025**	**٠.21**	**0.22**	**0.91**	**4.14**	**0.36**
	A x B	**0.69**	**0.032**	**٠.29**	**0.32**	**1.29**	**5.86**	**0.60**

As to the same effect on shoot fresh and dry weight, results indicated that treatment with salicylic acid recorded 682.9 and 114.2 g, being 391.6 and 346.6%, respectively more than control. Also, it was clear that application of algae extracts had significantly increased plant height, stem diameter and number of branches compared with paclobutrazol by 7.2, 6.7 and 18.8%, respectively. While the number of internodes showed no significant increase. Paclobutrazol surpassed algae extract in number of leaves and fresh and dry weights of shoot by 25.8, 14.2 and 7.5%, respectively.

Water deficit dramatically decreases plant growth and development; it enhances accumulation of ROS in plant cells which reduces photosynthetic pigment content (Fghire *et al.*, 2015; Aziz *et al.*, 2018; Winnicki *et al.*, 2019). Moreover, drought stress reduces ion uptake that affects metabolic processes, causes inhibition of cell division and elongation as a result of osmotic stresses that affects cell turgor resulting in inhibition of shoot growth (Rao *et al.*, 2016; Elewa *et al.*, 2017; Nadali *et al.*, 2021; Yadav *et al.*, 2020). In this concern, many authors reported that drought stress negatively affected the vegetative characters of quinoa.

plants (Elewa *et al.*, 2017; Aziz *et al.*, 2018; Iqbal *et al.*, 2018; Ali *et al.*, 2019; Nadali *et al.*, 2021). Moreover, SA, PBZ and algae extract play a crucial role in alleviating the harmful effect of drought on plant growth. SA promote nutrient uptake, enhances assimilating of carbon, increase photosynthetic rate, decreases oxidative stress, and improve cell enlargement and elongation which improves plant growth (Ghazi, 2017; Abdelaal *et al.*, 2020; Yadav *et al.*, 2020). While, PBZ has an important role in reducing ROS, enhances amino acids production, improve activity of antioxidant enzymes, and delaying leaf senescence that promotes plant tolerance to drought stress (Soumya *et al.*, 2017; Tesfahun, 2018; Chandra and Roychoudhury, 2020; Kamran *et al.*, 2020). Moreover, *A. coffeaeformis* algal extracts are a rich source with photosynthetic pigments (chlorophyll, β-carotene and fucoxanthin), phenolic compounds which are important for free radical scavenging (El-Sayed *et al.*, 2018). In addition, algae extract rich with macro and microelements as well as plant phytohormones such as auxins and cytokinins which are important for cell divisions and enlargement which improve plant growth (Marhoon and Abbas, 2015 as well as Mogazy *et al.*, 2020). Similar results were obtained by Manzoor *et al.*, (2015) who reported that exogenous application of SA at 5 mM improved shoot fresh and dry weights of maize under drought stress conditions. Pal *et al.* (2016) found that exogenous application of PBZ at 1.6 ppm increased stem diameter and leaf number of tomato plants under drought stress. Moreover, El-Saadony *et al.* (2017) reported that spraying pea plant with SA at 100 ppm enhanced plant height and shoot fresh weight under drought stress conditions. Ghazi (2017) reported that plant height and fresh and dry weights of drought-stressed maize was significantly increased with application of SA at 200 mg^{-1}. According to Ilyas *et al.* (2017) SA at 10 Mm increased significantly shoot length, fresh and dry weights of wheat under drought. In addition, shoot dry weight of drought-stressed wheat plants was significantly increased with application of SA at 1.44 mM (Kareem *et al.*, 2017). Similarly, Mansori *et al.* (2019) stated that application of seaweed extract (*Fucus spiralis*) improved shoot length and leaves number of sag under normal and drought stress conditions. Abdelaal *et al.* (2020) reported that application of SA at 0.5 mM increased stem length, fresh and dry weights of barely under drought stress. Almaroai and Eissa (2020) found that foliar application of amphora algae extracts increased plant height, leaf number, and leaf area of onion plants under 50% of water irrigation level. According to El-Sayed *et al.* (2020) Plant fresh and dry weights of peanut were enhanced by application of algae extract (3%) under water deficit conditions. Moreover, Yadav *et al.* (2020) stated that plant height of wheat was significantly increased with application of 1 mM SA under drought stress. On the contrary, Hajihashemi and Ehsanpour (2013) reported that application of PBZ reduced shoot fresh and dry weights of Stevia plant under both normal and drought stress conditions. Parvin *et al.* (2015) found that leaf dry weight of strawberry was decreased in PBZ-treated plants under water stress conditions. Jungklang *et al.* (2017) reported that application of PBZ on *Curcuma alismatifolia* reduced significantly plant height and fresh weight under drought stress conditions.

3.2. Yield characters

Results in Table (3) showed that "spraying of quinoa drought stressed plants with salicylic acid or paclobutrazol or algae extract" had a significant effect on yield and most of yield components of quinoa plants. Inflorescence length, No. inflorescences/plant, No. seeds/plant, 1000-seed weight and seed yield/ha significantly decreased when the water supply of quinoa plant declined from 80 to 40% from field capacity. On the other hand, although inflorescence diameter declined with water supply 40% of field capacity but, with no significant difference between two levels of water supply (80 and 40%). Seed yield was significantly lower when

Table 3. Effect of salicylic acid, paclobutrazol and algae extract on yield characters of quinoa plant under two water regimes (combined data over 2019 and 2020 seasons).

Treatments		Inflorescence length (cm)	Inflorescence diameter (cm)	No. inflorescences / plant	No. seeds / plant	1000-seed weight (g)	Seed yield ha^{-1} (kg)
Irrigation (A)	Drought alleviating materials (B)						
Well water (80% FC)	Control	17.72	23.71	15.64	9524.3	3.56	2413.1
	Salicylic acid	19.14	26.95	17.11	9855.8	4.88	2814.4
	Paclobutrazo	18.60	25.82	16.51	9711.7	4.13	2517.1
	Seaweed	18.90	26.00	16.71	9827.6	4.57	2649.7
Mean		**18.59**	**25.62**	**16.49**	**9729.9**	**4.29**	**2598.6**
Drought (40% FC)	Control	14.16	22.42	14.01	7869.8	3.01	1734.3
	Salicylic acid	17.82	25.43	16.22	9455.5	3.84	2281.5
	Paclobutrazo	16.57	24.01	16.01	9411.7	3.57	2011.4
	Seaweed	17.22	25.08	16.30	9449.2	3.68	2197.8
Mean		**16.44**	**24.24**	**15.64**	**9046.6**	**3.53**	**2056.3**
Means of drought alleviating materials (B)	Control	15.94	23.07	14.83	8697.1	3.29	2073.7
	Salicylic acid	18.48	26.19	16.67	9655.7	4.36	2548.0
	Paclobutrazo	17.59	24.92	16.26	9561.7	3.85	2264.3
	Seaweed	18.06	25.54	16.51	9638.4	4.13	2423.8
F test	A	*	ns	*	**	*	**
LSD at 0.05	B	**1.51**	**ns**	**1.36**	**128.73**	**0.87**	**146.58**
	A x B	**1.64**	**ns**	**1.51**	**142.61**	**1.04**	**215.38**

the plants of quinoa were grown under 40% of field capacity (2056.3 kg ha^{-1}) and this decrease due to the adverse effect of drought on all parameters of yield components such as inflorescence length, inflorescence diameter, No. inflorescences plant^{-1}, no. seeds plant^{-1}, 1000-seed weight. These results are confirmed with those obtained by Geerts, *et al.* (2006); Al-Naggar *et al.* (2017a); Algosaibi *et al.* (2017); Telahigue *et al.* (2017) and Nadali *et al.* (2021) who reported that water deficit had a negative effect on yield components of quinoa plant.

As general foliar application of drought alleviating materials (salicylic acid, paclobutrazol and algae extract) significantly enhanced inflorescence length, no. inflorescences plant^{-1}, no. seeds plant^{-1}, 1000-seed weight and seed yield ha^{-1} compared with untried treatment (Table 3). Among drought alleviating materials, exogenous application of salicylic acid found to have the best treatment for inflorescence length (18.48 cm), inflorescence diameter (26.19 cm), no. inflorescences / plant (16.67), no. seeds / plant (9655.7), 1000-seed weight (4.36g) and seed yield / ha (2548.0kg). In addition, both salicylic acid and algae extract were as good as or better than paclobutrazol to mitigate the adverse effect of drought on aforementioned traits of quinoa plant. It was clear that, inflorescence diameter increased with the exogenous application of drought alleviating materials compared with tap water treatment but, without any significant differences. Results observed that the improvement of inflorescence length, inflorescence diameter, no. inflorescences / plant, no. seeds / plant, and 1000-seed weight under the exogenous application of salicylic acid, paclobutrazol and algae extract compared with application of tap water resulted in an increase in seed yield of quinoa plant.

