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# Application of Jasmonic Acid and Lithovit to Overcome Adverse Effects of Drought Stress in Wheat

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## ABSTRACT

Water deficit consider as one of the abiotic factors controlling growth and limiting wheat yield, through affecting on the physiological and biochemical processes within the plant tissues. Two field experiments were carried out in order to investigate the effect of rates from stress defense substances [Jasmonic acid (JA) and Lithovit (Li)] on growth, physiological traits, chemical constitutes and yield of wheat plants (Gemmeiza 11 cultivar) under three water regimes (100, 75 and 50% $ET_c$) at Experimental Farm, Faculty of Agriculture, Menoufia University, Shebin El-Kom, Egypt during the two growing winter seasons of 2016/2017 and 2017/2018. Exposing plants to water deficit levels (75% and I 50% $ET_c$) decreased in all growth characters studied, water relations (total water content, relative water content, osmotic pressure, transpiration rate and plasma membrane integrity), photosynthetic pigments, chemical composition (total carbohydrates, total soluble sugars, N and K) as well as yield and its components (number of spikes/ $m^2$, number of grains /spike, spike weight, 1000-grain weight, grain yield /fed and straw yield /fed) in comparison with well-watered plants (Control, 100 $ET_c$). However, plants grown under severe water stress (I 50% $ET_c$) recorded highest activities of peroxidase, phenoloxidase and increased proline content.Application of JA and lithovit combinations showed an additive effects on increasing all characters studied except transpiration rate, plasma membrane integrity, activities of peroxidase and phenoloxidase as well as proline content compared to untreated plants. Application rate 10 ppm JA + 5% lithovit surpassed most of the other tested characters studied in both growing seasons. The interactions between water regimes and stress defense substances (JA and Li) were found to be significant for most studied traits. Wheat grown under normal irrigation integrated with application of 10 ppm JA + 5% lithovit generally produced the highest values of growth, photosynthetic pigments as well as yield and its components. Moreover, application of 10 or 20 ppm jasmonic acid + 5% lithovit under water stress conditions led to an increase in all vegetative growth characters, water relations (total water content, relative water content and osmotic pressure), photosynthetic pigments, chemical composition of the leaves (total carbohydrates and total soluble sugars contents, N and K percentages) as well as yield and its components, while caused a significant decrease in transpiration rate, plasma membrane integrity, proline, activities of peroxidase and phenoloxidase enzymes. It could be recommended that application of JA integrated with lithovit (10 ppm JA + 5% Li) under water deficit conditions led to mitigate the adverse effects of drought stress and increased growth and productivity of wheat.

**Keywords:** Wheat, Water regimes, Jasmonic acid, Lithovit, Physiological traits, Yield, ET= Evaporatrom piration.

## INTRODUCTION

Wheat (*Triticum aestivum*.) is considering most important cereal crops grown in the world. It is the first strategic crop, represents the main diet for Egyptian population and sources of many food industries (Salleh, 2015). Nevertheless, there gap between production and consumption in Egypt since the local production annually varied and covers about 50% of requirements. Last winter season (2017/2018), the cultivated area of wheat roughly equal 3.15 million fed, produced about only 8.1 million tons according to Global Agricultural Information Network (GAIN report 2018). Increasing the cultivated area of wheat should be done in the reclaimed soils due to the limited areas of the Nile valley and the competition with other main crops. So, increasing production of unit area appears to be the important factors for narrowing this gap.

Water stress is one of the important abiotic factors affecting crop species distribution and limiting their growth and productivity around the world especially in the arid regions like Egypt (Mohammadi *et al*., 2013 and Hammad and Ali, 2014). In Egypt, spread of water deficit is a serious problem because of the lack of water quantity annually in the Nile River. This situation is due to the construction of the Ethiopian water dam which will affect the area of agricultural land as well as cultivated plant species in future periods. Plant growth under water stress is affected by changes in the efficiency of photosynthesis, uptake and translocation of nutrients and water and hormones formation (Gontia-Mishra *et al*., 2016). Water deficit affect directly or indirectly photosynthesis through affecting the carbohydrate metabolism and consequently crop yield (Ma *et al*., 2014 and Zakaria *et al*., 2018).

Application of stress defense substances can help plants to tolerant drought through affecting some physiological and biochemical processes. Jasmonic acid [3-oxo-2-(2-cis-pentenyl)-cyclopentane-1-acetic acid] is an organic compound including plant growth regulator, affects biochemical and physiological processes in the plant tissues. It enhances induction promotion of carotenoid biosynthesis, root formation and protein synthesis (Hassanein *et al*., 2009 and Anjum *et al*., 2016). Using new types of nano fertilizers is one of the effective ways for increasing the global agricultural productions to meet the future demands of the world population (Shallan *et al*., 2016). Lithovit (a Nano-$CaCO_3$) is natural foliar fertilizer made from natural mineral limestone deposits with some nutrients. It is a new nano technological fine powder created by tribodynamic activation and micronization. It is a natural fertilizer releases $CO_2$, consequently that reflected in enhancing the net photosynthesis rates and rise promoted effects on growth and yield of various plants (Shallan *et al*., 2016; Morsy *et al*., 2018 and Zakaria *et al*., 2018). In this concern, Kumar (2011) reported that nano fertilizers have emerged as an alternative to conventional fertilizers for slow release and efficient use of water and fertilizers by plants. Spraying lithovit is penetrate leaves stomata directly after application and partially when leaves surface is get wet by dew at night. $CaCO_3$ converted into carbon dioxide within plant leaf structure so as to improve photosynthetic efficiency (Zakaria *et al*., 2018).

Therefore, this study aimed to identify optimal application of jasmonic acid and/or lithovit rates in order to reduce the harmful effects of water stress on wheat plants. The physiological and biochemical changes as well as yield and its components of wheat grown under various water regimes were also studied.

## MATERIALS AND METHODS

**Experimental procedures**

Two field experiments were carried out in order to investigate the effects of stress defense treatments (Jasmonic acid "JA" and Lithovit "Li") on growth, physiological traits, chemical constitutes and yield of wheat plants (Gemmeiza 11 cultivar) grown under different water regimes. The experimental were conducted out at Experimental Farm, Faculty of Agriculture, Menoufia University, Shebin El-Kom during the two growing winter seasons of 2016/2017 and 2017/2018. The experiments included twenty-seven treatments which were the combination of three water regimes and nine levels of jasmonic acid and lithovit as follows:

**A- water regimes**

1- well- watered plants (I 100% $ET_c$)
2- moderate water stress (I 75% $ET_c$)
3- severe water stress (I 50% $ET_c$)

**B- stress defense substances**

1- JA 0 ppm + Li 0 % (Control).
2- JA 0 ppm + Li 2.5 %.
3- JA 0 ppm + Li 5.0 %.
4- JA 10 ppm + Li 0 %.
5- JA 10 ppm + Li 2.5 %.
6- JA 10 ppm + Li 5.0 %.
7- JA 20 ppm + Li 0 %.
8- JA 20 ppm + Li 2.5 %.
9- JA 20 ppm + Li 5.

The tested treatments were arranged in a split plot design system with three replicates, where water regimes randomly occupied in main plots, while stress defense treatments were randomly distributed in sub-plots. In all tested water regimes, five irrigation were applied with tested levels at 25, 55, 86, 110 and 131 days after sowing (DAS) in both seasons. Irrigation water was supplied from pump supplied with flow meter, established at head of experimental field to calculated the discharge water supply. Tested JA rates were prepared by soaking wheat grains immediately before planting with six hours, then grains were transferred to clean surface to air-dried before planting, while lithovit rates were applied by foliar application twice at 35 and 50 days after sowing (DAS). Lithovit fertilizer contains calcium carbonate (79.19 %), nitrogen (0.06%), phosphate (0.01%), potassium oxide (0.21), magnesium carbonate (4.62%), sulphate (0.33%), iron (1.31%), zinc (0.005%), manganese (0.014%), copper (0.002%) and selenium dioxide (11.41%) according to (Jackson, 1973 and Page *et al*., 1982 as shown in Tables, 1 a and b).

**Study area and data recorded**

The expected farm is lying in northern Nile Delta, Egypt (latitude 30°31'39"N, longitude 31°04'03"E), 12 m above mean sea level. Physical and chemical characters of the texture of the soil used is clay loam. It has a relatively heavy texture permeable. The climate is arid with low average precipitation and temperature around 22-26 °C during the growing winter season. Penman-Monteith method was used to estimate reference evapotranspiration ($ET_o$) using meteorological data collected from Central Laboratory for Agricultural Climate, Egypt during growth period (Table 2), then crop evapotranspiration ($ET_c$) was calculated according the Equation (1) as follows:

$$ET_c = ET_o \times K_c$$

**Where;** **$ET_o$ : Reference evapotranspiration (mm/day)**
**$K_c$: Crop coefficient during plant growth stages**

**Table 1a. Mechanical and chemical properties of experimental soil.**

| Seasons | Texture class | Sand % | Silt % | Clay % | pH | E.C. ds/m | O.M. % | Available nutrients (ppm) N | P | K |
|---|---|---|---|---|---|---|---|---|---|---|
| 2016/17 | Clay loam | 32.05 | 34.89 | 31.81 | 7.86 | 0.64 | 1.73 | 31.14 | 9.62 | 353.72 |
| 2017/18 | Clay loam | 32.08 | 34.84 | 31.77 | 7.67 | 0.68 | 1.76 | 32.87 | 9.83 | 341.39 |

