Minufiya J. Agric. Res. Vol. 33 No.6: 1355-1375 (2008) "http://www.mujar.net"

RESPONSE OF WHEAT PLANTS GROWN UNDER WATER STRESS IN RELATION TO JASMONIC ACID

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(Received: Nov. 2, 2008)

ABSTRACT: *Two pot experiments were conducted under greenhouse conditions to study the effect of four levels of water stress (100, 80, 60 and 40% from field capacity) and four concentrations of Jasmonic acid (JA) (0, 50, 100 and 150 ppm) and their combination on growth characters, water relations, plant pigments, certain biochemical constitutes, phytohormons, yield and its components of wheat plants. The results showed that water stress decreased all growth characters, total and relative water content, free water, transpiration rate, phynoloxidase activity, N, P and K (%), activators phytohormones, yield and its attributes. Meanwhile, the bound water, bound/free water ratio, leaf water deficit, total sugars, proline content were increased. The lower level of water stress (80% F.C.) increased total carbohydrates, plant pigments, yield and its components. JA at 50 ppm increased all growth characters, total and relative water content, free water, transpiration rate, plant pigments, carbohydrates, proline content, phynoloxidase activity, N, P and K (%), phytohormones and yield attributes, meanwhile JA at 150 ppm had a negative effect on these aspects. The combination of 50 ppm of JA with all levels of water stress led to an increase in all growth characters, total and relative water content, free water, plant pigments, carbohydrates, proline content, N, P, K (%), phytohormones and yield and its components. Accordingly, JA at 50 ppm was recommended for best growth of wheat plants grown under normal or water stress conditions.*

Key words: *Wheat plants, water stress, Jasmonic acid (JA), growth, water relations, plant pigments, chemical constitutes, phtohormones, yield.*

INTRODUCTION

Wheat (*Triticum aesitivum L.*) is one the most important cereal crops grown in the world. Wheat is the main diet for the Egyptian population so it has been considered the first strategic food crop. In Egypt, there is a gap between production 6.6 million ton and consumption 12.3 million ton (Cabinet Information Center, 2007). Therefore, increasing wheat production becomes an important national goal to reduce the gab between wheat production and food consumption. Increasing the cultivated area of wheat should be done in the reclaimed lands due to the limited areas of the Nile valley and the competition of the main crops. Therefore improving both quantitative and qualitative characteristics of wheat were and still the aim of many investigators. In Egypt, agriculture development is limited by severe environmental conditions. Water stress (drought) the most important factor affecting the production of wheat. Water requirement is the water need to raising a crop in a given period of time under field condition. It includes consumptive use and other economically unavoidable losses. Jasmonic acid (JA) naturally occurring plant growth regulator, affect on different physiological and biochemical processes. JA also has enhanced induction promotion of carotenoids biosynthesis, tuber formation, rooting and protein synthesis (Creelman *et al.*, 1997; Koda 1992; Sembdner and parthier, 1993). That is the aim of this study to identify the suitable treatment of JA to reduce the harmful effect of water stress with studying the physiological mechanism or changes under these situation photosynthetic pigments, water relations, chemical constituents and yield components.

MATERIALS AND METHODES

Two pot experiments were performed under greenhouse conditions, at Faculty of Agriculture, Minufiya University, Shibin El-Kom during the two growing seasons of 2005/2006 and 2006/2007 to investigate the effect of water stress and its combination with jasmonic acid (JA) on growth, some physiological and biochemical aspects in wheat plants. Wheat grains (*Triticum asitivum* L. cv. Sakha 93) were obtained from wheat Researches Institute Agriculture Researches Center in Cairo. Grains of wheat were soaked in jasmonic acid (JA) at the concentrations (0, 50, 100 and 150 ppm) for 6 hours before sowing and grains had left dried on stainless surface for 24 h. Jasmonic acid (JA), 3-oxo-2-2-cis-pentenyl cyclopentanon, 1-acetic acid. JA was kingdely obtained from prof. Miersch at the Department of Plant Biochmistry, Martin Luther University, Halle / Salla, Germany. The chemical structure of JA and its derivatives are shown in Fig (1).

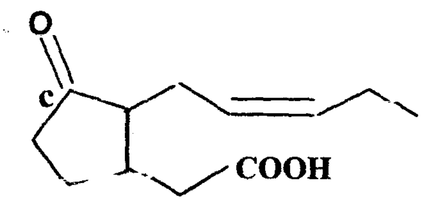

Fig (1): Structure of Jasmonic acid (JA) (Vick and Zimmermann, 1986).

Thirty grains per pot were sown at 15th November in both seasons in pots 40 cm, each pot contains 15 kg of clay loamy soil. The physical and chemical characteristics (Page, 1984) of experimental soil are shown in Table (1).

Table (1): Some physical and chemical properties of the studied soil.