The observed improvement of yield characters in quinoa may be due to the stimulating of growth and enhancement of photosynthesis and nutrient uptake as a function of phenolic compounds (salicylic acid) which consider a plant growth regulator. Furthermore, exogenous application of salicylic acid was found to increase photosynthetic rate, internal CO_2 concentration, stomatal conductance, and water use efficiency in *Brassica juncea* (Fariduddin *et al.*, 2003). The alleviating effect of salicylic acid under water stress including several mechanisms such as, improving plant growth through improved carbon assimilation subsequently increasing plant biomass (Kang *et al.*, 2012), or alleviate plant growth inhibition (Kang *et al.*, 2013), increasing water use efficiency (El-Mageed *et al.*, 2016 and Aldesuquy 2014), antioxidant enzyme activities which decline harmful effect of ROS (Hafez and Hafez 2016 as well as Sedaghat *et al.*, 2017) and increasing proline and abscisic acid (ABC) content (Noreen *et al.*, 2012 and Nazar *et al.*, 2015). Concerning the mechanism of paclobutrazol in enhancing the protection of plants, it depends on regulating some plant hormones, reducing gibberellic acid level, and momentary rise in ABA level (Masia *et al.*, 1994; Rademacher 1997 and Zhu *et al.*, 2004). The mechanism in which *A. coffeaeformis* algal extracts mitigates the adverse effect of drought on plant depending on high content of photosynthetic pigments (chlorophyll, β-carotene and fucoxanthin), phenolic compounds which is important for free radical scavenging (El-Sayed *et al.*, 2018), macro and microelements as well as phytohormones (auxins and cytokinins) which are important for cell divisions and enlargement resulting in improving plant growth (Marhoon and Abbas, 2015 and Mogazy *et al.*, 2020).

Significant irrigation regime×drought alleviating materials interactions existed on the above-mentioned characters of quinoa in combined data over 2019 and 2020 seasons (Table 3). Well water plant of quinoa (80%FC) produced the highest value of inflorescence length (19.14cm), inflorescence diameter (26.95cm), No. inflorescences plant^{-1} (17.11), No. seeds plant^{-1} (9855.8), 1000-seed weight (4.88) and seed yield ha^{-1} (2814.4kg) with the exogenous application of salicylic acid. On the contrary, stressed plant of quinoa (40%FC) recorded the lowest value of inflorescence length (14.16cm), inflorescence diameter (22.42cm), no. inflorescences plant^{-1} (14.01), no. seeds plant^{-1} (7869.8), 1000-seed weight (3.01) and seed yield ha^{-1} (1734.3kg) under untreated plants in combined data over both seasons.

3.3. Anatomical studies

3.3.1. Anatomy of leaf blade

As shown in Table (4) and Fig. (1), drought stress has an adverse effect on leaf anatomical structure. Lamina thickness was dramatically decreased by 57.9% less than the control plants, this reduction was reflected on palisade and spongy tissue thicknesses which decreased by 56.5 and 56.1%, respectively. A slight increment occurred in midvein thickness in drought-treated plants which increased by 4.2 % more than the control plant, while, the length and width of main vascular bundle were decreased by 21.9 and 5.35%, respectively. Moreover, xylem tissue thickness and number of xylem row bundle^{-1} were decreased by 27.5 and 16.6%, respectively. Phloem tissue thickness and xylem vessel diameter were increased in drought-stressed plants compared with control plants. The reduction in lamina thickness in drought-stressed plants could be attributed to the negative effect of drought on the cell division of mesophyll that reduces leaf elongation (Abd Elbar, *et al.*, 2019). Additionally, the reduction in mesophyll may also result from shrunken volumes of mesophyll, and compacted palisade layers in drought-stressed leaves with reduced intercellular spaces (Agami, 2013; Abd Elbar, *et al.*, 2019). Furthermore, drought affects palisade and spongy tissues which causes deformation in both tissues (Zhang *et al.*, 2015; Assem *et al.*, 2017). A reduction in leaf size of quinoa under drought stress was reported by Al-Naggar *et al.* (2017b) that leaf thickness, palisade and spongy tissues were significantly reduced in moderate (65 % FC) and sever (35 % FC) drought stress.

Regarding drought stress, plants treated with SA, PBZ, or algae extract were exhibited a prominent increase in most leaf anatomical structure. Midvien, lamina, palisade and spongy tissue thicknesses were increased in plants treated with Pac, SA, and algae compared with drought stressed plants, except midvein thickness of plants treated with algae did not show any increment. Moreover, main vascular bundle length and width, xylem and phloem thicknesses were increased at the same treated plants compared with drought stressed plants.

Table 4. Effect of salicylic acid, paclobutrazol and algae extract on leaf of quinoa plant under two water regimes in 2020 season.

Characters	Treatments				
	Control	**Drought**	**Drought + SA 100 ppm**	**Drought + PBZ 20 ppm**	**Drought + algae 1 mm L^{-1}**
Mid-vein thickness	1246.6	1298.81	1568.1	1339.05	1021.01
Lamina thickness	278.8	117.3	265.13	310.9	238.5
Palisade tissue thick	139.7	60.73	101.85	126.4	115.26
Spongy tissue thick	120.9	53.11	136.97	166.40	113.95
Dimension of the main vascular					
Length	345.0	269.26	376.81	340.6	297.87
Width	164.6	155.78	220.89	201.43	200.23
Xylem thick	210.5	152.57	229.00	220.22	200
Phloem thick	54.1	66.53	86.46	75.61	70
No. of xylem row bundle^{-1}	6	5	5	5	4
Xylem vessel diam	33.9	34.02	36.07	33.5	35.00