**Table 1b. Physical properties of experimental soil depths.**

| Properties Soil depth | Field capacity % | Permanent wilting point% | Available soil water % | Bulk Density g/cm$^3$ |
|---|---|---|---|---|
| 0-30 cm | 38.8 | 19.1 | 19.7 | 1.31 |
| 30-45 cm | 38.0 | 18.8 | 19.2 | 1.37 |
| 45-60 cm | 37.1 | 17.9 | 19.2 | 1.38 |

**Table 2. Monthly meteorological data of experimental site.**

| Month | 2016/2017 season Temperature (°C) Max. | Min. | Relative humidity (%) | Wind speed km/h | Rain (mm) | 2017/2018 season Temperature (°C) Max. | Min. | Relative humidity (%) | Wind speed km/h | Rain (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| November | 25.17 | 16.40 | 56.70 | 25.87 | 0.60 | 23.83 | 15.65 | 56.87 | 23.47 | 2.55 |
| December | 18.84 | 11.52 | 56.52 | 22.94 | 4.00 | 22.00 | 13.47 | 58.55 | 23.81 | 0.64 |
| January | 18.26 | 9.77 | 56.71 | 20.21 | 1.04 | 19.16 | 11.84 | 55.63 | 30.62 | 6.13 |
| February | 19.96 | 10.39 | 59.89 | 22.13 | 2.03 | 23.50 | 13.89 | 51.07 | 23.75 | 7.16 |
| March | 23.81 | 14.84 | 52.16 | 24.30 | 0.00 | 27.84 | 16.39 | 45.88 | 18.81 | 2.03 |
| April | 27.87 | 16.87 | 48.57 | 30.87 | 4.20 | 29.10 | 18.03 | 45.95 | 27.00 | 3.05 |

**Crop management practices**

The experimental sub plot area was 14 m$^2$ (4 m long and 3.5 m width). Empty area (1.5 m) was lefted as a buffer area among all plots in order to eliminate any water leakage. Sowing was done on the 6$^{th}$ and 8$^{th}$ November of the first and second seasons, respectively by hand drilled method with a distance among rows 15 cm using a rate of 350 grains/m$^2$. Maize is the preceding crop in both seasons. Soil application of calcium superphosphate was applied during soil preparation at a rate of 150 kg/fed. Nitrogen fertilizer at a rate of 75 kg N/fed in the form of urea (46.5 % N) was splitted into two doses. First dose being applied immediately before first irrigation and second one was applied before second irrigation. Potassium at a rate 24 kg $K_2O$/fed was added in the form of potassium sulphate (48 kg $K_2O$/fed) in one dose before first irrigation. Other agricultural practices were performed as recommended by Agric. Res. Center, Giza, Egypt.

**Measurements:**

- **Vegetative growth traits:** at 70 DAS, sample guarded plants of square area (50 x 50 cm) were uprooted carefully using mattock at random from each experimental plot. Roots were dipped in water to remove the soil then washed. Vegetative traits were recorded as mean values of the individual guarded plants of square area as follows: plant height (cm), root volume ($cm^3$), number of tillers /plant, leaf area /plant ($cm^2$) as well as root and shoot dry weights /plant (g.).

**Physiological parameters:**

Water relations: at 85 DAS, total water content (TWC, %), relative water content (RWC, %), osmotic pressure (OP, atm) transpiration rate (mg/g fresh wt. hr), plasma membrane integrity (PMI, %) were estimated in the choats according to Gosev (1960) and Kreeb (1990), Barrs and Weatherley (1962), Gosev (1960), Kreeb (1990), Yan and Dai (1996) respectively. Photosynthetic pigments (chlorophyll a, b and carotenoids were extracted from the fresh leaf samples ($4^{th}$ upper leaf) using pure acetone (85%) and calculated as mg/g dry weight according to the formulas outline by Wettstein (1957). Total carbohydrates and total sugars (mg/g dry weight) were determined in leaves using the phenol sulfuric acid method as outlined by AOAC (2000). Antioxidant enzymes activities of peroxidase and phenoloxidase (O.D./g fresh weight) were determined according to Fehrman and Dimond (1967) and Broesh (1954). Proline content (µg/g dry weight) was determined according to Bates *et al*. (1973) using ninhydrin method. Percentages of N, P, K and Ca were determined in leaves as a described by AOAC (2000).

**Yield and its components:** At maturity stage, plant samples of one square meter were harvested from central each experimental plot to determine number of spikes/$m^2$, number of grains /spike as a mean values of twenty spikes, spike weight (g.) as a mean values of twenty spikes, 1000-grain weight (g.). Grain and straw yields /$m^2$ were converted to grain yield /fed (ton) and straw yield /fed (ton).

**Statistical analysis**

Data were subjected to statistical analysis of variance (ANOVA). Least significant differences (LSD) test was used to compare the treatment means at probability of 5% according to the procedures outlined by Snedecor and Cochran (1980) using CoStat computer software program (version 6.4).

## RESULTS AND DISCUSSION

**Growth characters:**

Data in Table (3) showed that wheat plants grown under water stress levels (75% and 50% $ET_c$) recorded significant decreases in all growth traits. This decrease was increased with increasing water deficit level in comparison with well-watered plants (100% $ET_c$). Irrigation with I 50% $ET_c$ caused inhibition in plant height, root volume, tillers number, leaf area, dry weight of root and dry weight of shoot reached about 23.18, 40.77, 64.67, 10.76, 18.99 and 20.73 %, respectively as an average of both seasons compared to normal irrigation (I 100% $ET_c$). In this concern, Anjum *et al*., (2016) mentioned that drought stress at any growth stage substantially reduced the growth of wheat. This reduction was observed when plants were exposed to drought stress in jointing stage compared with that recorded in heading or grain filling stage. Sarto *et al*., (2017) mentioned that drought affects germination in the initial phase, tillers number in the tillering stage, and plant height in the elongation stage of wheat. Water deficit in plants reduces the plant-cell's water potential and turgor, which elevate the solute's concentrations in the cytosol and extracellular matrices. Cell enlargement decreases leading to growth inhibition and reproductive failure. This is followed by more accumulation of abscisic acid and compatible osmolytes like proline, which cause wilting. At this stage, overproduction of reactive oxygen species (ROS) and formation of radical scavenging compounds such as ascorbate and glutathione further aggravate the adverse influence (Lisar *et al.,* 2012).

Data in the same table, demonstrate that there are a significant increases in all growth characters except plant height due to application different stress defense treatments (JA and Li) compared to untreated plants. Soaking grains with JA at a rate of 20 ppm with or without lithovit caused reduction in plant height. Moreover, it can be noticed that application of 10 ppm JA + 5 % Li was the most effective treatment for increasing plant height, root volume, tillers number, leaf area and root and shoot dry weights by about 4.47, 37.08, 85.35, 8.22, 14.20 and 9.46 %, respectively as an average of both seasons compared to untreated plants. Similar trends were observed by Pigolev *et al*. (2018) who cleared that modification of the jasmonate pathway is a suitable tool for the modulation of developmental traits and stress responses in wheat. This reflected in increasing vegetative growth characters. Huang *et al.* (2017) mentioned that JA have functions in a remarkable number of plant developmental events, including primary root growth and reproductive development. Moreover, Hamoda *et al.* (2016) found that application of lithovit caused significant increases in plant growth parameters.

Concerning the interaction treatments between JA and Li, Table (3) shows that growth characters reached to the maximum values when wheat plants grown under I 100% $ET_C$ and treated with 10 ppm JA + 5 % Li followed by 20 ppm JA + 5 % Li in both seasons. However, the lowest values were obtained by plants grown under I 50% $ET_C$ especially when untreated with any stress defense treatments except plant height which obtained by 20 ppm JA + 0% Li. Application of JA and / or Li caused significant increases in wheat growth under water deficit conditions. The present results are agreement with Maswada and Abd El-Rahman (2014) who cited that maximum increases in growth (root and shoot dry weight, relative growth rate and net assimilation rate) were recorded by application of lithovit with or without water deficit treatments compared to untreated plants. Anjum *et al*., (2016) stated that application of methyl jasmonate effectively assuaged the damaging effects of water deficit. In addition, there is a beneficial effect of methyl jasmonate on dry biomass of treated plants under drought as well as normal conditions. Also, lithovit has an important effect on photosynthesis process (Table, 5). Similar trend was reported by Huang *et al.,* (2017) who stated that application of JA caused improving in growth characters of wheat plants grown under stress conditions.

**Table 3. Effect of water regimes, stress defense substances and their interactions on vegetative growth characters of wheat plants grown under the two growing seasons.**