Properties	Value	Properties	Value
Physical analysis:		Soluble ions (meq/100 g soil):	
Sand %	15.50	Ca^{+2} + Mg^{+2}	1.75
Silt %	31.85	Na^{+}	2.84
Clay %	52.65	K^{+}	0.56
		HCO_3^{-}	1.75
Chemical analysis:		Cl^{-}	1.60
PH	8.2	SO_4^{-2}	1.80
O.M. %	0.55	Total N (100)	0.12
Ec. (mmhos/cm)	2.50	Avail. P(ppm)	99.0

After 15 days the seedlings were thinned to 15 uniform seedlings. This experiment included four levels of available water 100, 80, 60 and 40% of field capacity. The treatments were arranged in split plot design with four replicates and the main plot was water stress. All pots were fertilized at the recommended rates of N, K and P fertilizers. The N was added as NH_4NO_3 (33.5% N) at a rate of 220 kg/fed (2.5 g/pot), while the K was added as K_2SO_4 (48% K_2O) at a rate of 100 kg/fed (1g/pot). Supper phosphate was broadcasted during soil preparation Nitrogen and potassium were added, in three equal doses at 45, 55 and 65 days after sowing, phosphorus fertilizer was added as supper phosphate (15.5% P_2O_5) at a rate of 220 kg/fed (2.5 g/pot). After sowing, the pots were watered immediately by tap water. Weeds and best control as well as other agriculture practices were used whenever necessary.

The plants sample from each treatment was taken after 81 days from sowing, to determine the following data:

1- Growth characters: Plant height (cm), number of tillers per plant, leaf area per plant [total leaf area (cm^2 / plant) using the dry weight method described by Aase (1978) as follow: Y= 25.97 + 113.65 * X Where's, Y= Total leaf area in cm^2 and X = Total dry matter (g)], relative growth rate (RGR) [RGR= (LN w_2 - LN w_1) × (t_2-t_1) "mg/g (DW)/day"], net assimilation rate (NAR) [NAR = [(w_2 - w_1) ($\log_e A_2$- $\log_e A_1$)] / [(A_2-A_1) (t_2-t_1)] "g/ m^2/day" Where: w_1 and w_2 = Total dry weight /plant at t_1 and t_2 (date of sampling), A_1 and A_2 = Leaf area /plant (cm^2) at t_1 and t_2, respectively Log_e = The normal logarithm (2.7185)], dry weight of whole plant (g). (Plant materials were dried in an electric oven at 70°C for 72 hours then used it for chemical analysis).

2- Water relations: Total water content (TWC, %), bound water percentage (%), free water percentage (%), leaf water deficit (LWD, %) and relative water content (RWC, %), osmotic pressure of cell sap (πs, bar) and the transpiration rate (mg $H_2O.cm^{-2}.h^{-1}$), were measured using the methods of Kreeb (1990).

3- **Photosynthetic pigments:** Chlorophyll a, b, carotenoids were estimated according to Wettstein (1957) then calculated as mg/g dry weight.

4- **Chemical analysis:**

a- Total carbohydrates and soluble sugars): Were determined colormetrically using the phenol sulfuric acid method as described by Dubois *et al.* (1956).

b- Proline concentration: In fresh leaves measured using the method described by Bates *et al.* (1973).

c- Enzymes activity: Peroxidase activity and phenoloxidase activity were measured in the fresh leaves using the method described by Fehrman and Dimond (1967), respectively.

d- Mineral composition: Nitrogen, phosphorus, potassium and sodium were determined in leaves (mg/g dwt.) using the methods described by A.O.A.C. (1995).

5- **Endogenous Phytohormones:** Ten grams fresh weight of shoots was extracted with 80% cold methanol according to the method of Shindy and Smith (1975). The acidic ethyl acetate fraction was concentrated to dryness to determine IAA, GA and ABA. Alkaline fraction was used to determine Cytokinins.

6- **Yield and its components:** At harvest, the spike length (cm), grain yield (g/plant), straw yield (g/plant) and 1000 grains weight were estimated.

All obtained data were subjected to statistical analysis using program COSTAT 6.311, The L.S.D test at 5% level of probability was used to compare the means of the treatments according to Gomez and Gomez (1984).

Results obtained in 2006/2007 showed almost the same trend as those of 2005/2006 season, so data of the latter season were found enough to be presented.

RESULTS AND DISCUSSION:

1- Growth characters:

Data illustrated at Table (2) showed clearly that there are significantly decrease in all plant growth characters under all water stress levels. The decrease of wheat growth as a result of decreasing available soil moisture content. This effect may be attributed to the inhibition of wheat growth which is the results of massive and irreversible expansion of small daughter cells produced by meristematic divisions and growth inhibition is therefore related to the inhibition of cell expansions as well as reduced rates of new cell production may make additional contribution to the inhibition of growth (Hsiao, 1973). Water stress causes losses in tissue water content, which reduce turgor pressure in the cell, thereby inhibiting enlargement and division of cells causing of reduce of plant growth. Consequently, water deficit decreased the growth rate, stem elongation and leaf expansion (Hale and Orcutt, 1987). These results are in agreement with the findings of Kimura *et al.* (1994) on sweet basil, El-Adgham and Sorial (1995) on tomato, Selim and Ali (1997) on common beans, Hammad (2000) on sweet basil and peppermint, EL-Fakharany (2003) on sweet basil and Mahouachi *et al.* (2007) on papaya.