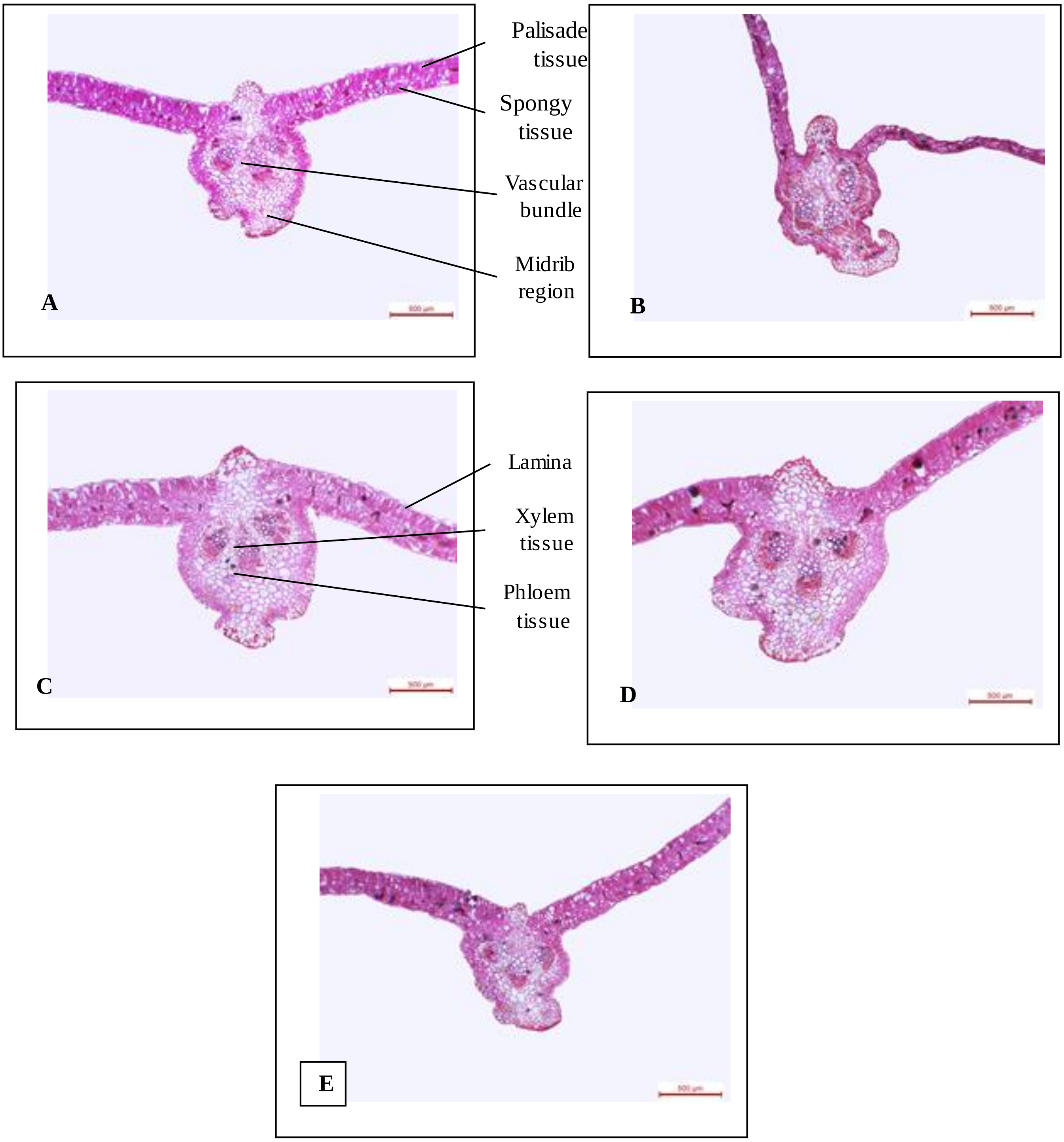

Fig. 1. Cross sections of the leaf blade of quinoa plant grown under drought stress (40% FC), and exogenous application of SA, PBZ or Algae extract

A: control (unstressed plants), B: drought stressed plants, C: stressed plants treated with 100 ppm SA, D: stressed plants treated with 20 ppm PBZ, E: drought stressed plants treated with 1 g L^{-1} algae extract.

In this concern, El-Saadony *et al.* (2017) reported that SA involved in nutrients and ion uptake, improves photosynthesis process that helping in mitigating the harmful effect of drought. In addition, PBZ is important in plant protection against drought stress by reducing ROS and improves enhancing antioxidative capacity of the plants (Abbasi *et al.*, 2015). Likewise, Algae extract rich with plant hormones (auxins and cytokinins) that important in enhancing plant growth (Boghdady *et al.*, 2016; Enan *et al.*, 2016).

Results of this study were in harmony with Tsegaw *et al.* (2005) who found that palisade and spongy tissues of potato were increased in PBZ treated plants at a concentration of 67.5mg L^{-1}. Agami (2013) on lettuce, reported that application of SA at 10^{-3}M caused a prominent increase in midvein, blade and mesophyll thicknesses, average diameter of vessels and average number of vessels $bundles^{-1}$ in drought-stressed plants. According to Abdelaal (2015) application of 1.0 mM SA enhanced leaf anatomical stricter of faba bean under drought stress. Moreover, Salama and Yousef (2015) found that 1.5 ml L^{-1} seaweed extract increased midvein and lamina thicknesses as well as vascular bundle size of basil plant. Furthermore, Rodrigues *et al.* (2016) reported that PBZ affected only thickness palisade and spongy parenchyma tissues of Toona ciliate leaf. Abd El-Aal and Mohamed (2017) found a prominent increase in leaf palisade and spongy tissue thickness of geranium after application of PBZ at 60 ppm. El-Saadony *et al.* (2017) reported that foliar spray of SA at 100 ppm increased all leaf anatomical characters in different field capacities (100, 60 and 30 % field capacity) of pea plants. As reported by Mogazy *et al.* (2020), foliar spray with Amphora algae extract at 2 g l^{-1} increased all anatomical characters of lupine plants under drought stress. Similarly, Nassar *et al.* (2020) found that application of 1 ml/l seaweed extract increased thickness of midvein and lamina as well as vascular bundle length and width of sweet marjoram.

3.3.2. Anatomy of the main stem

Data in Table (5) and Figure (2) showed that stem diameter decreased of the untreated plants under drought stress by 11.4 % less than the control plants. This reduction was reflected in thickness of cortex, vascular tissues, xylem and phloem which decreased by 70.0, 10.6, 3.5 and 15.9%, respectively below control (80% FC). Although a negligible increase of 2% over the control in pith diameter was observed. Spraying quinoa with SA, Pac and SE at 40% FC increased all previously mentioned characters more than that of the control. On the other hand, the cortex thickness in control plants is larger than in treated plants. The highest values of the aforementioned characters were recorded in the plants treated with SA at 40% FC. The stem diameter of SA treated plants increased by 68.6% more than drought-stressed plants, this increment could be mainly due to the increase in vascular tissue thickness which increased by 61.9% more than those of the control. Meanwhile, the thickness of xylem and phloem tissue was increased with SA by 69.4 and 61.9%, respectively over the control plant. As well as an increment of 35.1% over the control in pith thickness was observed with SA.

In the same table, results showed that applied algae extract at 40% FC increased markedly the diameter of the main stem and the thickness of cortex, vascular tissues, xylem and phloem compared with Pac. These increments were 8.8, 7.9, 6.3, 9.9 and 8.6%, respectively more than Pac. As well as, treated plants with algae increased the thickness of pith by 4.2% more than Pac.- treated plants.

The increment of stem histological parameters resulting from different treatments with SA, PBZ or algae extract under drought stress were resulting from the crucial role of the aforementioned treatments on different physiological processes of plants. In this concern, SA is important for regulating photosynthesis and other processes which enhance plant growth (Abdelaal *et al.*, 2020). Moreover, PBZ stimulates cytokinins synthesis, which is important for cell divisions and enlargement, and improving stem diameter (Tsegaw *et al.*, 2005). Similarly, the increment of stem diameter of seaweed treated plants maybe resulting from the important action of cytokinins in enhancing cell divisions, and improving the cambium activity in xylem and phloem that led to form new vascular bundles, and increase the stem diameter (Marhoon and Abbas 2015). Similar results were recorded by Tsegaw *et al.* (2005) who reported that treatment of potato with PBZ at a concentration of 67.5 mg/L increased cortex thickness and pith diameter.

Table 5. Effect of salicylic acid, paclobutrazol and algae extract on stem of quinoa plant under two water regimes in 2020 season.

Histological characters	Treatments				
	Control	Drought	Drought + SA 100 ppm	Drought + PBZ 20 ppm	Drought + algae 1 mm L^{-1}
Stem diameter	9100.2	8060.3	13595.4	11830.0	12870.4
Cortex thickness	500.6	150.0	380.0	380.3	410.5
Vascular tissue thickness	1688.7	1508.9	2444.2	2263.6	2406.2
Xylem tissue thickness	776.7	652.5	1105.1	956.6	1039.0
Phloem tissue thickness	447.3	431.8	699.5	623.4	685.5
Pith thickness	6500.3	6630.0	8960.2	8265.5	8610.3