| Water regimes ($ET_c$) | Stress defense substances JA (ppm) + Li (%) | Plant height (cm) | Root volume ($cm^3$) | No of tillers / plant | Leaf area ($cm^2$) | Dry wt. (g.) Root | Dry wt. (g.) Shoot | Plant height (cm) | Root volume ($cm^3$) | No of tillers / plant | Leaf area ($cm^2$) | Dry wt. (g.) Root | Dry wt. (g.) Shoot |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2016 /2017 Season | | | | | | 2017 /2018 Season | | | | | |
| 100 % | | 75.54 | 3.401 | 3.77 | 239.23 | 0.860 | 2.055 | 73.75 | 3.298 | 3.56 | 235.39 | 0.820 | 3.001 |
| 75 % | | 69.54 | 3.232 | 3.15 | 234.18 | 0.814 | 2.028 | 63.45 | 3.056 | 3.15 | 231.69 | 0.771 | 2.351 |
| 50 % | | 60.02 | 2.056 | 1.22 | 213.59 | 0.704 | 1.918 | 54.66 | 1.912 | 1.37 | 209.98 | 0.657 | 2.090 |
| LSD at 5% | | 2.93 | 0.043 | 0.208 | 2.216 | 0.051 | 0.101 | 5.08 | 0.141 | 0.250 | 2.281 | 0.062 | 0.232 |
| | 0.0 JA + 0.0 Li | 68.66 | 2.469 | 2.00 | 220.15 | 0.750 | 1.953 | 63.36 | 2.385 | 1.89 | 217.68 | 0.680 | 2.266 |
| | 0.0 JA + 2.5 Li | 69.83 | 2.576 | 2.33 | 221.36 | 0.769 | 1.960 | 65.73 | 2.586 | 2.33 | 220.88 | 0.730 | 2.486 |
| | 0.0 JA + 5.0 Li | 70.93 | 3.070 | 3.11 | 225.64 | 0.794 | 1.983 | 66.88 | 2.739 | 2.88 | 222.29 | 0.754 | 2.501 |
| | 10.0 JA + 0.0 Li | 68.35 | 2.864 | 2.55 | 231.99 | 0.804 | 2.016 | 62.58 | 2.643 | 2.55 | 225.00 | 0.756 | 2.486 |
| | 10.0 JA + 2.5 Li | 68.55 | 3.170 | 2.77 | 234.45 | 0.814 | 2.030 | 64.19 | 2.798 | 2.77 | 232.42 | 0.777 | 2.538 |
| | 10.0 JA + 5.0 Li | 71.68 | 3.465 | 3.55 | 237.88 | 0.834 | 2.048 | 66.24 | 3.189 | 3.66 | 235.93 | 0.799 | 2.570 |
| | 20.0 JA + 0.0 Li | 64.49 | 2.475 | 2.44 | 227.12 | 0.772 | 1.990 | 61.37 | 2.662 | 2.44 | 223.69 | 0.730 | 2.469 |
| | 20.0 JA + 2.5 Li | 65.43 | 2.805 | 2.55 | 229.41 | 0.784 | 2.002 | 62.49 | 2.806 | 2.66 | 224.26 | 0.741 | 2.474 |
| | 20.0 JA + 5.0 Li | 67.39 | 3.174 | 3.11 | 232.99 | 0.811 | 2.022 | 62.73 | 2.988 | 3.00 | 229.03 | 0.778 | 2.536 |
| LSD at 5% | | 4.83 | 0.025 | 0.321 | 5.050 | 0.091 | 0.127 | 3.54 | 0.101 | 0.398 | 3.705 | 0.071 | 0.249 |
| | 0.0 JA + 0.0 Li | 72.78 | 2.972 | 3.00 | 233.12 | 0.826 | 2.022 | 69.96 | 2.873 | 2.67 | 229.52 | 0.786 | 2.713 |
| | 0.0 JA + 2.5 Li | 74.65 | 3.267 | 3.33 | 236.77 | 0.848 | 2.042 | 74.22 | 3.160 | 3.00 | 234.44 | 0.810 | 3.019 |
| | 0.0 JA + 5.0 Li | 77.45 | 3.861 | 4.33 | 239.87 | 0.871 | 2.059 | 76.48 | 3.218 | 3.66 | 235.90 | 0.834 | 3.043 |
| | 10.0 JA + 0.0 Li | 74.92 | 3.267 | 3.67 | 239.65 | 0.860 | 2.057 | 72.45 | 3.074 | 3.33 | 230.78 | 0.798 | 2.983 |
| 100% | 10.0 JA + 2.5 Li | 75.50 | 3.564 | 3.67 | 239.63 | 0.860 | 2.058 | 75.56 | 3.246 | 3.67 | 238.85 | 0.826 | 3.056 |
| | 10.0 JA + 5.0 Li | 79.22 | 3.861 | 4.67 | 244.74 | 0.893 | 2.085 | 78.87 | 3.735 | 4.67 | 242.69 | 0.861 | 3.103 |
| | 20.0 JA + 0.0 Li | 73.15 | 2.971 | 3.33 | 237.65 | 0.844 | 2.046 | 72.81 | 3.304 | 3.33 | 235.58 | 0.810 | 3.016 |
| | 20.0 JA + 2.5 Li | 74.88 | 3.267 | 3.67 | 238.74 | 0.856 | 2.052 | 72.89 | 3.476 | 3.67 | 231.43 | 0.814 | 2.996 |
| | 20.0 JA + 5.0 Li | 77.33 | 3.581 | 4.33 | 242.89 | 0.878 | 2.075 | 70.49 | 3.591 | 4.00 | 239.28 | 0.846 | 3.083 |
| | 0.0 JA + 0.0 Li | 70.44 | 2.950 | 2.67 | 228.45 | 0.769 | 1.998 | 64.52 | 2.729 | 2.33 | 226.47 | 0.683 | 2.151 |
| | 0.0 JA + 2.5 Li | 71.46 | 2.967 | 3.00 | 227.86 | 0.799 | 1.995 | 66.68 | 2.902 | 3.00 | 230.14 | 0.766 | 2.383 |
| | 0.0 JA + 5.0 Li | 74.54 | 3.269 | 3.33 | 233.41 | 0.833 | 2.024 | 67.74 | 2.959 | 3.33 | 229.59 | 0.794 | 2.386 |
| | 10.0 JA + 0.0 Li | 69.38 | 3.267 | 3.00 | 236.47 | 0.826 | 2.040 | 62.54 | 3.103 | 3.00 | 230.73 | 0.786 | 2.362 |
| 75% | 10.0 JA + 2.5 Li | 69.90 | 3.569 | 3.33 | 236.58 | 0.829 | 2.041 | 63.40 | 3.051 | 3.33 | 232.26 | 0.790 | 2.375 |
| | 10.0 JA + 5.0 Li | 70.94 | 3.861 | 3.67 | 239.21 | 0.841 | 2.056 | 65.02 | 3.534 | 3.67 | 237.33 | 0.806 | 2.411 |
| | 20.0 JA + 0.0 Li | 64.72 | 2.673 | 3.00 | 233.14 | 0.795 | 2.022 | 59.63 | 2.988 | 3.00 | 232.53 | 0.758 | 2.355 |
| | 20.0 JA + 2.5 Li | 65.46 | 2.970 | 3.00 | 234.47 | 0.803 | 2.029 | 60.09 | 3.045 | 3.33 | 232.96 | 0.766 | 2.360 |
| | 20.0 JA + 5.0 Li | 69.01 | 3.564 | 3.33 | 238.00 | 0.829 | 2.049 | 61.47 | 3.189 | 3.33 | 233.20 | 0.790 | 2.375 |
| | 0.0 JA + 0.0 Li | 62.75 | 1.485 | 0.33 | 198.87 | 0.656 | 1.839 | 55.61 | 1.551 | 0.67 | 197.04 | 0.572 | 1.934 |
| | 0.0 JA + 2.5 Li | 63.39 | 1.494 | 0.67 | 199.45 | 0.660 | 1.842 | 56.30 | 1.695 | 1.00 | 198.07 | 0.615 | 2.057 |
| | 0.0 JA + 5.0 Li | 63.80 | 2.079 | 1.67 | 203.65 | 0.679 | 1.866 | 56.42 | 2.040 | 1.67 | 201.37 | 0.635 | 2.074 |
| | 10.0 JA + 0.0 Li | 60.75 | 2.059 | 1.00 | 219.84 | 0.728 | 1.951 | 52.74 | 1.753 | 1.33 | 213.48 | 0.683 | 2.114 |
| 50% | 10.0 JA + 2.5 Li | 60.25 | 2.376 | 1.33 | 227.15 | 0.754 | 1.990 | 53.61 | 2.097 | 1.33 | 226.14 | 0.715 | 2.182 |
| | 10.0 JA + 5.0 Li | 61.87 | 2.673 | 2.33 | 229.68 | 0.769 | 2.004 | 54.84 | 2.298 | 2.67 | 227.78 | 0.730 | 2.197 |
| | 20.0 JA + 0.0 Li | 55.60 | 1.782 | 1.00 | 210.57 | 0.675 | 1.901 | 51.65 | 1.695 | 1.00 | 202.97 | 0.623 | 2.035 |
| | 20.0 JA + 2.5 Li | 55.95 | 2.177 | 1.00 | 215.01 | 0.694 | 1.925 | 54.49 | 1.896 | 1.00 | 208.39 | 0.643 | 2.065 |
| | 20.0 JA + 5.0 Li | 55.83 | 2.376 | 1.67 | 218.09 | 0.725 | 1.942 | 56.23 | 2.183 | 1.67 | 214.62 | 0.699 | 2.151 |
| LSD at 5% | | 8.36 | 0.089 | 0.555 | 8.676 | 0.157 | 0.220 | 6.12 | 0.174 | 0.684 | 6.421 | 0.019 | 0.430 |

**Physiological parameters:**

**Water relations:**

Significant decreases in TWC, RWC, OP and PMI in both seasons and transpiration rate in second season were detected with increasing water deficit (Table 4). The major decrease was achieved by plants exposing to severe drought in both seasons (50% $ET_C$) which reached about 13.48, 13.45, 13.45, 13.86 and 15.09% respectively compared to normal irrigation (100% $ET_C$). Water stress not only affects plant water relations through the reduction of water content, turgor and total water, it also affects stomatal closure, limits gaseous exchange and reduces transpiration rate Lisar *et al.* (2012). The negative effects of water deficit on total water content, free water, relative water content and transpiration rate were previously reported by Hammad and Ali (2014) and Ilyas *et al.* (2017).