Table (2): Effect of water stress, JA and their interaction on growth characters of wheat plants at 81 days during growing season of 2005 – 2006.

Characters / Treatments: Water levels (F.C. %)	JA levels (ppm)	Plant height (cm)	No of Tillers / plant	Leaf area (cm^2)	RGR	NAR	Dry weight of whole plant (g)
100		77.77	2.25	221.44	0.40	0.40	1.87
80		74.65	1.50	219.78	0.28	0.29	1.85
60		75.82	0.58	210.15	0.25	0.22	1.77
40		66.63	0.00	186.35	0.19	0.16	1.56
	0.0	75.44	0.92	215.16	0.41	0.30	1.81
	50	76.52	1.67	237.65	0.48	0.35	2.01
	100	72.83	1.08	207.04	0.14	0.23	1.74
	150	70.08	0.67	177.87	0.09	0.18	1.48
100	0.0	78.00	2.00	226.09	0.59	0.49	1.91
	50	79.80	3.67	267.01	0.65	0.54	2.27
	100	78.07	2.33	204.43	0.23	0.33	1.72
	150	75.20	1.00	188.21	0.12	0.24	1.57
80	0.0	77.27	1.67	225.94	0.39	0.30	1.90
	50	72.13	2.00	247.76	0.46	0.38	2.10
	100	75.10	1.33	222.22	0.15	0.25	1.87
	150	74.10	1.00	183.20	0.11	0.23	1.53
60	0.0	76.17	0.00	217.12	0.36	0.25	1.83
	50	78.97	1.00	235.73	0.41	0.32	1.99
	100	74.77	0.67	210.32	0.12	0.17	1.77
	150	73.37	0.67	177.44	0.10	0.15	1.47
40	0.0	70.33	0.00	191.47	0.29	0.16	1.60
	50	75.20	0.00	200.08	0.39	0.18	1.68
	100	63.37	0.00	191.20	0.05	0.17	1.60
	150	57.63	0.00	162.64	0.04	0.12	1.35
LSD 5%	Water	0.375	0.288	3.709	0.034	0.062	0.033
	JA	0.342	0.314	2.902	0.024	0.047	0.026
	Water*JA	0.683	0.628	5.813	0.047	0.092	0.051

Results in Table (2) indicated that application of JA at 50 ppm led to clearly improving in the above mentioned growth characters, meanwhile the level of 150 ppm decreased the all growth characters under studying. The overall effect of JA on the number of branches and dry weight of shoots showed a significant increase, this effect may be attributed to the inhibiting effect of JA on the apical dominance as a result of reducing auxin transport to apical merestims and this stimulating the growth of buds leading to a subsequent release of more branches and consequently increasing the number / plant and finally increase leaves number and stems and roots dry weight (Ueda *et al.*, 1994). Similar results were obtained by Gendy and Selim (1994) on broad bean, JinFeng *et al.* (1999) on tobacco, EL- Fakharany (2003) on sweet basil.

The interaction between water stress conditions and 50 ppm of JA decreased the harmful effect of water stress on all growth characters meanwhile JA at 150 ppm had a negative effect on these respects at the same conditions. JA was able to increase the tolerance of wheat and other plants grown under stress condition, and may be attributed to its important plant growth, development and regulates the expression of plant defense genes in response to various stresses such as drought and salinity (RenGao *et al.*, 2007). These results are in agreement with RuiChi and HuangQing (1995) on groundnut, YunCong *et al.* (1999) on apple and El-Fakharany (2003) on sweet basil.

2- Water relations:

Data presented in Table (3) showed that water stress at all levels used had a positive effect on bound water, bound / free water, leaf water deficit and osmotic pressure of leaves of wheat plants, whereas decreased total water content, free water, relative water content and transpiration rate. Increasing the amount of water supply to the soil led to an increase in the amount of water absorption and, this is turn, led to an increase in the bound water content and reduction in the total and free water of leaf cells owing to utilization of sugars and their metabolites in the building new tissues. Decreasing the transpiration water loss due to partial desiccation and stomatal closure in the plants grown under low moisture regimes. The reduction in TWC and RWC under water stress condition explained by El-Khoreiby and Salem (1989) who reported that, the decrease in total and relative water content in leaves under water stress may be due to the direct effect of soil moisture on TWC and RWC which related to the available soil water content. Moreover the total and relative water content in leaves were decreased as the level of soil moisture decreased and this may be due to relatively low root ability to absorb water from the soil or decreased hydraulic conductivity of soil under drought stress condition (Gawish, 1992). The increase in osmotic pressure under water stress levels may be due to an increase in sugars content. Similar results were obtained by Selim and Ali

(1997) on common beans, Abd El-Fattah and Sorial (2001) on taro plants, El-Fakharany (2003) on sweet basil and Mahouachi *et al.* (2007) on papaya seedlings.