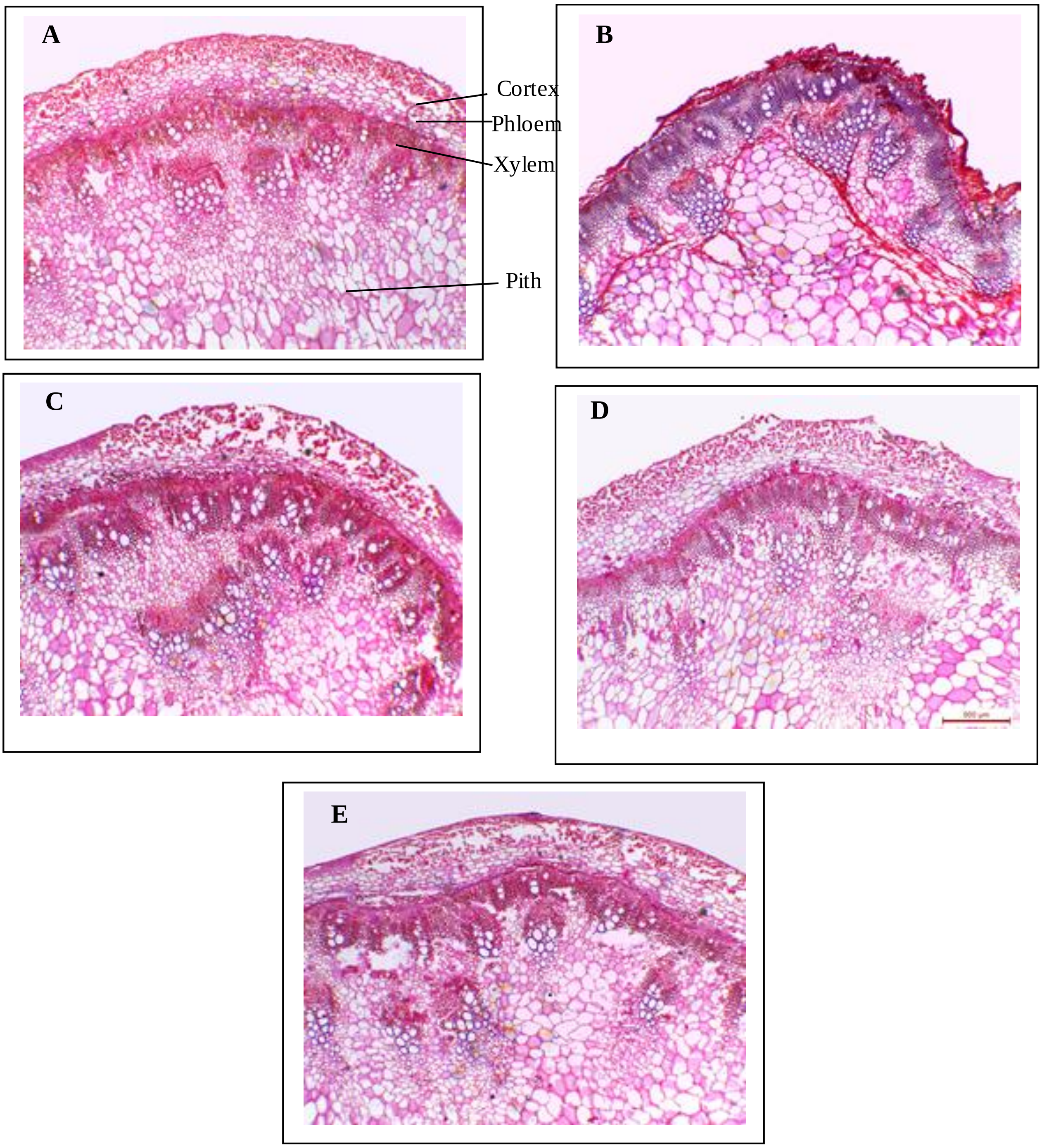

Fig. 2. Cross sections through the median portion of the main stem of quinoa plants grown under drought stress (40% FC), and exogenous application of SA, PBZ, or Algae extract.

A: control (unstressed plants), B: drought stressed plants, C: stressed plants treated with 100 ppm SA, D: stressed plants treated with 20 ppm PBZ, E: drought stressed plants treated with 1 g L^{-1} algae extract

Furthermore, Abdelaal (2015) found that all stem histological characters of bean plants were increased in 1.0 mM SA treated plants under drought stress. Moreover, Marhoon and Abbas (2015) on sweet pepper, reported that foliar spray of seaweed extract at 6 ml. L^{-1} enhanced significantly cortex thickness compared with control. Similarly, Salama and Yousef (2015) on basil, found that foliar spray with 1.5 ml/L seaweed extract increased stem diameter, as well as thickness of cortex, phloem and xylem tissues. Mogazy *et al.* (2020) reported that application of 2g l-1 Amphora algae extract improved stem histological characters under drought stress of lupine plants.

3.4. Chemical composition

3.4.1. Mineral elements, total carbohydrate and crude protein content

Application of salicylic acid, paclobutrazol and algae extract at 40% FC on percentages of Nitrogen, Phosphorus, Potassium, Magnesium and Calcium total carbohydrates and crude protein of quinoa seeds were presented in Table (6). Regarding the drought effects, it's obvious from Table (6) that Nitrogen(N), Phosphorus (P), Potassium, Magnesium and Calcium, total carbohydrates and crude protein were reduced in drought-stressed plants compared with control plants. These decrements were 6.87, 18.18, 7.35, 9.68, 8.57, 12.97, and 6.85 % less than the control plants, respectively. The reduction of macroelements in drought-stressed plants may result from the adverse effects of drought on plant nutrient absorption and decreasing of carbon dioxide (Ghazi 2017). In addition, the reduction of total carbohydrates of seeds under drought stress may related to the reduction of enzymes and metabolic activities which reduces the movement of different nutrients to seeds (Ali *et al.*, 2010). Moreover, drought stress negatively affects the activity of photosynthesis, which reduces the carbohydrate content in mature leaves which leads to a decrement in of carbohydrate contents of seeds (Elewa *et al.*, 2017). These results is corroborate with Ali *et al.* (2010) who reported that kernel sugar and protein contents were reduced in water-stressed maize plants. Furthermore, Ali and Ashraf (2011) reported that exposing maize plant to drought stress significantly reduced macro-minerals (K, Mg, P, N and Ca), sugar and protein contents in seed. In addition, nitrogen, phosphorous, and potassium contents, as well as the percentages of carbohydrates and protein were significantly decreased in seeds of drought-stressed quinoa plants (Elewa *et al.*, 2017). In contrast, many authors reported that N, K, total carbohydrates and total soluble protein in shoot increases under drought conditions (Gupta *et al.*, 2012; Ouzounidou *et al.*, 2014; Manzoor *et al.*, 2015 and Noreen *et al.*, 2017).

Table 6. Effect of salicylic acid, paclobutrazol and algae extract on some elements content (%), total carbohydrates (%) and crude protein (%) of quinoa plant under two water regimes in 2020 season.

Treatment	N	P	K	Mg	Ca	Total carbohydrates D.W	Crude protein
Control (80%FC)	1.31	0.33	0.68	0.31	0.70	47.80	8.18
Drought (40%FC)	1.22	0.27	0.63	0.28	0.64	41.6	7.62
Drought + SA 100 ppm	3.01	0.48	0.76	0.47	0.84	59.50	18.81
Drought + PBZ 20 ppm	1.93	0.39	0.74	0.39	0.72	53.20	12.06
Drought + algae 1 mm L^{-1}	2.11	0.43	0.72	0.42	0.73	56.30	13.18

Plants treated with SA, PBZ or algae extract improved all the aforementioned macro-elements, total carbohydrates and crude protein under drought stress conditions. The highest increment in Nitrogen, Phosphorus, Potassium, Magnesium and Calcium, total carbohydrates, and crude protein were noted in drought-stressed plants treated with SA by 146.72, 77.78, 20.63, 67.86, 31.25, 43.03 and 146.85 % more than those of untreated plants under the same stress conditions, respectively.

Application of SA, PBZ or Amphora algae extract has an important effect in minimizing the adverse effect of drought on plant chemical constituents. SA is crucial in reducing the deleterious effect of drought by enhancing the antioxidant enzyme activity, and nitrate reductase that leads to an increment in protein synthesis (Abdallah *et al.*, 2015; Ghazi, 2017). In addition, SA plays a crucial role in protein formation, increasing the formation of antioxidant compounds, improves the activity of nitrate reductase which is important for protein synthesis (Ghazi, 2017). Moreover, SA plays an important role as ROS scavenger which is important in protecting plants during seed filling stage from oxidative damage induced by drought (Ali and Ashraf, 2011). PBZ has a beneficial role in mitigating drought by increases of photosynthetic pigment, enhancement the accumulation of osmolytes, reduces oxidative stress and reducing lipid peroxidation (Waqas *et al.*, 2017). In addition, Algae extract is rich with major and minor nutrients, amino acids and phytohormone which are important in reducing the harmful effect of drought (El-Sayed *et al.*, 2015). Similar suggestions were reported by Agami (2013) on lettuce, found that total soluble proteins contents were significantly decreased in drought stressed (60% FC) plants compared with non-water-stressed plants, application of SA at the concentration of 10^{-3}M significantly improved total soluble proteins. Moreover, Hajihashemi and Ehsanpour (2013) reported that carbohydrates content of Stevia was reduced in drought stressed plants, while application of PBZ improved it. Zewail (2014) Reported that application of seaweed extract at 4 ml/l increased mineral elements N,P,K,Mg, Ca, total carbohydrate, and crude protein concentrations in leaves as well as crude protein concentration in seeds of common bean. Moreover, Nazar *et al.* (2015) reported that drought stress reduced N content in stressed plants compared to control.