The recorded data in table (4) showed also that treated wheat plants with JA + Li rates registered increase in TWC, RWC and OP compared to untreated plants. On the other hand, JA and Li rates applied recorded a decrease in PMI in both seasons and transpiration rate in one season when compared with the untreated plants. Treated wheat with 0.25 µM methyl jasmonate caused increases in photosynthesis under drought conditions due to enhancing water relations and antioxidant (Ma *et al*., 2014). Foliar spray with $CaCO_3$ in the form of lithovit (a Nano-$CaCO_3$) at a rate of 7.5g/L significantly decreased leaf water deficient, osmotic pressure and plasma membrane permeability, while significantly increased total water and relative water contents in cotton leaves (El-Shazly, 2017). Application of Li + JA increased photosynthetic pigments, consequently total and soluble sugars, which resulted in the control of the osmotic pressure in the plant cell and this in turn reflected in increasing water content of plant. This enhancement done in wheat plants grown under water deficit conditions may be due to that JA acts as a natural resistor in the plant to resist stress conditions, as well as the activation of photosynthesis by lithovit.With regard to the interaction treatments effects, data in Table (4) declared that plants which were grown under normal irrigation (I 100% $ET_c$) and treated with JA + Li rates especially 10 ppm JA+ 5% Li produced the highest mean values of TWC, RWC and OP, respectively. Meanwhile, plants grown under severe stress level (I 50% $ET_c$) and treated by 10 ppm JA + 5% Li recorded decreases in transpiration rate and PMI. Prior *et al.* (2011) pointed out that application of more $CO_2$ can increase plant water use efficiency. Relative water content in cotton leaves were decreased under drought stress conditions in comparison with well-watered plants of Giza 94 cultivar (Shallan *et al.,* 2016). In this concern, Similarly, Morsy *et al.* (2018) indicated that application of nano-fertilizer (400 ppm lithovit) to plants cultivated under different irrigation levels had significant effects on most water relation parameters.

**Table 4. Effect of water regimes, stress defense substances and their interactions on water relations of wheat plants grown under the two growing seasons.**

| Water regimes ($ET_c$) | Stress defense substances JA (ppm) + Li (%) | TWC (%) | RWC (%) | OP (atm) | Trans-piration rate (mg/g fw.hr) | Plasma membrane Perm. (%) | TWC (%) | RWC (%) | OP (atm) | Trans-piration rate (mg/g fw.hr) | Plasma membrane Perm. (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2016 /2017 Season | | | | | 2017 /2018 Season | | | | |
| 100 % | | 82.18 | 72.45 | 8.40 | 0.025 | 36.478 | 81.19 | 68.16 | 8.26 | 0.028 | 43.04 |
| 75 % | | 75.66 | 66.70 | 7.74 | 0.022 | 33.273 | 74.74 | 62.86 | 7.61 | 0.025 | 39.27 |
| 50 % | | 71.10 | 62.68 | 7.27 | 0.021 | 31.420 | 70.24 | 59.02 | 7.15 | 0.024 | 37.08 |
| LSD at 5% | | 4.560 | 4.020 | 0.470 | NS | 1.853 | 4.500 | 3.840 | 0.460 | 0.003 | 2.190 |
| | 0.0 JA + 0.0 Li | 73.47 | 63.91 | 6.76 | 0.024 | 35.83 | 72.64 | 56.66 | 6.66 | 0.027 | 42.11 |
| | 0.0 JA + 2.5 Li | 73.50 | 65.36 | 7.14 | 0.023 | 34.25 | 73.07 | 58.88 | 7.07 | 0.026 | 40.50 |
| | 0.0 JA + 5.0 Li | 76.31 | 66.88 | 8.26 | 0.023 | 32.68 | 75.35 | 56.53 | 8.12 | 0.026 | 38.64 |
| | 10.0 JA + 0.0 Li | 77.57 | 68.21 | 7.93 | 0.023 | 34.09 | 75.02 | 62.05 | 7.64 | 0.025 | 39.54 |
| | 10.0 JA + 2.5 Li | 77.67 | 68.18 | 7.95 | 0.022 | 33.57 | 77.73 | 68.18 | 7.92 | 0.025 | 39.13 |
| | 10.0 JA + 5.0 Li | 79.47 | 69.79 | 8.88 | 0.022 | 32.02 | 79.12 | 69.79 | 8.80 | 0.023 | 38.12 |
| | 20.0 JA + 0.0 Li | 75.91 | 67.74 | 7.30 | 0.024 | 35.05 | 75.56 | 67.74 | 7.23 | 0.027 | 41.50 |
| | 20.0 JA + 2.5 Li | 76.39 | 68.01 | 7.77 | 0.023 | 33.57 | 74.36 | 68.01 | 7.54 | 0.026 | 39.19 |
| | 20.0 JA + 5.0 Li | 76.52 | 67.41 | 8.21 | 0.022 | 32.46 | 75.69 | 62.27 | 8.09 | 0.025 | 39.44 |
| LSD at 5% | | 1.333 | 0.735 | 0.265 | NS | 1.531 | 0.810 | 1.658 | 0.268 | 0.003 | 1.499 |
| 100% | 0.0 JA + 0.0 Li | 80.60 | 70.11 | 7.42 | 0.026 | 38.24 | 79.69 | 62.16 | 7.31 | 0.029 | 44.95 |
| | 0.0 JA + 2.5 Li | 81.09 | 72.11 | 7.88 | 0.025 | 37.25 | 80.62 | 64.96 | 7.80 | 0.028 | 44.05 |
| | 0.0 JA + 5.0 Li | 83.63 | 73.30 | 9.05 | 0.025 | 35.29 | 82.58 | 61.96 | 8.90 | 0.028 | 41.72 |
| | 10.0 JA + 0.0 Li | 82.44 | 72.48 | 8.43 | 0.025 | 37.25 | 79.72 | 65.94 | 8.12 | 0.027 | 43.21 |
| | 10.0 JA + 2.5 Li | 83.02 | 72.88 | 8.50 | 0.024 | 36.25 | 83.09 | 72.88 | 8.47 | 0.027 | 42.25 |
| | 10.0 JA + 5.0 Li | 83.88 | 73.66 | 9.37 | 0.024 | 34.31 | 83.51 | 73.66 | 9.29 | 0.025 | 40.84 |
| | 20.0 JA + 0.0 Li | 80.66 | 71.98 | 7.76 | 0.026 | 37.24 | 80.29 | 71.98 | 7.69 | 0.029 | 44.10 |
| | 20.0 JA + 2.5 Li | 81.14 | 72.24 | 8.26 | 0.025 | 37.20 | 78.98 | 72.24 | 8.01 | 0.028 | 43.42 |
| | 20.0 JA + 5.0 Li | 83.15 | 73.25 | 8.92 | 0.024 | 35.27 | 82.25 | 67.67 | 8.79 | 0.027 | 42.86 |
| 75% | 0.0 JA + 0.0 Li | 71.36 | 62.07 | 6.57 | 0.023 | 35.86 | 70.55 | 55.03 | 6.47 | 0.026 | 42.15 |
| | 0.0 JA + 2.5 Li | 70.93 | 63.08 | 6.89 | 0.022 | 33.58 | 70.52 | 56.83 | 6.82 | 0.025 | 39.71 |
| | 0.0 JA + 5.0 Li | 74.20 | 65.03 | 8.03 | 0.022 | 32.31 | 73.27 | 54.97 | 7.90 | 0.025 | 38.20 |
| | 10.0 JA + 0.0 Li | 78.01 | 68.59 | 7.98 | 0.022 | 33.25 | 75.44 | 62.40 | 7.69 | 0.024 | 38.57 |
| | 10.0 JA + 2.5 Li | 77.62 | 68.14 | 7.95 | 0.021 | 33.19 | 77.69 | 68.14 | 7.92 | 0.024 | 38.68 |
| | 10.0 JA + 5.0 Li | 80.49 | 70.68 | 8.99 | 0.021 | 31.92 | 80.13 | 70.68 | 8.91 | 0.022 | 38.00 |
| | 20.0 JA + 0.0 Li | 76.34 | 68.12 | 7.34 | 0.023 | 35.25 | 75.99 | 68.12 | 7.27 | 0.026 | 41.74 |
| | 20.0 JA + 2.5 Li | 76.86 | 68.43 | 7.82 | 0.022 | 32.24 | 74.81 | 68.43 | 7.58 | 0.025 | 37.63 |
| | 20.0 JA + 5.0 Li | 75.11 | 66.17 | 8.06 | 0.022 | 31.86 | 74.30 | 61.13 | 7.94 | 0.025 | 38.72 |
| 50% | 0.0 JA + 0.0 Li | 68.45 | 59.54 | 6.30 | 0.022 | 33.38 | 67.68 | 52.79 | 6.21 | 0.025 | 39.24 |
| | 0.0 JA + 2.5 Li | 68.48 | 60.90 | 6.65 | 0.021 | 31.91 | 68.08 | 54.86 | 6.59 | 0.024 | 37.73 |
| | 0.0 JA + 5.0 Li | 71.09 | 62.31 | 7.69 | 0.021 | 30.45 | 70.20 | 52.67 | 7.57 | 0.024 | 36.00 |
| | 10.0 JA + 0.0 Li | 72.27 | 63.55 | 7.39 | 0.021 | 31.76 | 69.89 | 57.81 | 7.12 | 0.023 | 36.84 |
| | 10.0 JA + 2.5 Li | 72.36 | 63.52 | 7.41 | 0.020 | 31.28 | 72.42 | 63.52 | 7.38 | 0.023 | 36.46 |
| | 10.0 JA + 5.0 Li | 74.04 | 65.02 | 8.27 | 0.020 | 29.83 | 73.71 | 65.02 | 8.20 | 0.021 | 35.51 |
| | 20.0 JA + 0.0 Li | 70.72 | 63.11 | 6.80 | 0.022 | 32.65 | 70.40 | 63.11 | 6.74 | 0.025 | 38.67 |
| | 20.0 JA + 2.5 Li | 71.17 | 63.36 | 7.24 | 0.021 | 31.28 | 69.28 | 63.36 | 7.02 | 0.024 | 36.51 |
| | 20.0 JA + 5.0 Li | 71.29 | 62.80 | 7.65 | 0.021 | 30.24 | 70.52 | 58.02 | 7.54 | 0.023 | 36.75 |
| LSD at 5% | | 2.305 | 1.263 | 0.459 | NS | 2.648 | 1.400 | 2.848 | 0.464 | NS | 2.593 |

**Photosynthetic pigments:**

Plants cultivated under water stress levels I 75 and I 50% $ET_c$ recorded significant decreases in chlorophyll a, chlorophyll b and carotenoids in the leaves (Table 5). The decrease in plant pigments was increased a concentration depended it with increasing water deficit level. The process of photosynthesis is particularly sensitive to the effects of drought stress. Plant's resistance to water deficiency yields metabolic changes along with functional and structural rearrangements of photosynthesizing apparatus.