Table (3): Effect of water stress, JA and their interaction on water relations of wheat plants at 81 days during growing season of 2005 – 2006.

Characters / Treatments: Water levels (F.C. %)	JA levels (ppm)	TWC (%)	Bound water (%)	Free water (%)	Bound water/ Free water ratio	LWD (%)	RWC (%)	Osmotic pressure C.S. (bar)	Trans-piration rate (mg / cm^2.h)
100		77.75	11.38	66.37	0.17	25.94	74.06	7.76	0.68
80		74.33	12.69	61.65	0.21	26.65	73.35	8.38	0.46
60		73.25	13.15	60.11	0.22	30.44	69.56	9.11	0.36
40		71.35	15.78	55.57	0.28	33.91	66.09	11.08	0.24
	0.0	75.00	12.59	62.41	0.20	30.09	69.91	8.91	0.47
	50	76.35	12.19	64.16	0.19	24.29	75.72	8.26	0.60
	100	73.83	13.49	60.34	0.23	30.21	69.79	9.23	0.42
	150	71.50	14.73	56.77	0.26	32.36	67.64	9.92	0.25
100	0.0	78.00	10.93	67.07	0.16	25.73	74.27	7.61	0.76
	50	80.00	10.40	69.60	0.15	24.53	75.47	7.14	0.84
	100	77.00	11.78	65.22	0.18	25.93	74.07	7.68	0.73
	150	76.00	12.40	63.60	0.19	27.58	72.42	8.61	0.39
80	0.0	76.00	11.40	64.60	0.18	27.78	72.22	8.23	0.52
	50	76.33	11.09	65.24	0.17	20.83	79.17	7.68	0.67
	100	74.00	13.86	60.14	0.23	28.91	71.09	8.67	0.37
	150	71.00	14.40	56.60	0.25	29.08	70.92	8.93	0.28
60	0.0	74.00	12.32	61.68	0.20	31.28	68.72	9.03	0.35
	50	76.00	12.08	63.92	0.19	24.00	76.00	8.16	0.58
	100	73.00	12.47	60.53	0.21	32.00	68.00	9.33	0.32
	150	70.00	15.71	54.29	0.29	34.48	65.52	9.91	0.17
40	0.0	72.00	15.70	56.30	0.28	35.57	64.43	10.78	0.26
	50	73.06	15.17	57.89	0.26	27.78	72.22	10.06	0.31
	100	71.33	15.86	55.47	0.29	33.99	66.01	11.24	0.25
	150	69.00	16.40	52.60	0.31	38.30	61.70	12.24	0.14
LSD 5%	Water	0.577	0.571	0.353	0.006	0.197	0.197	NS	NS
	JA	0.486	0.247	0.904	0.002	0.166	0.166	NS	NS
	Water*JA	0.973	0.794	1.209	0.008	0.337	0.337	NS	NS

The obtained results in Table (3) cleared that, the treatment of JA at 50 ppm increased the total water content, free water, relative water content and transpiration rate, and decreased the bound water, bound / free water, leaf water deficit and osmotic pressure. In contrast, JA at the levels of 100 and 150 ppm increased bound / free water ratio, leaf water deficit and osmotic pressure meanwhile decreased total water content, free water, relative water content and transpiration rate. Wheat plants treated with JA showed an improving water balance where they had a higher water potential than untreated plants. It is possible that this effect was caused by increasing the root to shoot ratio or decrease root resistance to water flow in plants treated with JA (Todorov *et al.*, 1998). Plants treated with growth inhibitors under saline condition significantly increased osmotic pressure in leaf tissues (Gendy and Sorial, 2002). The same trend was observed by Leshem *et al.* (1994) on wheat, ZhiMin *et al.* (1999) on apple trees, YunCong *et al.* (1999) on apple trees and El-Fakharany (2003) on sweet basil.

The interaction between water stress and JA at 50 ppm caused some changes in leaf water relations: total water content, free water, relative water content and the transpiration rate were increased, whereas bound water, bound / free water ratio, leaf water deficient sclerophylly degree and osmotic pressure were decreased. This improvement was more pronounced in the severe water stress levels of 60 and 40% F.C, meanwhile, the interaction between water stress levels and JA levels of 100 and 150 ppm had a negative effect on the above aspects. The improving plant water relations under stress conditions by application of JA may be due to the increasing of xylem and phloem tissue and their width (Zaghlool and Ibrahim, 2000 and El-Fakharany, 2003).