Moreover, the application of 0.5 mM SA increased N content of mustard plant under both drought stressed and non-stressed conditions. In addition, Parvin *et al*. (2015) reported that protein content of strawberry increased under the higher levels of drought stress and PBZ treatments. According to Boghdady *et al*. (2016) the highest increment of N, P, K, Ca, Mg content and crude protein percentage were achieved by application of seaweed extract at the concentration of 1 ml/L of chickpea plant. Abd El-Aal and Mohamed (2017) showed that application of PBZ at 60 mg/L increased the total percentages of N, P, K, and total carbohydrates in leaf of geranium plant. Furthermore, El-Saadony *et al*. (2017) reported that N, P, K, protein and total carbohydrate of seeds of pea plants grown in sandy soil were significantly decreased under water-deficit conditions (30% FC), while foliar application of SA at 100 ppm improved the previous parameters under drought stress. Ghazi (2017) reported that mineral content (total nitrogen, phosphorus and potassium percentages), crude protein, and total carbohydrates % of Maize leaves were decreased under water deficit conditions (50% FC), while a foliar spray of SA enhanced all the aforementioned constituents under both normal and drought stress conditions. According to Rao *et al*. (2021) application of SA at 100 ppm increased significantly K content in leaf of maize plants under drought stress.

3.4.2. Amino acids Content

Analysis of amino acids in quinoa seeds detected seven types, these were, Tryptophan, Leucine, Lysine, Phenylalanine, Histidine, Methionine and Valine (Table 7). The seeds of quinoa plant contain high concentration of Phenylalanine, Leucine and Lysine and low concentration of Tryptophan. Regarding the drought stress, the obtained results showed that exposing plants to drought stress (40% FC) reduced the concentration of all amino acids compared with control plants. Meanwhile, foliar spray with SA, PBZ or algae extract at 40% FC improved the concentration of all the aforementioned amino acids compared with the untreated plants under the same drought conditions. The highest increment was recorded in SA treated plants at 40% FC, these increments were 14.4, 18.7, 21.5, 23.3, 35.7, 32.7 and 31.1% for tryptophan, leucine, lysine, phenylalanine, histidine, methionine and valine, respectively, over than the untreated drought-stressed plants.

Table 7. Effect of salicylic acid, paclobutrazol and algae extract on amino acid concentrations of quinoa seeds under two water regimes in 2020 season.

Treatment	Tryptophan	Leucine	Lysine	Phenylalanine	Histidine	Methionine	Valine
Control (80%FC)	10.71	50.13	48.16	55.39	24.09	32.16	35.51
Drought	10.52	48.92	46.05	51.14	22.18	29.41	33.20
Drought + SA 100	12.04	58.07	55.96	63.08	30.11	39.05	43.54
Drought + PBZ 20	11.03	52.42	50.82	57.26	25.46	32.88	36.44
Drought + algae 1	11.23	54.65	52.87	59.12	27.01	34.72	38.27

Results are in agreement with Al.Asbahi *et al*. (2012) found that amino acids in tomato leaves showed different responses to drought stress as follows; valine, leucine, and alanine significantly reduced, while arginine and lysine were increased, histidine and serine didn't change significantly. According to Boghdady *et al*. (2016) application of 1 ml/l seaweed extract increased the concentration of all essential and non-essential amino acid content in chickpea seeds compared with the control plants. Moreover, Farhangi-Abriz, and Ghassemi-Golezani (2016) stated that application of SA increased the content of different essential amino acid as; leucine, lysine, methionine and valine contents in soybean seeds, but it had no significant effect on phenylalanine. Setia *et al*. (1996) found that PBZ improved free amino acid in matured seeds of Brassica juncea (L.). On the contrary of this study, Sankar *et al*. (2014) found that the amino acid content increased under drought stress, while application of PBZ (10 mg/l) decreased amino acids content compared with drought-stressed plants in the leaves of peanut plants.

3.4.3. Fatty acids Content

Fatty acids composition of seeds of sprayed quinoa with salicylic acid, algae extract, and paclobutrazol at 40% FC are presented in Table (8). Data showed that drought stress significantly decreased quinoa seed oil content, (Table 8). In this concern, Ali *et al*. (2010) reported that although drought stress did not change the total saturated and unsaturated fatty acids of sunflower kernel oil, it increased oleic/linoleic ratio, the contents of oleic acid increased, and linoleic acid decreased. In addition, Ali and Ashraf (2011) found that drought stress increased the content of oleic and linoleinic acids while linoleic acid decreased, and had no significant effect on palmitic and stearic acids. Rebey *et al*. (2012) stated that mono and polyunsaturated fatty acids reduced under moderate (50% FC) and severe (25% FC) water deficit, while the saturated fatty acid (palmitic acid) increased under water deficit conditions. On the other hand, treatment with salicylic acid, algae extract and paclobutrazol has a positive impact on seed oil content, where, salicylic acid at 100 ppm is the most efficient treatment. Fatty acids (linolenic, miristic, palmitic, oleic, linoleic and stearic) were significantly decreased in drought-stressed quinoa seeds as compared with control seeds. This reduction was 17.6% in linolenic, 22.2% in miristic, 8.6% in palmitic, 2.4% in oleic, 2.8% in linoleic and 19.7% in stearic acid in seeds at 40%. The highest content of linolenic, miristic, palmitic, oleic, linoleic and stearic was detected in seeds of quinoa plants treated with 100 ppm salicylic acid under drought stress, and recorded 9.4, 0.4, 10.4, 24.7, 51.0 and 0.7%, respectively. In this concern, Setia *et al.* (1996) on *Brassica juncea*, reported that pacolobutrazol enhanced the seed oil content. Moreover, Jadhav *et al.* (2013) reported that application of SA at 100 ppm enhanced linoleic acid contents, while the application of SA at a concentration of 5 ppm reduced palmitic acid and stearic acids contents of groundnut seeds. Khani Basiri *et al.* (2017) found that application of SA at 0.2 gl^{-1} was effective in increasing the content of unsaturated fatty acids (Linoleic and oleic acids), and decreasing the content of unsaturated fatty acids (palmitic and stearic acids) and improved the quality of the kernels of sunflower. Seleem and Taha (2019) found that foliar spray of SA at 100 mg l^{-1} increased the content of unsaturated fatty acids (oleic, linoleic and linolenic acids), and decreased the content of saturated fatty acids (lauric, palmitic and stearic acids) of sunflower seeds.

Table 8. Effect of salicylic acid, algae extract and paclobutrazol on fatty acid concentrations (%) of quinoa seeds under two water regimes in 2020 season.

Treatment	Linolenic	Miristic	Palmitic	Oleic	Linoleic	Stearic
Control (80%FC)	4.61	0.11	9.07	20.09	46.11	0.73
Drought (40%FC)	3.92	0.09	8.35	19.61	44.84	0.61
Drought + SA 100 ppm	9.47	0.40	10.42	24.77	51.06	0.79
Drought + PBZ 20 ppm	5.83	0.22	9.46	21.39	47.03	0.76
Drought + algae 1 mm L^{-1}	7.52	0.31	9.52	22.05	49.18	0.84

4. CONCLUSION

Based on our findings mentioned above, it could be concluded that treatment with salicylic acid, paclobutrazol and algae extract proved a significant increase in morphological and yield parameters of quinoa plant compared with untreated plants under drought stress conditions. Application of salicylic acid at 80% of FC had the highest values for morphological, yield and anatomical characters. All measured chemical composition in seeds such as percentages of nitrogen, phosphor, magnesium and calcium besides iron, manganese, zinc and copper were positively affected by salicylic acid at 40% of FC. In this investigation spraying plants with salicylic acid under water deficit treatment demonstrates its significant importance for total carbohydrates, crude protein, amino and fatty acids compared with untreated plants.

5. REFERENCES

Abbasi A, Shekari F, Mustafavi SH (2015). Effect of paclobutrazol and salicylic acid on antioxidants enzyme activity in drought stress in wheat. Idesia, 33(4):5-13.

Abd El-Aal MMM, Mohamed YFY (2017). Effect of pinching and paclobutrazol on growth, flowering, anatomy and chemical compositions of potted geranium (*Pelargonium zonal* L.) plant. International Journal of Plant & Soil Science, 17(6):1-22.

Abd Elbar OH, Farag RE, Shehata SA (2019). Effect of putrescine application on some growth, biochemical and anatomical characteristics of *Thymus vulgaris* L. under drought stress. Annals of Agricultural Sciences, 64(2):129-137.

Abdallah MMSA, El-Bassiouny HMS, Elewa TAE, El-Sebai TN (2015). Effect of salicylic acid and benzoic acid on growth, yield and some biochemical aspects of quinoa plant grown in sandy soil. Int. J. ChemTech. Res, 8: 216-225.