Photosynthesis decreases with the reduction in the relative water content (RWC) and leaf water potential (Lisar *et al.,* 2012), where water deficit affects stomatal closure, limits gaseous exchange, reduces transpiration and arrests carbon assimilation rates (Lisar *et al.,* 2012 and Marcinska *et al*., 2013).

Application of stress defense substances resulted in an improvement in leaf pigments content in favor of 10 ppm JA + 5 % Li for chlorophyll a and b and by 20 ppm JA + 5 % for carotenoids. As an average of both seasons, application of 10 ppm JA + 5 % Li enhanced chlorophyll a and b by 7.56 and 8.41%, respectively when compared with untreated wheat plants. Li is directly involved in the stimulation of photosynthesis, because it supplies the plant with carbon dioxide (as a form of nano calcium carbonate). In addition, JA stimulates plants because it is a natural phytohormone and enters into many metabolism processes includes photosynthesis process.

**Table 5. Effect of water regimes, stress defense substances and their interactions on photosynthetic pigments in leaves of wheat grown under the two growing seasons.**

| Water regimes ($ET_c$) | Stress defense substances JA (ppm) + Li (%) | Chl. a (mg/g d.wt.) | Chl. b (mg/g d.wt.) | Carotenoids (mg/g d.wt.) | Chl. a (mg/g d.wt) | Chl. b (mg/g d.wt.) | Carotenoids (mg/g d.wt.) |
|---|---|---|---|---|---|---|---|
| | | 2016 /2017 Season | | | 2017 /2018 Season | | |
| 100 % | | 4.24 | 1.65 | 1.44 | 4.19 | 1.83 | 1.42 |
| 75 % | | 3.82 | 1.51 | 1.32 | 3.79 | 1.68 | 1.29 |
| 50 % | | 3.35 | 1.42 | 1.14 | 3.38 | 1.60 | 1.08 |
| LSD at 5% | | 0.29 | 0.07 | 0.15 | 0.12 | 0.011 | 0.20 |
| | 0.0 JA + 0.0 Li | 3.72 | 1.46 | 1.22 | 3.69 | 1.63 | 1.17 |
| | 0.0 JA + 2.5 Li | 3.76 | 1.47 | 1.26 | 3.77 | 1.65 | 1.22 |
| | 0.0 JA + 5.0 Li | 3.92 | 1.52 | 1.32 | 3.88 | 1.70 | 1.25 |
| | 10.0 JA + 0.0 Li | 3.84 | 1.55 | 1.32 | 3.74 | 1.74 | 1.27 |
| | 10.0 JA + 2.5 Li | 3.85 | 1.55 | 1.34 | 3.84 | 1.72 | 1.33 |
| | 10.0 JA + 5.0 Li | 4.00 | 1.59 | 1.33 | 3.97 | 1.76 | 1.29 |
| | 20.0 JA + 0.0 Li | 3.66 | 1.53 | 1.26 | 3.62 | 1.71 | 1.23 |
| | 20.0 JA + 2.5 Li | 3.71 | 1.54 | 1.29 | 3.64 | 1.72 | 1.26 |
| | 20.0 JA + 5.0 Li | 3.78 | 1.53 | 1.38 | 3.93 | 1.68 | 1.35 |
| LSD at 5% | | 0.17 | 0.053 | 0.131 | 0.21 | 0.081 | 0.122 |
| | 0.0 JA + 0.0 Li | 4.09 | 1.61 | 1.35 | 4.05 | 1.79 | 1.33 |
| | 0.0 JA + 2.5 Li | 4.17 | 1.63 | 1.41 | 4.15 | 1.81 | 1.40 |
| | 0.0 JA + 5.0 Li | 4.35 | 1.68 | 1.46 | 4.29 | 1.85 | 1.43 |
| | 10.0 JA + 0.0 Li | 4.23 | 1.65 | 1.45 | 4.08 | 1.85 | 1.39 |
| 100% | 10.0 JA + 2.5 Li | 4.26 | 1.67 | 1.45 | 4.27 | 1.83 | 1.45 |
| | 10.0 JA + 5.0 Li | 4.42 | 1.68 | 1.49 | 4.40 | 1.85 | 1.47 |
| | 20.0 JA + 0.0 Li | 4.11 | 1.63 | 1.42 | 4.09 | 1.80 | 1.41 |
| | 20.0 JA + 2.5 Li | 4.18 | 1.64 | 1.44 | 4.07 | 1.82 | 1.39 |
| | 20.0 JA + 5.0 Li | 4.33 | 1.67 | 1.52 | 4.28 | 1.84 | 1.48 |
| | 0.0 JA + 0.0 Li | 3.71 | 1.41 | 1.21 | 3.69 | 1.57 | 1.18 |
| | 0.0 JA + 2.5 Li | 3.73 | 1.42 | 1.21 | 3.78 | 1.57 | 1.23 |
| | 0.0 JA + 5.0 Li | 3.94 | 1.48 | 1.30 | 3.89 | 1.64 | 1.27 |
| | 10.0 JA + 0.0 Li | 3.89 | 1.56 | 1.37 | 3.81 | 1.74 | 1.33 |
| 75% | 10.0 JA + 2.5 Li | 3.90 | 1.55 | 1.37 | 3.84 | 1.73 | 1.34 |
| | 10.0 JA + 5.0 Li | 4.03 | 1.61 | 1.36 | 4.01 | 1.78 | 1.33 |
| | 20.0 JA + 0.0 Li | 3.68 | 1.54 | 1.33 | 3.69 | 1.71 | 1.29 |
| | 20.0 JA + 2.5 Li | 3.72 | 1.55 | 1.35 | 3.72 | 1.72 | 1.34 |
| | 20.0 JA + 5.0 Li | 3.78 | 1.50 | 1.42 | 3.72 | 1.67 | 1.33 |
| | 0.0 JA + 0.0 Li | 3.35 | 1.35 | 1.10 | 3.34 | 1.54 | 1.01 |
| | 0.0 JA + 2.5 Li | 3.38 | 1.37 | 1.17 | 3.37 | 1.56 | 1.03 |
| | 0.0 JA + 5.0 Li | 3.48 | 1.41 | 1.19 | 3.45 | 1.60 | 1.04 |
| | 10.0 JA + 0.0 Li | 3.41 | 1.44 | 1.13 | 3.33 | 1.63 | 1.09 |
| 50% | 10.0 JA + 2.5 Li | 3.40 | 1.44 | 1.21 | 3.40 | 1.61 | 1.20 |
| | 10.0 JA + 5.0 Li | 3.51 | 1.48 | 1.15 | 3.50 | 1.65 | 1.08 |
| | 20.0 JA + 0.0 Li | 3.19 | 1.42 | 1.02 | 3.09 | 1.63 | 0.98 |
| | 20.0 JA + 2.5 Li | 3.22 | 1.43 | 1.07 | 3.13 | 1.63 | 1.04 |
| | 20.0 JA + 5.0 Li | 3.22 | 1.42 | 1.20 | 3.79 | 1.52 | 1.24 |
| LSD at 5% | | 0.29 | 0.08 | NS | 0.36 | 0.114 | NS |

The interaction treatments between water regimes and stress defense substances (Table, 5) indicated that, treated plants grown under normal irrigation with 10 ppm JA + 5 % Li produced the highest significant values of photosynthetic pigments compared to other combination treatments. The same rate improving leaf content from chlorophyll a and chlorophyll b under drought stress conditions. It can be noticed that the application of stress defense substances overcome the deleterious effects of water stress in photosynthetic pigments. Similar results were registered by Maswada and Abd El-Rahman (2014) who cited that highest increases in photosynthetic pigments and total soluble sugars were recorded by application of lithovit under normal or water deficit conditions compared to untreated plants.

**Chemical compositions:**

Water deficit levels (75% and 50% $ET_c$) caused significant decreases in total carbohydrates, total sugars and N %, while caused an increases in peroxidase and phenoloxidase activities and proline content in wheat leaves as compared with well waters plants (Table 6). On the other side, the differences in P % and Ca % under different water regimes failed to reach the level of significance. Negative effects in uptake, transport and metabolism of nutrients that happened under water stress may be associated with inhibition that occurred in root volume (Table 3) which led to decreases in leaf area and photosynthesis rates (Gontia-Mishra *et al*., 2016). The changes in chemical composition results are in harmony with those reported by Hammad and Ali (2014) and Ilyas *et al*. (2017).

Data in Table (6) showed also that applying JA and Li caused significant increases in total carbohydrates, total sugars, N %, P %, K % and Ca % in wheat leaves. Application of 10 ppm JA + 5% lithovit gave the highest values compared to other rates and untreated plants except P and Ca% which obtained by 20 ppm JA + 5% lithovit. The increases percentage reached about 9.30% in total carbohydrates, 4.94% total sugars, 8.54 in N % and 11.56 in K % when compared with results of untreated plants. This superiority may be related to the importance roles of JA and Li in enhancement growth performance and photosynthesis as previously discussed. On the other hand, untreated plants scored the highest values of peroxidase, phenoloxidase and proline compared with those obtained from JA and Li combination rates. Similar results were obtained by Attia *et al*. (2016).