3- Photosynthetic pigments:

Data recorded in Table (4) indicated that, the concentrations of chl. a, chl. b, chl. a + b and carotenoids in leaves were increased from 100 to 60% F.C. then were decreased at 40% F.C. In general, it can be concluded that, the decrease in photosynthetic rate under drought stress related to the reduction in stomatal conductance and transpiration rate (Chartzoulakis *et al.*, 1999). Prolonged water stress which limited photosynthesis led also to less of sucrose phosphate synthetase activity (Vassy and Sharky. 1989 and Dubey and Singh, 1999). These results are in agreement with those obtained by Abo El-Kheir *et al.* (1994) on soybean, El-Adgham and Sorial (1995) on tomato and Selim and Ali (1997) on common beans.

Table (4) showed also that all levels of JA under studying caused a significant increase in chlorophylls concentrations (chl. a, chl. b, chl. a + b and carotenoids) in leaves of wheat plants. The results are in accordance to the results obtained by (Popova *et al.*, 1988) on barley, ZhiMin *et al.* (1999) on malus, YunCong *et al.* (1999) on apple trees. Also, Gendy and Sorial (2002) on rice plants.

The photosynthetic pigments concentration were significantly increased in the plants grown under water stress levels 40 and 60% F.C. and treated

before sowing with JA at 50 ppm. Similar findings have been reported by El-Fakharany (2003) on sweet basil.

Table (4): Effect of water stress, JA and their interaction on photosynthetic pigments (mg /g dwt) of wheat plants at 81 days during growing season of 2005 – 2006.

Treatments: Water levels (F.C.%)	JA levels (ppm)	Chl. a	Chl. b	Chl. a+b	Carotenoids
100		2.95	1.28	4.22	1.15
80		3.42	1.45	4.77	1.36
60		3.21	1.40	4.51	1.23
40		2.92	1.24	4.06	1.13
	0.0	2.37	1.25	3.54	1.15
	50	4.16	1.45	5.54	1.31
	100	3.39	1.38	4.69	1.23
	150	2.58	1.28	3.78	1.18
100	0.0	2.14	1.18	3.32	1.11
	50	4.04	1.38	5.42	1.24
	100	3.12	1.33	4.45	1.15
	150	2.49	1.21	3.70	1.11
80	0.0	2.75	1.38	4.03	1.31
	50	4.35	1.57	5.82	1.46
	100	3.81	1.46	5.17	1.36
	150	2.75	1.39	4.04	1.30
60	0.0	2.42	1.28	3.60	1.10
	50	4.27	1.52	5.69	1.32
	100	3.50	1.47	4.87	1.28
	150	2.66	1.32	3.88	1.22
40	0.0	2.15	1.17	3.21	1.08
	50	3.99	1.33	5.23	1.22
	100	3.12	1.25	4.28	1.13
	150	2.42	1.19	3.51	1.10
LSD 5 %	Water	0.129	0.095	0.133	0.091
	JA	0.581	0.117	0.194	0.111
	Water*JA	0.716	0.164	0.279	0.132

4- Chemical composition:

a- Carbohydrates:

The obtained results presented in Table (5) indicated that, the water stress levels at 80 and 60% F.C increased the total carbohydrates in root, stem and

leaves of wheat plants, meanwhile the level of 40% F.C. decreased it. Different levels of water supplies increased the soluble sugars in root, stem and leaves of wheat plants. From the above mentioned results it can be concluded that the carbohydrates are disturbed under water deficit and this often leads to accumulation of sugars (Kramer, 1983). The observed results have similar trends like those of the obtained by Ali *et al.* (1998) on rose plants, El-Garhy (2002) on faba bean.

It can be noticed from the data presented in Table (5) that the concentrations of total carbohydrates and soluble sugars were increased in different plant organs of wheat plants treated with JA levels. Similar results were reported by YanPing *et al.* (2001) on apple trees and Gendy and Sorial (2002) on rice plants. The increase in carbohydrates and sugars concentration due to JA may be attributed to the capacity of wheat plants for CO_2 assimilation (Ravnikar *et al.*, 1995 a, b).

The combination of water supplies with JA applications caused an increase in total carbohydrates and soluble sugars in root, stem and leaves of wheat plants. Similar results were obtained by El-Fakharany (2003) on sweet basil.

b- Proline:

Data in Table (5) showed that all water levels increased the proline concentration in wheat leaves compared with the control plants. There are several positive roles of proline accumulation in stress metabolism i.e. it may serve as an adaptive for stress metabolism. In this concern it was found that, proline acts as a compatible solute regulation and reducing water loss from the plant during deficit of water (Boggess *et al.*, 1976). Similar results were obtained by Hamed *et al.* (1994) on fenugreek plants and Zhou and Wang (1997) on peas.

The same Table showes that the applications of JA had an increase on proline concentration of wheat leaves. Similar results were obtained by Parthir *et al.* (1992) on barley seedlings.