Abdelaal KA, Attia KA, Alamery SF, El-Afry MM. Ghazy AI. Tantawy DS. Al-Doss AA. El-Shawy ESE, M Abu-Elsaoud A, Hafez YM (2020). Exogenous application of proline and salicylic acid can mitigate the injurious impacts of drought stress on barley plants associated with physiological and histological characters. Sustainability, 12(5):1736.

Abdelaal KhAA (2015). Effect of salicylic acid and abscisic acid on morpho-physiological and anatomical characters of faba bean plants (*Vicia faba* L.) under drought stress. Journal of Plant Production, 6(11):1771-1788.

Agami RA (2013). Salicylic acid mitigates the adverse effect of water stress on lettuce (*Lactuca* *sativa* L.). Journal of Applied Sciences Research, 9(11):5701-5711.

Al.Asbahi AA, Al.Maqtari AM, Naji KM (2012). ABA biosynthesis defective mutants reduce some free amino acids accumulation under drought stress in tomato leaves in comparison with Arabidopsis plants tissues. Journal of Stress Physiology & Biochemistry, 8(2):180-192.

Aldesuquy HS (2014). Glycine betaine and salicylic acid induced modification in water relations and productivity of drought wheat plants. Journal of Stress Physiology and Biochemistry, 10(2):55-73.

Algosaibi AM, Badran AE, Almadini AM, El-Garawany MM (2017). The effect of irrigation intervals on the growth and yield of quinoa crop and its components. Journal of Agricultural Science, 9(9):182-191.

Ali OI, Fghire R, Anaya F, Benlhabib O, Wahbi S (2019). Physiological and morphological responses of two quinoa cultivars (*Chenopodium quinoa* Willd.) to drought stress. Gesunde Pflanzen, 71(2):123-133.

Ali Q, Ashraf M (2011). Exogenously applied glycinebetaine enhances seed and seed oil quality of maize (*Zea mays* L.) under water deficit conditions. Environmental and experimental botany, 71(2):249-259.

Ali, Q, Ashraf M, Anwar F (2010). Seed composition and seed oil antioxidant activity of maize under water stress. Journal of the American Oil Chemists' Society, 87(10):1179-1187.

Almaroai YA, Eissa MA (2020). Role of Marine Algae Extracts in Water Stress Resistance of Onion under Semiarid Conditions. Journal of Soil Science and Plant Nutrition, 1-10.

Al-Naggar AMM, Abd El-Salam RM, Badran AEE, El-Moghazi MM (2017a). Genotype and drought effects on morphological, physiological and yield traits of quinoa (*Chenopodium quinoa* Willd.). Asian Journal of Advances in Agricultural Research, 1-15.

Al-Naggar AMM, Abd El-Salam RM, Badran AEE, Boulos ST, El-Moghazi MM, (2017b). Leaf anatomical Characteristics and Its Heritability of Different Quinoa (*Chenopodium quinoa* Willd.) Genotypes as Influenced by Moderate and Severe Water Stress. Asian Journal of Biology, 4(2):1-14.

Assem N, El Hafid L, Lamchouri F (2017). Impact of water stress on the leaf tissues of two Moroccan varieties of durum wheat (*Triticum durum* Desf). Journal of Materials, 8(10):3583-3487.

Aziz A, Akram NA, Ashraf M (2018). Influence of natural and synthetic vitamin C (ascorbic acid) on primary and secondary metabolites and associated metabolism in quinoa (*Chenopodium quinoa* Willd.) plants under water deficit regimes. Plant Physiology and Biochemistry, 123,192-203.

Bazile D, Pulvento C, Verniau A, Al-Nusairi MS, Ba D, Breidy J, Hassan L, Mohammed MI, Mambetov O, Otambekova M, Sepahvand NA (2016). Worldwide evaluations of quinoa: preliminary results from post international year of quinoa FAO projects in nine countries. *Frontiers in Plant Science*, 7, 850.

Boghdady MS, Selim AH, Dalia N, Rania MA, Azza MS (2016). Influence of foliar spray with seaweed extract on growth, yield and its quality, profile of protein pattern and anatomical structure of chickpea plant (*Cicer arietinum* L.). Middle East J. Appl. Sci., 6(1):207-221.

Chandra S, Roychoudhury A (2020). Penconazole, Paclobutrazol, and Triacontanol in Overcoming Environmental Stress in Plants. In Protective Chemical Agents in the Amelioration of Plant Abiotic Stress: Biochemical and Molecular Perspectives (pp. 510-534). John Wiley & Sons Ltd.

Choukr-Allah R, Rao NK, Hirich A, Shahid M, Alshankiti A, Toderich K, Gill S, Butt KUR (2016). Quinoa for marginal environments: toward future food and nutritional security in MENA and Central Asia regions. Frontiers in plant science, 7, 346.

Cregg B, Ellison-Smith D (2020). Application of Paclobutrazol to Mitigate Environmental Stress of Urban Street Trees. Forests, 11(3):355.

Ebrahim M, Abdel-Ati AA, Hussin SA, Ali SH, Eisa SS (2018). Evaluation of some *Chenopodium* quinoa cultivars under saline soil conditions in Egypt. Arab Universities Journal of Agricultural Sciences, 26(1):337-347.

Elewa TE, Sadak MS, Dawood MG (2017). Improving drought tolerance of quinoa plant by foliar treatment of trehalose. Agricultural Engineering International: CIGR Journal, Special, (245-254).

Abd El-Mageed TA, Semida WM, Mohamed GF, Rady MM (2016). Combined effect of foliar-applied salicylic acid and deficit irrigation on physiological–anatomical responses, and yield of squash plants under saline soil. South African journal of botany, 106,8-16.

El-Saadony FM, Nawar DA, Zyada HG (2017). Effect of foliar application with salicylic acid, garlic extract and proline on growth, yield and leaf anatomy of pea (*Pisum sativum* L.) grown under drought stress. Middle East J. Appl. Sci, 7(3):633-650.

El-Sadek A, Balah M, Romani A, Francesca Ieri F, Vignolini P, Salem E, Moselhy N, Virtuosi I (2017). Allelopathic potential of quinoa (*Chenopodium quinoa* Willd.) genotypes on the germination and initial development of some weeds and crops. Egyptian Journal of Desert Research, 67(1):25-45.

El-Sayed AB, Aboulthana WM, El-Feky Amal M, Ibrahim Noha E, Seif MM (2018 a). Bio and phyto-chemical effect of *Amphora coffeaeformis* extract against hepatic injury induced by paracetamol in rats. Molecular Biology Reports. 1:19.

El-Sayed S, Ramadan AA, Hellal F (2020). Drought stress mitigation by application of algae extract on peanut grown under sandy soil conditions. Asian J. Plant Sci., 19(3):230-239.

El-Sayed SAA, Hellal FA, Nofal OA, El-Karamany MF, Bakry BA (2015). Influence of algal extracts on yield and chemical composition of moringa and alfalfa grown under drought condition. Int J Environ, 4,151-157.

Enan SAAM, El-Saady AM, El-Sayed AB (2016). Impact of foliar feeding with alga extract and boron on yield and quality of sugar beet grown in sandy soil. Egypt J Agronematol, 38(2):319-336.

Farhangi-Abriz S, Ghassemi-Golezani K (2016). Improving amino acid composition of soybean under salt stress by salicylic acid and jasmonic acid. Journal of Applied Botany and Food Quality, 89, 243 - 248.

Fariduddin Q, Hayat S, Ahmad A (2003). Salicylic acid influences net photosynthetic rate, carboxylation efficiency, nitrate reductase activity, and seed yield in Brassica juncea. Photosynthetica, 41(2):281-284.

Farooq M, Hussain M, Wahid A, Siddique KHM (2012). Drought stress in plants: an overview. In Plant responses to drought stress (pp. 1-33). Springer, Berlin, Heidelberg.

Fghire R, Anaya F, Ali OI, Benlhabib O, Ragab R, Wahbi S (2015). Physiological and photosynthetic response of quinoa to drought stress. Chilean journal of agricultural research, 75(2):174-183.

Gámez AL, Soba D, Zamarreño ÁM, García-Mina JM, Aranjuelo I, Morales F (2019). Effect of water stress during grain filling on yield, quality and physiological traits of Illpa and Rainbow quinoa (*Chenopodium quinoa* Willd.) cultivars. Plants, 8(6):173.

Geerts S, Mamani RS, Garcia M, Raes D (2006). Response of quinoa (*Chenopodium quinoa* Willd.) to differential drought stress in the Bolivian Altiplano: Towards a deficit irrigation strategy within a water scarce region. In Proceedings of the 1st International Symposium on Land and Water Management for Sustainable Irrigated Agriculture, Adana Turkey, (4-8) CD-rom.