Results in Table (6) indicated also that there was significant interaction for the studied components except P and Ca percentages. Application of stress defense substances (JA and /or Li) overcome the negative effect of water deficit and significantly increased total carbohydrates, total sugars, N % and K % in wheat leaves in favor of 10 ppm JA + 5 % Li rate. The highest increases in this chemical constitutes were recorded when treated well-watered plants with 10 ppm JA + 5 % Li rate, while, caused a decrease in peroxidase, phenoloxidase and proline. Similar results were observed by Maswada and Abd El-Rahman (2014) who recorded maximum increases in total soluble sugars content by treated wheat plants with Lithovit under normal or water deficit condition compared to control.

Nutrients used for plant growth and biomass production generally come from the internal cycling of reserve materials, which require water for their solubilization and translocation (Singh and Singh 2004). Limited nutrient uptake is a general phenomenon in crop plants grown under water deficit. Subramanian *et al* (2006) reported reduced nitrogen (N) and phosphorous (P) contents in roots and shoots of tomato seedlings grown under drought. Similarly, McWilliams (2003) reported reduced N and potassium (K) uptake in cotton (Gossypium hirsutum L.) under drought. In marigold seedlings, P content under drought was severely reduced (Asrar and Elhindi 2011).

Nutrient absorption is governed by interactions at the soil–root interface, including (1) root morphology and growth rate, (2) nutrient absorption kinetics of the roots; and (3) soil nutrient supply (Gutierrez-Boemand and Thomas 1999).

Decreased soil water availability affects the rate of diffusion in many plant nutrients and finally the composition and concentration of soil solution (Singh and Singh 2004). With limited water supply, nutrient uptake by roots decreases because a decline in soil-water potential slows the diffusion rate of nutrients between the soil matrix and root surface (Farooq *et al*. 2009a). Lower transpiration rate and impaired active transport, due to a lack of energy input and altered membrane permeability, decreases root nutrient adsorbing power of crop plants under drought (Kramer and Boyer 1995; Baligar *et al*. 2001).

Impaired enzyme activity involved in nutrient assimilation under drought stress also disturbs nutrient acquisition. The activity of nitrate reductase in leaves and nodules of common bean (Phaseolus vulgaris L.) and dhainicha (Sesbania aculeata L.) is substantially decreased under drought (Ashraf and Iram 2005)

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**Table 6. Effect of water regimes, stress defense substances and their interactions on chemical constituents in wheat leaves (average data of both seasons).**

| Water regimes ($ET_c$) | Stress defense substances JA (ppm) + Li (%) | Total carboh-ydrates (mg/g d.wt) | Total sugars (mg/g d.wt) | Per-oxidase O.D./g f.wt after 2 min. | Phenol-oxidase O.D./g f.wt after 45 min. | Proline µg/g d.wt | N % | P % | K % | Ca % |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 % | | 241.34 | 119.06 | 154.46 | 134.80 | 397.40 | 3.93 | 0.384 | 1.932 | 0.347 |
| 75 % | | 236.58 | 117.65 | 165.21 | 146.35 | 447.02 | 3.87 | 0.352 | 1.631 | 0.340 |
| 50 % | | 212.69 | 110.85 | 177.43 | 160.01 | 484.48 | 3.52 | 0.314 | 1.547 | 0.319 |
| LSD at 5% | | 5.52 | 2.15 | 6.27 | 3.76 | 12.93 | 0.15 | NS | 0.19 | NS |
| | 0.0 JA + 0.0 Li | 220.73 | 113.37 | 174.64 | 160.32 | 550.213 | 3.63 | 0.311 | 1.574 | 0.322 |
| | 0.0 JA + 2.5 Li | 224.05 | 114.09 | 170.25 | 149.86 | 520.950 | 3.68 | 0.328 | 1.702 | 0.330 |
| | 0.0 JA + 5.0 Li | 227.21 | 114.97 | 166.87 | 147.79 | 515.897 | 3.73 | 0.358 | 1.715 | 0.333 |
| | 10.0 JA + 0.0 Li | 230.48 | 115.89 | 169.11 | 150.36 | 524.350 | 3.80 | 0.349 | 1.709 | 0.336 |
| | 10.0 JA + 2.5 Li | 236.68 | 117.69 | 161.41 | 142.59 | 477.813 | 3.88 | 0.371 | 1.730 | 0.343 |
| | 10.0 JA + 5.0 Li | 241.26 | 118.97 | 153.75 | 134.66 | 456.563 | 3.94 | 0.391 | 1.756 | 0.339 |
| | 20.0 JA + 0.0 Li | 227.91 | 115.18 | 165.67 | 147.04 | 505.150 | 3.72 | 0.312 | 1.712 | 0.332 |
| | 20.0 JA + 2.5 Li | 229.25 | 115.55 | 168.51 | 149.21 | 501.433 | 3.77 | 0.320 | 1.727 | 0.335 |
| | 20.0 JA + 5.0 Li | 234.24 | 116.97 | 161.05 | 141.64 | 476.320 | 3.84 | 0.411 | 1.706 | 0.349 |
| LSD at 5% | | 3.57 | 2.06 | 8.08 | 10.64 | 9.85 | 0.21 | 0.023 | 0.13 | 0.038 |
| | 0.0 JA + 0.0 Li | 234.30 | 117.74 | 169.12 | 149.38 | 476.28 | 3.82 | 0.330 | 1.679 | 0.337 |
| | 0.0 JA + 2.5 Li | 239.26 | 118.41 | 157.88 | 136.76 | 408.50 | 3.92 | 0.351 | 1.971 | 0.345 |
| | 0.0 JA + 5.0 Li | 242.32 | 119.25 | 150.86 | 131.97 | 398.80 | 3.96 | 0.390 | 1.984 | 0.349 |
| | 10.0 JA + 0.0 Li | 238.04 | 118.02 | 163.51 | 145.47 | 430.25 | 3.91 | 0.381 | 1.920 | 0.345 |
| 100% | 10.0 JA + 2.5 Li | 243.88 | 119.71 | 146.42 | 125.94 | 354.66 | 3.98 | 0.410 | 1.982 | 0.351 |
| | 10.0 JA + 5.0 Li | 249.42 | 121.25 | 141.55 | 122.54 | 344.99 | 4.05 | 0.442 | 1.995 | 0.351 |
| | 20.0 JA + 0.0 Li | 240.54 | 118.77 | 152.76 | 132.27 | 407.08 | 3.84 | 0.340 | 1.993 | 0.342 |
| | 20.0 JA + 2.5 Li | 238.45 | 118.14 | 163.04 | 143.06 | 408.18 | 3.91 | 0.350 | 1.987 | 0.344 |
| | 20.0 JA + 5.0 Li | 245.81 | 120.24 | 144.97 | 125.81 | 347.90 | 4.01 | 0.462 | 1.879 | 0.361 |
| | 0.0 JA + 0.0 Li | 230.33 | 115.89 | 171.76 | 154.81 | 550.76 | 3.78 | 0.312 | 1.591 | 0.325 |
| | 0.0 JA + 2.5 Li | 233.34 | 116.77 | 170.01 | 150.12 | 549.94 | 3.81 | 0.330 | 1.627 | 0.338 |
| | 0.0 JA + 5.0 Li | 235.11 | 117.22 | 168.74 | 148.87 | 547.75 | 3.85 | 0.362 | 1.632 | 0.341 |
| | 10.0 JA + 0.0 Li | 236.44 | 117.60 | 167.88 | 148.75 | 547.42 | 3.88 | 0.350 | 1.637 | 0.339 |
| 75% | 10.0 JA + 2.5 Li | 237.98 | 118.04 | 165.03 | 146.90 | 505.96 | 3.90 | 0.373 | 1.642 | 0.344 |
| | 10.0 JA + 5.0 Li | 242.75 | 119.39 | 148.97 | 128.99 | 463.61 | 3.96 | 0.390 | 1.652 | 0.344 |
| | 20.0 JA + 0.0 Li | 236.61 | 117.69 | 166.63 | 148.75 | 509.18 | 3.87 | 0.313 | 1.607 | 0.340 |
| | 20.0 JA + 2.5 Li | 237.57 | 117.95 | 165.17 | 146.95 | 507.69 | 3.89 | 0.320 | 1.637 | 0.342 |
| | 20.0 JA + 5.0 Li | 239.05 | 118.34 | 162.68 | 142.97 | 497.84 | 3.92 | 0.421 | 1.652 | 0.349 |
| | 0.0 JA + 0.0 Li | 197.57 | 106.49 | 183.05 | 176.78 | 623.60 | 3.30 | 0.292 | 1.451 | 0.304 |
| | 0.0 JA + 2.5 Li | 199.55 | 107.10 | 182.86 | 162.69 | 604.41 | 3.31 | 0.303 | 1.510 | 0.306 |
| | 0.0 JA + 5.0 Li | 204.21 | 108.45 | 181.01 | 162.52 | 601.14 | 3.37 | 0.321 | 1.530 | 0.310 |
| | 10.0 JA + 0.0 Li | 216.96 | 112.05 | 175.93 | 156.85 | 595.38 | 3.60 | 0.315 | 1.571 | 0.324 |
| 50% | 10.0 JA + 2.5 Li | 228.17 | 115.31 | 172.79 | 154.93 | 572.82 | 3.77 | 0.330 | 1.565 | 0.335 |
| | 10.0 JA + 5.0 Li | 231.61 | 116.27 | 170.73 | 152.45 | 561.09 | 3.80 | 0.341 | 1.622 | 0.323 |
| | 20.0 JA + 0.0 Li | 206.57 | 109.07 | 177.63 | 160.11 | 599.19 | 3.44 | 0.283 | 1.535 | 0.313 |
| | 20.0 JA + 2.5 Li | 211.72 | 110.56 | 177.32 | 157.63 | 588.43 | 3.52 | 0.290 | 1.556 | 0.318 |
| | 20.0 JA + 5.0 Li | 217.85 | 112.33 | 175.51 | 156.14 | 583.22 | 3.60 | 0.351 | 1.587 | 0.337 |
| LSD at 5% | | 6.17 | 3.56 | 14.02 | 18.40 | 17.04 | 0.36 | NS | 0.22 | NS |