The interaction between water supplies and JA applications caused an increase in proline concentration in leaves of wheat plants. These results are in accordance with the findings by Todorov *et al.* (1998) on maize plants.

c- Enzymes activities:

Results in Table (5) showed that water stress levels at 80, 60 and 40% F.C increased the peroxidase enzyme activity in leaves of wheat plants and this increase was more pronounced at water stress level 40% F.C. Meanwhile a great decrease in the activity of phenoloxidase in the leaves of wheat plants was reported with increasing the water deficit. Zhou and Wang (1997) on peas and, came to the same results.

The data in Table (5) showed that different JA levels increased the peroxidase enzyme activity in leaves of wheat plants, and this activity was increased with increasing JA levels. The levels of JA at 100 and 150 ppm decreased the phenoloxidase enzyme activity but the level of JA at 50 ppm increased it as compared with the untreated plants. These results are partly in agreement with those obtained by Moons *et al.* (1997) on rice.

The interactions between water stress levels (80, 60 and 40% F.C.) and JA at 100 and 150 ppm caused a marked increase in peroxidase enzyme activity in wheat leaves whereas the interaction between the level of JA 50 ppm and the same stress levels decreased its activity. The interaction between JA levels 100 and 150 ppm with all water levels decreased the activity of phenoloxidase enzyme but the interaction between JA at level 50 ppm with all water stress levels increased its activity.

Table (5): Effect of water stress, JA and their interaction on some chemicals of wheat plants at 81 days during growing season of 2005 – 2006.

Characters / Treatments		Total carbohydrates			Soluble sugars			Proline content µg lucine / gm D.wt	Enzymes activity	
Water levels (F.C. %)	JA levels (ppm)	root	stem	leaves	root	stem	leaves		Peroxidase (O.D./g Fwt)	Phenoloxidase (O.D./ g Fwt)
100		107.5	294.1	248.4	91.5	124.8	121.2	1499.4	2.89	1.05
80		115.3	299.6	258.5	87.0	114.2	104.9	1557.8	2.84	0.97
60		112.7	286.1	258.6	93.4	133.0	120.2	1623.8	3.04	0.84
40		107.8	244.5	205.3	96.9	136.0	121.6	1698.6	3.13	0.61
	0.0	111.1	273.4	236.9	84.7	118.6	108.4	1564.3	2.98	0.96
	50	113.1	287.8	248.2	96.6	131.5	122.1	1589.2	2.71	1.09
	100	110.4	283.7	243.8	95.0	130.4	121.1	1623.3	3.05	0.79
	150	108.6	279.3	241.9	92.5	127.5	116.3	1602.6	3.11	0.63
100	0.0	107.7	284.0	247.3	74.8	100.2	96.9	1498.0	2.89	1.15
	50	109.1	307.5	250.2	100.8	136.4	136.0	1517.5	2.51	1.28
	100	108.0	298.4	248.0	97.6	135.2	133.8	1506.1	2.94	0.99
	150	105.2	286.3	248.0	92.7	127.3	118.2	1475.8	3.06	0.76
80	0.0	116.2	288.7	253.4	80.5	110.7	102.2	1526.3	2.85	1.11
	50	118.3	306.4	262.1	90.3	117.3	106.9	1547.7	2.55	1.25
	100	114.5	303.1	260.9	89.6	115.3	105.8	1581.1	2.97	0.83
	150	112.2	300.1	257.7	87.6	113.5	104.6	1576.0	2.99	0.69
60	0.0	113.4	281.4	245.7	89.1	129.7	116.2	1593.7	3.03	0.91
	50	116.6	289.7	267.7	96.4	135.4	121.6	1616.8	2.83	0.99
	100	111.2	287.3	261.9	94.9	134.3	122.3	1632.6	3.10	0.81
	150	109.5	285.8	259.1	93.3	132.7	120.6	1651.8	3.18	0.64
40	0.0	107.2	239.6	201.3	94.2	133.9	118.4	1639.0	3.14	0.66
	50	108.4	247.4	212.8	99.0	136.9	123.8	1674.9	2.95	0.82
	100	107.9	246.1	204.4	97.9	136.7	122.5	1773.5	3.19	0.53
	150	107.5	245.0	202.6	96.4	136.4	121.7	1706.9	3.22	0.44

d- Mineral status:

Data observed in Table (6) show that, water stress at 80, 60 and 40% F.C. increased the concentrations of Na in leaves and decreased that of N, P and K. In this context, Nawar and Ezz, (1993) on apricot seedlings found that, water stress increased N concentration. They attributed this to the sharp reduction in the growth and dry matter accumulation of these seedlings. The obtained results are in agreement with those obtained by Karunyal and Kailash (1994) on tomato plants, Selim and Ali (1997) on common beans and Abd El- Fattah and Sorial (2001) on taro plants.

Data presented in Table (6) showed that, JA at 50 ppm increased the N, P and K concentrations. All levels of JA increased the K concentration, meanwhile decreased the Na concentration in leaves of wheat plants. These results are in conformity by those obtained by Kang *et al.* (2005) on rice cultivars.