Ghazi D, (2017). Impact of Drought Stress on Maize (*Zea mays*) Plant in Presence or Absence of Salicylic Acid Spraying. Journal of Soil Sciences and Agricultural Engineering, 8(6):223-229.

Gupta S, Agarwal VP, Gupta NK (2012). Efficacy of putrescine and benzyladenine on photosynthesis and productivity in relation to drought tolerance in wheat (*Triticum aestivum* L.). Physiology and Molecular Biology of Plants, 18(4):331-336.

Hafez EM, Hafez YM (2016). Pivotal influence of chemical inducers on antioxidant enzyme activities and barley yield under biotic and abiotic stresses. Egypt. J. Agron, 38(2):209-224.

Hajihashemi S, Ehsanpour AA (2013). Influence of exogenously applied paclobutrazol on some physiological traits and growth of Stevia rebaudiana under in vitro drought stress. Biologia, 68(3):414-420.

Ilyas N, Gull R, Mazhar R, Saeed M, Kanwal S, Shabir S, Bibi F (2017). Influence of salicylic acid and jasmonic acid on wheat under drought stress. *Communications in Soil Science and Plant Analysis*, 48(22):2715-2723.

Iqbal H, Yaning C, Waqas M, Shareef M, Raza ST (2018). Differential response of quinoa genotypes to drought and foliage-applied H_2O_2 in relation to oxidative damage, osmotic adjustment and antioxidant capacity. Ecotoxicology and environmental safety, 164, 344-354.

Jackson ML (1973). Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd. New Delhi.

Jadhav SH, Bhambudekar SB, Patil DB (2013). Effect of salicylic acid on fatty acid composition of groundnut seeds. National Conference of plant physiology on 'Current Trend in Plant Biology Reasearch, 740-741 pp.

Jungklang J, Saengnil K, Uthaibutra J (2017). Effects of water-deficit stress and paclobutrazol on growth, relative water content, electrolyte leakage, proline content and some antioxidant changes in *Curcuma alismatifolia* Gagnep. cv. Chiang Mai Pink. Saudi Journal of Biological Sciences, 24(7):1505-1512.

Kamran M, Ahmad S, Ahmad I, Hussain I, Meng X, Zhang X, Javed T, Ullah M, Ding R, Xu P, Gu W (2020). Paclobutrazol application favors yield improvement of maize under semiarid regions by delaying leaf senescence and regulating photosynthetic capacity and antioxidant system during grain-filling Stage. Agronomy, 10(2):187.

Kang G, Li G, Xu W, Peng X, Han Q, Zhu Y, Guo T (2012). Proteomics reveals the effects of salicylic acid on growth and tolerance to subsequent drought stress in wheat. Journal of Proteome Research, 11(12):6066-6079.

Kang GZ, Li GZ, Liu GQ, Xu W, Peng XQ, Wang CY, Guo TC (2013). Exogenous salicylic acid enhances wheat drought tolerance by influence on the expression of genes related to ascorbate-glutathione cycle. Biologia Plantarum, 57(4): 718-724.

Kareem F, Rihan H, Fuller MP (2017). The effect of exogenous applications of salicylic acid and molybdenum on the tolerance of drought in wheat. Agricultural Research & Technology, 9(4):1-9.

Khani Basiri H, Sedghi M, Sharifi RS (2017). 'Effect of salicylic acid on the quality of edible oil and fatty acids composition in different regions of sunflower (*Helianthus annuus* L.) heads'. Iranian Journal of Plant Physiology, 8(1):2285-2292.

Lipiec J, Doussan C, Nosalewicz A, Kondracka K (2013). Effect of drought and heat stresses on plant growth and yield: a review. International Agrophysics, 27(4):463-477.

Mansori M, Farouk IA, Hsissou D, El Kaoua M (2019). Seaweed extract treatment enhances vegetative growth and antioxidant parameters in water stressed *Salvia officinalis* L. J. Mater. Environ. Sci., 10(8):756-766.

Manzoor K, Ilyas N, Batool N, Ahmad B, Arshad M (2015). Effect of Salicylic Acid on the Growth and Physiological Characteristics of Maize under Stress Conditions. Journal of the Chemical Society of Pakistan, 37(3):588-593.

Marhoon IA, Abbas MK (2015). Effect of foliar application of seaweed extract and amino acids on some vegetative and anatomical characters of two sweet pepper (*Capsicum annuum* L.) cultivars. International Journal of Research Studies in Agricultural Sciences, 1(1):35-44.

Masia A, Pitacco A, Braggio L, Giulivo C (1994). Hormonal responses to partial drying of the root system of Helianthus annuus. Journal of Experimental Botany, 45(1):69-76.

Mogazy AM, Seleem EA, Mohamed GF (2020). Mitigating the Harmful Effects of Water Deficiency Stress on White Lupine (*Lupinus albus* L.) Plants by Using Algae Extract and Hydrogen Peroxide. Journal of Plant Production, 11(10): 921-931.

MSTAT-C (1991). A Software Program for Design, Management, and Analysis of Agronomic Research Experiments. Michigan State University, East Lansing MI.

Nadali F, Asghari HR, Abbasdokht H, Dorostkar V, Bagheri M (2021). Improved Quinoa Growth, Physiological Response, and Yield by Hydropriming under Drought Stress Conditions. Gesunde Pflanzen, 73(1):53-66.

Nassar MA, EL-kobisy OS, Shaaban SA, Abdelwahab HM (2020). Seaweed extract enhancing growth, fresh herb and essential oil of sweet marjoram (*Origanum majorana* L.). Plant Archives, 20, 3094-3101.

Nawar DA, Ibraheim SKA (2014). Effect of algae extract and nitrogen fertilizer rates on growth and productivity of peas. Middle East J Agric Res, 3(4):1232-1241.

Nazar R, Umar S, Khan NA, Sareer O (2015). Salicylic acid supplementation improves photosynthesis and growth in mustard through changes in proline accumulation and ethylene formation under drought stress. South African Journal of Botany, 98, 84-94.

Nazar R, Umar S, Khan NA, Sareer O (2015). Salicylic acid supplementation improves photosynthesis and growth in mustard through changes in proline accumulation and ethylene formation under drought stress. South African Journal of Botany, 98, 84-94.

Nofal FH, El-Segai MU, Seleem EA (2015). Response of Calendula officinalis L. plants to growth stimulants under salinity stress. American-Eurasian J. Agric. & Environ. Sci, 15(9):1767-1778.

Noreen S, Ashraf M, Akram NA (2012). Does exogenous application of salicylic acid improve growth and some key physiological attributes in sunflower plants subjected to salt stress?. Journal of Applied Botany and Food Quality, 84(2):169.

Noreen S, Fatima K, Athar HUR, Ahmad S, Hussain K (2017). Enhancement of physio-biochemical parameters of wheat through exogenous application of salicylic acid under drought stress. J. Anim. Plant Sci, 27(1):153-163.

Ouzounidou G, Ilias I, Giannakoula A, Theoharidou I (2014). Effect of water stress and NaCl triggered changes on yield, physiology, biochemistry of broad bean (*Vicia faba*) plants and on quality of harvested pods. Biologia, 69(8):1010-1017.

Pal S, Zhao J, Khan A, Yadav NS, Batushansky A, Barak S, Rewald B, Fait A, Lazarovitch N, Rachmilevitch S (2016). Paclobutrazol induces tolerance in tomato to deficit irrigation through diversified effects on plant morphology, physiology and metabolism. Scientific reports, 6(1):1-13.

Parvin S, Javadi T, Ghaderi N (2015). Proline, protein, RWC and MSI contents affected by paclobutrazol and water deficit treatments in strawberry cv. Paros. Cercetari Agronomice in Moldova, 48(1):107-114.

Rademacher W (1997). Bioregulation in crop plants with inhibitors of gibberellins biosynthesis. Proceedings of the Plant Growth Regulation Society of America 24, 27-31.

Rajaram MG, Nagaraj S, Manjunath M, Boopathy AB, Kurinjimalar C, Rengasamy R, Jayakumar T, Sheu JR, Li JY (2018). Biofuel and biochemical analysis of *Amphora coffeaeformis* RR03, a novel marine diatom, cultivated in an open raceway pond. Energies, 11(6):1341.

Rao NS, Laxman RH, Shivashankara KS (2016). Physiological and morphological responses of horticultural crops to abiotic stresses. In Abiotic stress physiology of horticultural crops (pp. 3-17). Springer, New Delhi.