**Yield and its components**

Data presented in Table (7) showed the effects of water regimes, stress defense substances and their interaction on yield and its components of wheat during the two growing seasons of 2016/2017 and 2017/2018. There were significant differences in yield characters obtained by different water regimes (100, 75 and 50 $ET_c$) in the two seasons. It is evident that the highest mean values were obtained from well-watered plants (100% $ET_c$) followed by moderate water stress (I 75% $ET_c$), while exposing plants to severe stress (50% $ET_c$) had the lowest averages. As an average of both seasons, irrigation with I 50% $ET_c$ caused decreases in number of spikes/ $m^2$, number of grains /spike, spike weight, 1000-grain weight, grain yield /fed and straw yield /fed by 28.58, 21.94, 36.31, 29.90, 47.73 and 32.29 % compared to 100% $ET_c$ and by 21.40, 13.06, 27.64, 26.13, 37.47 and 19.10 % compared to 75% $ET_c$, respectively. From these results, it can be suggested that the inferiority of yield characters caused by irrigation at I 50% $ET_c$ may be due to negative effects of water deficit on vegetative growth (Table 3), physiological and biochemical traits (Tables 4, 5 and 6) as previously discussed. These results are in line with those outlined by Waraich and Ahmad (2010), Mohammadi *et al*. (2013) and Mwadzingeni *et al.* (2016).

The data in same table declared that all yield and its characters were significantly increased by application rates of stress defense substances (JA and/or lithovit) compared to untreated plants in both seasons. The highest significant values of number of spikes/ $m^2$, spike weight, 1000-grain weight, grain yield /fed and straw yield /fed were obtained by application of 10 ppm JA + 5% lithovit in both seasons. This combination treatment caused significant increases more than untreated plants by 30.84, 35.22, 19.68, 32.74

and 28.89 for number of spikes/m$^2$, spike weight, 1000-grain weight, grain yield /fed and straw yield /fed, respectively as an average of both growing seasons. However, the highest mean value of number of grains /spike was obtained when plants treated with 20 ppm JA + 5% lithovit. The superiority of JA with two concentrations (10 and 20 ppm) integrated with 5% lithovit in yield characters may be due to that combinations caused high positive effect in growth performance and physiological and biochemical traits more than those obtained from other combinations and untreated wheat plants. These results are in agreement with El-Wakeil and Volkmar (2012) and Maswada and Abd El-Rahman (2014).

**Table 7. Effect of water regimes, stress defense substances and their interactions on yield and its components of wheat grown under the two growing seasons.**

| Water regimes ($ET_c$) | Stress defense substances JA (ppm) + Li (%) | Spikes No./ m$^2$ | Grains No. /spike | Spike wt. (g.) | 1000-grain wt. (g.) | Grain yield /fed (ton) | Straw yield / fed (ton) | Spikes No./ m$^2$ | Grains No. /spike | Spike wt. (g.) | 1000-grain wt. (g.) | Grain yield /fed (ton) | Straw yield / fed (ton) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2016 /2017 Season | | | | | | 2017 /2018 Season | | | | | |
| I 100 % | | 344.63 | 62.60 | 2.89 | 45.21 | 2.995 | 3.474 | 355.07 | 60.32 | 2.70 | 43.73 | 2.886 | 3.363 |
| I 75 % | | 314.30 | 55.21 | 2.60 | 42.67 | 2.565 | 2.894 | 321.44 | 55.15 | 2.32 | 41.74 | 2.351 | 2.828 |
| I 50 % | | 244.56 | 48.97 | 1.95 | 30.94 | 1.576 | 2.353 | 255.15 | 46.98 | 1.61 | 31.41 | 1.498 | 2.276 |
| LSD at 5% | | 19.73 | 3.54 | 0.062 | 1.86 | 0.212 | 0.161 | 24.37 | 2.79 | 0.064 | 0.91 | 0.137 | 0.254 |
| | 0.0 JA + 0.0 Li | 264.78 | 51.15 | 2.08 | 35.90 | 2.038 | 2.546 | 273.11 | 49.90 | 1.98 | 35.39 | 1.856 | 2.462 |
| | 0.0 JA + 2.5 Li | 286.22 | 52.99 | 2.29 | 39.03 | 2.150 | 2.692 | 291.67 | 52.54 | 2.13 | 37.57 | 2.087 | 2.732 |
| | 0.0 JA + 5.0 Li | 294.00 | 54.11 | 2.41 | 39.74 | 2.321 | 2.833 | 303.67 | 53.28 | 2.29 | 38.22 | 2.228 | 2.729 |
| | 10.0 JA + 0.0 Li | 296.00 | 53.59 | 2.48 | 39.15 | 2.356 | 2.966 | 303.67 | 54.22 | 2.11 | 39.57 | 2.186 | 2.846 |
| | 10.0 JA + 2.5 Li | 314.67 | 56.08 | 2.68 | 40.69 | 2.481 | 3.082 | 321.89 | 54.22 | 2.35 | 40.29 | 2.468 | 2.960 |
| | 10.0 JA + 5.0 Li | 350.00 | 60.22 | 2.96 | 43.59 | 2.604 | 3.235 | 353.78 | 55.78 | 2.53 | 41.73 | 2.565 | 3.220 |
| | 20.0 JA + 0.0 Li | 297.45 | 54.59 | 2.37 | 38.23 | 2.416 | 2.850 | 305.78 | 55.00 | 2.06 | 38.43 | 2.062 | 2.689 |
| | 20.0 JA + 2.5 Li | 296.00 | 55.60 | 2.50 | 39.06 | 2.489 | 2.907 | 311.22 | 55.07 | 2.10 | 39.30 | 2.235 | 2.766 |
| | 20.0 JA + 5.0 Li | 311.33 | 62.00 | 2.60 | 41.09 | 2.553 | 3.052 | 330.22 | 57.34 | 2.33 | 40.13 | 2.516 | 2.993 |
| LSD at 5% | | 17.58 | 2.91 | 0.047 | 1.61 | 0.160 | 0.142 | 21.16 | 2.08 | 0.060 | 0.74 | 0.115 | 0.197 |
| | 0.0 JA + 0.0 Li | 311.33 | 58.33 | 2.64 | 42.59 | 2.663 | 3.167 | 322.33 | 56.67 | 2.57 | 42.37 | 2.400 | 3.092 |
| | 0.0 JA + 2.5 Li | 330.67 | 60.67 | 2.68 | 44.77 | 2.784 | 3.261 | 340.67 | 59.33 | 2.81 | 43.32 | 2.893 | 3.352 |
| | 0.0 JA + 5.0 Li | 336.00 | 61.70 | 2.77 | 45.32 | 2.901 | 3.460 | 347.33 | 59.70 | 2.95 | 43.86 | 2.966 | 3.232 |
| | 10.0 JA + 0.0 Li | 323.67 | 61.33 | 2.84 | 43.50 | 2.957 | 3.506 | 341.67 | 60.00 | 2.65 | 42.95 | 2.755 | 3.471 |
| 100 | 10.0 JA + 2.5 Li | 372.33 | 62.67 | 3.26 | 46.96 | 3.139 | 3.732 | 371.33 | 59.67 | 2.81 | 44.95 | 3.086 | 3.591 |
| | 10.0 JA + 5.0 Li | 403.00 | 66.67 | 3.37 | 48.14 | 3.299 | 3.846 | 395.67 | 62.00 | 2.96 | 45.15 | 3.157 | 3.711 |
| | 20.0 JA + 0.0 Li | 332.67 | 59.80 | 2.72 | 43.86 | 2.991 | 3.280 | 342.33 | 61.33 | 2.34 | 42.59 | 2.714 | 3.112 |
| | 20.0 JA + 2.5 Li | 325.33 | 61.50 | 2.84 | 44.23 | 3.078 | 3.393 | 351.00 | 60.50 | 2.42 | 43.32 | 2.893 | 3.232 |
| | 20.0 JA + 5.0 Li | 366.67 | 70.70 | 2.93 | 47.56 | 3.147 | 3.619 | 383.33 | 63.70 | 2.73 | 45.04 | 3.113 | 3.471 |
| | 0.0 JA + 0.0 Li | 267.00 | 50.63 | 2.07 | 35.67 | 2.248 | 2.429 | 275.67 | 50.70 | 2.08 | 35.85 | 1.923 | 2.413 |
| | 0.0 JA + 2.5 Li | 300.33 | 51.60 | 2.43 | 42.22 | 2.334 | 2.757 | 302.33 | 52.63 | 2.16 | 40.77 | 2.052 | 2.743 |
| | 0.0 JA + 5.0 Li | 311.67 | 53.00 | 2.61 | 42.77 | 2.559 | 2.834 | 322.00 | 54.33 | 2.32 | 41.68 | 2.309 | 2.743 |
| | 10.0 JA + 0.0 Li | 316.00 | 52.63 | 2.61 | 43.13 | 2.537 | 2.921 | 313.33 | 54.67 | 2.32 | 42.77 | 2.284 | 2.852 |
| 75 | 10.0 JA + 2.5 Li | 322.67 | 55.93 | 2.70 | 43.32 | 2.633 | 2.935 | 334.67 | 54.33 | 2.40 | 42.77 | 2.565 | 2.852 |
| | 10.0 JA + 5.0 Li | 346.33 | 59.50 | 3.06 | 46.41 | 2.746 | 3.238 | 356.00 | 57.00 | 2.72 | 43.95 | 2.734 | 3.181 |
| | 20.0 JA + 0.0 Li | 320.00 | 55.33 | 2.53 | 42.95 | 2.622 | 2.964 | 321.67 | 57.33 | 2.24 | 42.41 | 2.137 | 2.852 |
| | 20.0 JA + 2.5 Li | 320.33 | 56.60 | 2.74 | 43.13 | 2.689 | 2.935 | 327.00 | 56.70 | 2.16 | 42.59 | 2.462 | 2.852 |
| | 20.0 JA + 5.0 Li | 324.33 | 61.70 | 2.82 | 44.41 | 2.717 | 3.036 | 340.33 | 58.63 | 2.48 | 42.86 | 2.693 | 2.962 |
| | 0.0 JA + 0.0 Li | 216.00 | 44.50 | 1.54 | 29.43 | 1.205 | 2.042 | 221.33 | 42.33 | 1.28 | 27.96 | 1.246 | 1.882 |
| | 0.0 JA + 2.5 Li | 227.67 | 46.70 | 1.75 | 30.11 | 1.333 | 2.056 | 232.00 | 45.67 | 1.41 | 28.63 | 1.317 | 2.103 |
| | 0.0 JA + 5.0 Li | 234.33 | 47.63 | 1.84 | 31.14 | 1.503 | 2.206 | 241.67 | 45.80 | 1.60 | 29.13 | 1.411 | 2.214 |
| | 10.0 JA + 0.0 Li | 248.33 | 46.80 | 2.01 | 30.82 | 1.574 | 2.471 | 256.00 | 48.00 | 1.36 | 32.99 | 1.518 | 2.214 |
| 50 | 10.0 JA + 2.5 Li | 249.00 | 49.63 | 2.09 | 31.80 | 1.672 | 2.579 | 259.67 | 48.67 | 1.84 | 33.15 | 1.755 | 2.435 |
| | 10.0 JA + 5.0 Li | 300.67 | 54.50 | 2.45 | 36.22 | 1.767 | 2.621 | 309.67 | 48.33 | 1.92 | 36.08 | 1.804 | 2.768 |
| | 20.0 JA + 0.0 Li | 239.67 | 48.63 | 1.86 | 27.86 | 1.634 | 2.307 | 253.33 | 46.33 | 1.60 | 30.31 | 1.334 | 2.103 |
| | 20.0 JA + 2.5 Li | 242.33 | 48.70 | 1.92 | 29.83 | 1.701 | 2.392 | 255.67 | 48.00 | 1.72 | 31.98 | 1.351 | 2.214 |
| | 20.0 JA + 5.0 Li | 243.00 | 53.60 | 2.06 | 31.30 | 1.796 | 2.500 | 267.00 | 49.70 | 1.78 | 32.48 | 1.742 | 2.546 |
| LSD at 5% | | 30.41 | 5.09 | 0.084 | 2.79 | 0.277 | 0.246 | 36.61 | 3.60 | 0.106 | 1.28 | 0.199 | 0.340 |