Table (6): Effect of water stress, JA and their interaction on mineral composition (%) in leaves of wheat plants at 81 days during growing season of 2005 – 2006.

Treatments \ Minerals (%)		N	P	K	Na
Water levels (F.C. %)	JA levels (ppm)				
100		3.9	0.42	3.13	0.70
80		3.7	0.37	3.07	0.99
60		3.5	0.31	3.00	0.79
40		3.3	0.27	2.99	0.77
	0.0	3.6	0.31	2.99	0.88
	50	3.9	0.40	3.03	0.84
	100	3.5	0.36	3.06	0.79
	150	3.4	0.30	3.11	0.74
100	0.0	3.8	0.32	3.07	0.78
	50	4.1	0.51	3.13	0.75
	100	3.8	0.47	3.13	0.68
	150	3.8	0.36	3.18	0.59
80	0.0	3.7	0.33	3.02	1.07
	50	3.8	0.46	3.07	1.00
	100	3.6	0.38	3.07	0.96
	150	3.5	0.32	3.13	0.93
60	0.0	3.5	0.33	2.96	0.82
	50	3.8	0.33	2.96	0.82
	100	3.4	0.31	3.02	0.78
	150	3.1	0.27	3.07	0.75
40	0.0	3.3	0.27	2.91	0.85
	50	3.7	0.29	2.96	0.78
	100	3.2	0.26	3.02	0.75
	150	3.0	0.25	3.07	0.68

The combination of JA at lowest level (50 ppm) with water stress condition improved the mineral status not only by increasing the concentration of N, P, K and decreasing the concentration of Na, but also by regulating ionic balance.

5- Endogenous phytohormones:

Results presented in Table (8) showed that, the activators phytohormones (GA_3, IAA and kinetin) concentrations were significantly decreased at the higher level of water stress 40% F.C. The same level of water stress increased the content of ABA (inhibitor) in shoots of wheat plants. Similar results were obtained by Jitratham *et al.* (2006) on citrus trees and Mahouachi *et al.* (2007) on papaya seedlings.

Data recorded in Table (7) showed JA application at concentration of 50 ppm increased the phytohormones concentrations in shoots of wheat plants, meanwhile the application of JA at concentrations of 100 and 150 ppm had an inconsistent effect on phytohormones concentrations. These results confirmed by those obtained by RuiChi and HuangQing (1995) on groundnut seedlings.

The interaction between water stress level 40% F.C. (high stress) and JA level 50 ppm caused an increase in concentrations of GA_3, IAA, ABA and kinetin. Similar results were recorded by Jitratham *et al.* (2006) on citrus trees and Mahouachi *et al.* (2007) on papaya seedlings.

Table (7): Effect of jasmonic acid on endogenous phytohormones content (µg / 100 g F.W.) in shoots of wheat plants at 81 days from sowing during growing season of 2005 - 2006.

Horm. Conc. / Treatments	GA_3	IAA	Kinetin	ABA
Control	15846	684	1744	14
JA 50 ppm	20074	1264	2699	28
JA 100 ppm	19236	612	3870	23
JA 150 ppm	17246	183	1400	20

Table (8): Effect of water stress (high level) and their interaction with jasmonic acid on endogenous phytohormones content (µg / 100 g F.W.) in shoots of wheat plants at 81 days from sowing during growing season of 2005 - 2006.

Horm. Conc. / Treatments	GA_3	IAA	Kinetin	ABA
Control	15846	684	1744	14
JA 50 ppm	20074	1264	2699	28
Water stress (40 % F.C.)	10180	664	1446	23
W. 40 % F.C. + JA 50 ppm	14163	710	2123	55

6- Yield and its components:

Table (9) shows that, spike length, grains weight per plant, straw yield per plant and 1000 grain weight were significantly increased at the lowest of water stress (80% F.C.), then sharply decreased at 60 and 40 % F.C. (high stress). Water stress inhibited cell division and cell enlargement which lead to the reduction of growth and this reflect on yield (Hsiao, 1973). In addition, soil moisture plays an important role in plants growth and its yield as the dynamic and physical aspects of irrigation water (El-Wakil and Gaafar, 1988 a, b) on sunflowers. In this concern, IAA and GA_3 were decreased under the water stress conditions, meanwhile ABA increase in wheat plants as shown in the present, thus the plant growth as well as the yield were decreased. The same results were obtained by Selim and Ali (1997) on common beans.

An increase in spike length, grains weight per plant, straw yield per plant and 1000 grain weight were noticed in wheat plants grown under non stress conditions and preceded with JA at 50, 100 and 150 ppm (Table, 9). Methyl jasmonates was found to increase the concentration of free linolenic acid thus reflected on yield components on tomatoes (Czapski *et al.*, 1992).