Rebey IB, Jabri-Karoui I, Hamrouni-Sellami I, Bourgou S, Limam F, Marzouk B (2012). Effect of drought on the biochemical composition and antioxidant activities of cumin (*Cuminum cyminum* L.) seeds. Industrial Crops and Products, 36(1):238-245.

Rodrigues LDA, de Castro EM, Pereira FJ, Maluleque IF, Barbosa JPRAD, Rosado SDS (2016). Effects of paclobutrazol on leaf anatomy and gas exchange of *Toona ciliata* clones. Australian Forestry, 79(4):241-247.

Salama MA, Yousef RS (2015). Response of basil plant (*Ocimum sanctum* L.) to foliar spray with amino acids or seaweed extract. J. of Horticultural Science & Ornamental Plants, 7(3):94-106.

Sankar B, Gopinathan P, Karthishwaran K, Somasundaram R (2014). Biochemical content variation in Arachis hypogaea under drought stress with or without paclobutrazol and abscisic acid. J. Ecobiotechnol, 6, 9-14.

Sedaghat M, Tahmasebi-Sarvestani Z, Emam Y, Mokhtassi-Bidgoli A (2017). Physiological and antioxidant responses of winter wheat cultivars to strigolactone and salicylic acid in drought. Plant physiology and biochemistry, 119,59-69.

Seleem EA, Taha ZK (2019). Enhancement of biometrics, anatomical characteristics and fatty acids profile of sunflower plants by foliar application with yeast extract and salicylic acid. Middle East Journal of Agriculture Research, 8(4):1271-1280.

Setia RC, Kaur P, Setia N (1996). Influence of paclobutrazol on growth and development of fruit in *Brassica juncea* (L.) Czern and Coss. Plant growth regulation, 20(3):307-316.

Shaki F, Maboud HE, Niknam V (2019). Effects of salicylic acid on hormonal cross talk, fatty acids profile, and ions homeostasis from salt-stressed safflower. *Journal of Plant Interactions*, 14(1):340-346.

Shapiro SS, Wilk MB (1965). "Analysis of variance test for normality (complete samples)."Biometrika, 52 (3/4): 591–611.

Soumya PR, Kumar P, Pal M (2017). Paclobutrazol: a novel plant growth regulator and multi-stress ameliorant. Indian Journal of Plant Physiology, 22(3):267-278.

SPSS Statistics 17.0. (2008). SPSS for Windows. SPSS Inc.

Steel RGD, Torrie JH, Dicky DA (1997). Principles and procedures of statistics: a biometrical approach. 3rd Ed. McGraw Hill, Inc. Book Co. N.Y, (U.S.A.), pp:352-358.

Telahigue DC, Yahia LB, Aliane F, Belhouchett K, Toumi L (2017). Grain yield, biomass productivity and water use efficiency in quinoa (*Chenopodium quinoa* Willd.) under drought stress. J. Sci. Agric, 1, 222-232.

Tesfahun W (2018). A review on: Response of crops to paclobutrazol application. Cogent Food & Agriculture, 4(1):1525169.

Tsegaw T, Hammes S, Robbertse J (2005). Paclobutrazol-induced leaf, stem, and root anatomical modifications in potato. HortScience, 40(5):1343-1346.

Van Oosten MJ, Pepe O, De Pascale S, Silletti S, Maggio A (2017). The role of biostimulants and bioeffectors as alleviators of abiotic stress in crop plants. Chemical and Biological Technologies in Agriculture, 4(1):5.

Waqas M, Yaning C, Iqbal H, Shareef M, Rehman H, Yang Y (2017). Paclobutrazol improves salt tolerance in quinoa: Beyond the stomatal and biochemical interventions. Journal of Agronomy and Crop Science, 203(4):315-322.

Winnicki K, Ciereszko I, Leśniewska J, Dubis AT, Basa A, Żabka A, Hołota M, Sobiech L, Faligowska A, Skrzypczak G, Maszewski J, Polit JT (2019). Irrigation affects characteristics of narrow-leaved lupin (*Lupinus angustifolius* L.) seeds. Planta, 249:1731–1746.

Xia X, Tang Y, Wei M, Zhao D (2018). Effect of paclobutrazol application on plant photosynthetic performance and leaf greenness of herbaceous peony. Horticulturae, 4(1):5.

Yadav T, Kumar A, Yadav RK, Yadav G, Kumar R, Kushwaha M (2020). Salicylic acid and thiourea mitigate the salinity and drought stress on physiological traits governing yield in pearl millet-wheat. Saudi Journal of Biological Sciences, 27(8):2010-2017.

Youssef RA, El-Azab ME, Mahdy HA, Essa EM, Mohammed KA (2017). Effect of salicylic acid on growth, yield, nutritional status and physiological properties of sunflower plant under salinity stress. International Journal of Pharmaceutical and Phytopharmacological Research, 7(5):54-58.

Zewail RMY (2014). Effect of seaweed extract and amino acids on growth and productivity and some biocostituents of common bean (*Phaseolus vulgaris* L) plants. Journal of Plant Production, 5(8):1441-1453.

Zhang FJ, Zhang KK, Du CZ, Li J, Xing YX, Yang LT, Li YR (2015). Effect of drought stress on anatomical structure and chloroplast ultrastructure in leaves of sugarcane. Sugar Tech, 17(1):41-48.

Zhu LH, van de Peppel A, Li XY, Welander M (2004). Changes of leaf water potential and endogenous cytokinins in young apple trees treated with or without paclobutrazol under drought conditions. Scientia Horticulturae, 99(2):133-141.

الملخص العربي

استجابة نبات الكينوا المنزرع تحت ظروف الجفاف للرش الورقي بحمض الساليسيليك والباكلوبوترازول ومستخلص الطحالب

عزة محمود احمد سلامه[1]، انجي علاء سليم[1]، احمد عيسي غنيم[1] وربيع محمد عبد السلام[2]

[1]قسم النبات الزراعي، كلية الزراعة، جامعة القاهرة، الجيزة، مصر

[2]قسم المحاصيل، كلية الزراعة، جامعة القاهرة، الجيزة، مصر

كان الهدف من هذه الدراسة هو تقييم خصائص النمو والانتاجية لنبات الكينوا المنزرعة تحت اجهاد الجفاف باستخدام بعض منظمات النمو والمثبطات والمحفزات الحيوية. وقد اجريت التجربة بمحطة البحوث الزراعية بكلية الزراعة –جامعة القاهرة– الجيزة– مصر خلال موسمي زراعة متتاليين في الشتاء لعامي ٢٠١٩– ٢٠٢٠. وقد قسم الجزء الافقي من الارض الي نظامين من الري (المروي جيدا ويمثل ٨٠% من السعة الحقلية للارض و المعرض للجفاف ويمثل ٤٠% من السعة الحقلية للارض). اما الجزء الرأسي للارض فقد خصص للمواد المستخدمة لتقليل اثر الجفاف وهي (حمض السالسيليك والباكلوبوترازول ومستخلص الطحالب) بالاضافة الي معاملة الكنترول. وهي (ماء الصنبور).

اوضحت النتائج ان استخدام مواد التخفيف من الجفاف قد عزز بشكل معنوي قياسات النمو، طول النورات، عدد النورات لكل نبات، عدد البذور لكل نبات، وزن الالف بذرة و محصول البذور للنبات في الهكتار مقارنة بالنباتات غير المعالجة. بالاضافة الي، اظهر رش النبات بحمض السالسيليك و الباكلوبوترازول ومستخلص الطحالب عند سعة حقلية ٤٠% زيادة معنوية في النمو والخصائص الكيميائية مقارنة بالنباتات الغير معاملة. ادي تطبيق الرش الورقي بمعدل ١٠٠ جزء في المليون من حمض السالسيليك الي تغييرات ايجابية في النمو والمحصول والتركيب التشريحي للساق والاوراق في نبات الكينوا. كما ادي رش النباتات بالمواد المذكورة اعلاه الي زيادة جميع العناصر الكبري والصغري تقريبا، بالاضافة الي نسبة الكربوهيدرات الكلية والبروتين الخام في البذور. كما اوضح تحليل الاحماض الامينية في بذور الكينوا باستخدام محلل الاحماض الامينية عن وجود تركيز عالي من الفينيل الانين، الليسين واللايسين. وكذلك تم تحليل الاحماض الدهنية وتم الكشف عن نسبة عالية من اللينوليك.