With regard to the interaction effect between water regimes and stress defense substances, data in Table (7) showed significant effects for all yield and its component characters in both seasons. Treated wheat plants grown under normal irrigation regime (100% $ET_c$) with 10 ppm JA + 5% lithovit exhibited the highest significant values of yield characters followed by 20 ppm JA + 5.0% lithovit or 10 ppm JA + 2.5% lithovit at the same irrigation regime. Moreover, treated plants with 10 ppm JA + 5% lithovit enhanced the grain yield and straw yield /fed compared to untreated plants by 31.38 and 32.57, respectively under moderate water stress (75% $ET_c$) and by 45.70 and 37.33, respectively under severe water stress (50% $ET_c$). This superiority indicated that JA and lithovit have favorable roles in enhancing the tolerance of wheat plants to water stress by decrease adverse effects during growth stages. In this concern, Anjum *et al*., (2016) depicted that application of methyl jasmonate had a beneficial effect on grains number / spike and weight of grains/spike which led to higher grain and biological yield in treated wheat plants under water deficit as well as normal conditions.

## CONCLUSION

Water stress affects negatively plant growth, physiological and biochemical processes that lead to decrease yield and its components. This effect is associated with growth stage, timing and degree of water stress. From obtained result, it could be recommended that application of JA integrated with lithovit (10 ppm JA + 5% Li) under water deficit. This treatment lead to mitigate the adverse effects of drought stress and increase the growth and productivity of wheat.

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## اضافة حامض الجاسمونيك والليثوفيت للتغلب على الآثار الضارة الناتجة عن الإجهاد المائي للقمح

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**[١] قسم النبات الزراعي – كلية الزراعة – جامعة المنوفية – مصر**

**[٢] قسم المحاصيل – كلية الزراعة – جامعة المنوفية – مصر**

يُعد نقص الماء أحد العوامل البيئية التي تتحكم فى معدل النمو الخضرى وتحد من إنتاجية محصول القمح من خلال التأثيرعلى كفاءة بعض العمليات الفسيولوجية والكيميائية في النبات . لذا أجريت تجربتان حقليتان لدراسة تأثير استخدام تركيزات مختلفة من مضادات الاجهاد المائى (حامض الجاسمونيك ، مركب الليثوفيت) على النمو الخضرى بعض الخصائص الفسيولوجية والكيميائية ، محصول القمح ومكوناته (صنف جميزة ١١) النامى تحت معدلات استهلاك مائى (١٠٠، ٧٥ ، ٥٠% بخرنتح للمحصول) بالمزرعة البحثية لكلية الزراعة – جامعة المنوفية بشبين الكوم – مصر خلال موسمى الزراعة ٢٠١٧/٢٠١٦ ، ٢٠١٨/٢٠١٧. أوضحت النتائج أن تعريض نباتات القمح إلى مستويات الإجهاد المائى (٧٥ ، ٥٠ % من معدل الاستهلاك المائى) إلى حدوث انخفاض معنوى في جميع صفات النمو الخضري والعلاقات المائية (المحتوى المائي الكلي ، محتوى الماء النسبي ، الضغط الإسموزي ، معدل النتح ، نفاذية الغشاء البلازمي ) وصبغات البناء الضوئي ومحتوي (الكربوهيدرات الكلية ، السكريات الذائبة الكلية ، نسب النيتروجين والبوتاسيوم بالأوراق ) إضافة إلي المحصول ومكوناته (عدد السنابل بالمتر المربع ، عدد الحبوب بالسنبلة ، وزن حبوب السنبلة ، وزن ١٠٠٠ حبة ، محصول الحبوب للفدان ، ومصول القش للفدان) مقارنة بالنباتات المروية بمعدل ١٠٠% استهلاك مائى . هذا وقد أعطت النباتات المعرضة للاجهاد المائى (٥٠% استهلاك مائى) أعلى قيم لنشاط إنزيمي البيروكسيديز والفينول أوكسيديز وكذلك محتوى الاوراق من البرولين .ومن ناحية أخري فقد أدت إضافة مركبات حمض الجاسمونيك والليثوفيت إلى زيادة معظم الصفات المدروسة باستثناء معدل النتح ، نفاذية الغشاء البلازمي ، نشاط إنزيمي البيروكسيديز والفينول أوكسيديز ، محتوى الاوراق من البرولين وذلك مقارنة بالنباتات غير المعاملة . وقد تفوق التركيز ١٠ جزء فى المليون حامض جاسمونيك + ٥% ليثوفيت على بقية التركيزات الأخرى المختبرة وذلك لمعظم الصفات المدروسة فى كلا موسمى الزراعة . تُشير نتائج التفاعل بين معدلات الاستهلاك المائى ومضادات الاجهاد المائى إلى وجود اختلافات معنوية لمعظم الصفات المدروسة . وقد حققت النباتات النامية تحت معدل ١٠٠% استهلاك مائى والمعاملة بتركيز ١٠ جزء فى المليون حامض جاسمونيك + ٥% ليثوفيت أعلى قيم لصفات النمو الخضرى وصبغات التمثيل الضوئى والمحصول ومكوناته. هذا وقد حققت اضافة الجاسمونيك بتركيز ١٠ أو ٢٠ جزء فى المليون + ٥% ليثوفيت تحت ظروف الاجهاد المائى زيادة معنوية في جميع صفات النمو الخضري و العلاقات المائية (المحتوى المائي الكلي ، محتوى الماء النسبي ، الضغط الإسموزي) والصبغات الضوئية والمكونات الكيميائية الأخري في الأوراق (الكربوهيدرات الكلية ، السكريات الذائبة الكلية ، نسب النيتروجين والبوتاسيوم بالأوراق) إضافة إلي المحصول ومكوناته ، بينما احدثت انخفاضاً ملحوظاً في معدل النتح ، ونفاذية الغشاء البلازمي ، محتوى البرولين ، ونشاط إنزيمي البيروكسيديز والفينول أوكسيديز. وقد أوصت الدراسة بإمكانية معاملة نباتات القمح النامية تحت ظروف نقص الماء بتركيز ١٠ جزء فى المليون حامض الجاسمونيك + ٥% ليثوفيت لتقليل الآثارة الضارة الناتجة عن الاجهاد المائى ولزيادة نمو وانتاجية محصول القمح .