The effect of the interaction between JA and water stress on yield attributes showed that, applications of JA increased the above mentioned yield attributes in the stressed wheat plants. The hypothesis includes the assumption that stress activates membrane attacking lipases tolerate polyunsaturated fatty acids, which are metabolized to jasmonates *via* the jasmonic acid biosynthesis pathway (Sembdner and Parthire, 1993).

Table (9): Effect of water stress, JA and their interaction on yield of wheat plants during growing season of 2005 – 2006.

Treatments: Water levels (F.C. %)	JA levels (ppm)	Spike length (cm)	Grains wt. / plant (g)	Straw wt. / plant (g)	1000 grains wt. (g)
100		15.8	1.6	2.6	21.2
80		15.9	1.7	2.7	21.7
60		13.3	1.0	1.6	18.9
40		12.2	0.4	1.4	16.7
	0.0	13.5	1.0	2.0	19.0
	50	15.1	1.3	2.3	20.2
	100	14.6	1.3	2.1	19.8
	150	14.0	1.2	2.0	19.5
100	0.0	14.9	1.3	2.4	20.8
	50	16.5	1.9	2.8	21.6
	100	16.2	1.8	2.7	21.3
	150	15.8	1.5	2.4	20.9
80	0.0	15.4	1.6	2.6	21.3
	50	16.9	1.8	2.9	22.1
	100	15.8	1.7	2.7	22.0
	150	15.4	1.7	2.7	21.5
60	0.0	12.6	0.9	1.5	18.4
	50	14.0	1.1	1.7	19.5
	100	13.7	1.0	1.6	19.0
	150	12.7	1.0	1.5	18.7
40	0.0	11.1	0.3	1.3	15.6
	50	12.9	0.5	1.6	17.4
	100	12.5	0.5	1.4	16.9
	150	12.1	0.4	1.4	16.8
LSD 5%	Water	0.289	NS	0.010	NS
	JA	0.474	NS	0.094	NS
	Water*JA	0.951	0.074	0.098	0.211

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إستجابة نباتات القمح النامية تحت إجهاد مائي إلي حامض الجاسمونيك

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الملخص العربي:

أجريت تجربتي أصص بالصوبة الزجاجية لدراسة تأثير أربع مستويات من الإجهاد المائي وهي ١٠٠ ، ٨٠ ، ٦٠ ، ٤٠٪ من السعة الحقلية وكذلك أربع مستويات من حامض الجاسمونيك وهي صفر ، ٥٠ ، ١٠٠ ، ١٥٠ جزء في المليون والتفاعل بينهم علي صفات النمو الخضري ، العلاقات المائية ، الصبغات النباتية ، المكونات الكيميائية ، الهرمونات النباتية، المحصول ومكوناته لنباتات القمح وأظهرت النتائج أن:

أدت مستويات الإجهاد المائي إلي نقص في كلا من جميع صفات النمو الخضري ، محتوي الماء الكلي والنسبي ، الماء الحر ، معدل النتح ، نشاط إنزيم الفينول أوكسيديز ، محتوي الأوراق من النتروجين والفسفور والبوتاسيوم ، الهرمونات المنشطه ، المحصول ومكوناته. بينما أدت إلي زيادة الماء المرتبط ، النسبة بين الماء المرتبط والحر ، نقص محتوي الماء الورقي ، السكريات الذائبة الكلية ، البرولين.

أدي المستوي الأقل من الإجهاد المائي (٨٠٪ من السعة الحقلية) إلي زيادة في الكربوهيدرات الكلية ، الصبغات النباتية ، المحصول ومكوناته.

أدي مستوي ٥٠ جزء في المليون من حامض الجاسمونيك إلي زيادة في جميع صفات النمو الخضري ، محتوي الماء الكلي والنسبي ، الماء الحر ، معدل النتح ، الصبغات النباتية ، الكربوهيدرات ، نشاط إنزيم الفينول أوكسيديز ، محتوي الأوراق من النتروجين والفسفور والبوتاسيوم ، الهرمونات النباتية ، المحصول ومكوناته. بينما أدي تركيز ١٥٠ جزء في المليون من حامض الجاسمونيك إلي تقليل تلك الصفات سابقة الذكر.

أدي التفاعل بين حامض الجاسمونيك عند تركيز ٥٠ جزء في المليون وجميع مستويات الإجهاد المائي إلي زيادة في جميع صفات النمو الخضري ، محتوي الماء الكلي والنسبي ، الماء الحر ، معدل النتح ، الصبغات النباتية ، الكربوهيدرات ، نشاط إنزيم الفينول أوكسيديز ، محتوي الأوراق من النتروجين والفسفور والبوتاسيوم ، الهرمونات النباتية ، المحصول ومكوناته.

تبعا لذلك أظهر تركيز ٥٠ جزء في المليون من حامض الجاسمونيك أفضل معاملة لنمو نباتات القمح تحت الظروف العادية أو ظروف الإجهاد المائي.