Plant Archives Vol. 19, Supplement 2, 2019 pp.1550- 1557 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

ALLEVIATION OF SALT STRESS IN *OCIMUM BASILICUM* PLANTS BY JASMONIC ACID TREATMENT

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Abstract

A factorial experiment was conducted in green house of department of biology, University of babylon to alleviate the harmful effect of salt stress on *Ocimum basilicum* L. plants using jasmonic acid (JA). Six NaCl concentrations (0, 2, 4, 6, 8, 10) dSm/cm were used as salt stress treatments and four JA concentrations ($0, 10^{-4}, 10^{-5}, 10^{-6}$)M were used as hormonal treatment. Chlorophyll content, wet weight, dry weight, and leaf surface area were taken as morphological parameters. Auxin (IAA), gibberelline (GA) , cytokinin (CK) and abscisic acid (ABA) were determinated as biochemical parameters. Thus, we concluded that salt stress caused a reduction in vegetative characteristics including (chlorophyll content, the leaf surface area , wet and dry weight when the plants were exposed to salt stress (6, 8, 10) dsm\cm and it caused an decreased in the concentration of hormones (Auxin and Gibberellin) and does not affect the concentration of cytokinin, while caused an increase in (ABA) concentration while, spraying the unstressed and stressed plants with (JA 10^{-5}) Malleviate the harmful effect of salinity m by improving in vegetative characteristics including (chlorophyll content, the leaf surface area , wet and dry weight) and hormonal system within the plant.

Introduction

Soil salinity is one of the old problems that have plagued human civilization throughout the ages. Up to day, it is believed that the demise of the Sumerian civilization in southern Iraq was one of the main reasons for the accumulation of salts in agricultural lands due to irregular irrigation and high evaporation rates (Rath, 2018). So, high salinity of irrigation and soil water has an effect on all physiological and metabolic processes leading to reduce plant growth (Kaymakanova *et al*., 2009). It causes deficiency in surface leaf area, dry weight, chlorophyll content, stomata conductance and photosynthesis average (Shah, 2007).

Ocimum basilicum L. isan aromatic annual and perennial herb belong to the family *Lamiaceae*. Many studies have been reported to realize the morphological and biochemical changes of this plant during salinity stress which proved that salt stress cause a dramatic decrease of chlorophyll content and plant leaf area (Khaliq *et al*., 2015; Houneida *et al*., 2011). To alleviate this problem, many studies were conducted with the aim of alleviating or decreasing the inhibitory effect of salt stress on plant growth and increase plant tolerance to salt stress (Noreen and Ashraf, 2008; Houimli *et al*., 2008).

JA (JA) is a secondary metabolite, a molecule whose signal is derived from fatty acid, which shares many of the biological features of the plants. Such as evolution of pollen and grain, and defense of wounds from insects, pathogens and non biological stress. demonstrated that JAS performs direct defense against salt stress by stimulating protease inhibitors and by releasing acid for Acide Linoleïque (Tuner *et al*., 2002).

Materials and Methods

A Completely Randomized Design (CRD) experiment of two-factors with five replicates was used to determine the effect of salt stress on physiological parameters of basil (*Ocimum basilicum* L.) plants. These factors were including saline concentrations (0, 2, 4, 6, 8) dSm/cm/cm and JA concentrations ($0, 10^{-4}, 10^{-5}, 10^{-6}$) M.

Seeds of basil were planted in plastic pots (20*30) cm of 5 Kgvolume. Then the plants were daily irrigated with tap water until it reached 21 days old. Posteriorly, plans sequentially were daily sprayed with JA concentrations and irrigated with salt concentrations mentioned above.

Chlorophyll content, wet weight, dry weight and leaf surface area were measured as morphological parameters. Plant hormones were determined according to (Ergun *et al*., 2002).

Results

Figure (1) showed that the treatment of basil with (2, 4, 6) dSm/cm/cm NaCl caused a significant increase in chlorophyll content to be (31.63, 31.21, 28.23) SPAD respectively compared with unstressed plants (control) (23.8) SPAD. While, the highest salt concentration 10 dSm/cm/cm had a negative effect on the chlorophyll content (22.908) SPAD when compared with the control (SP 23.79).

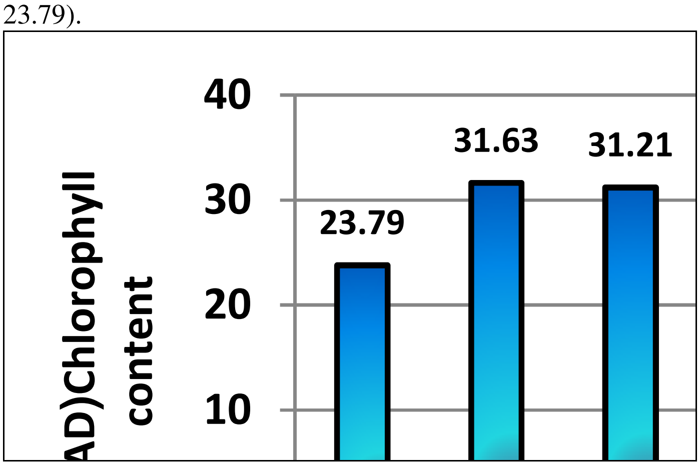

Fig. 1 : Effect of salt concentrations on leafcontent of chlorophyll (spad) LSD 0.05 = 1.67

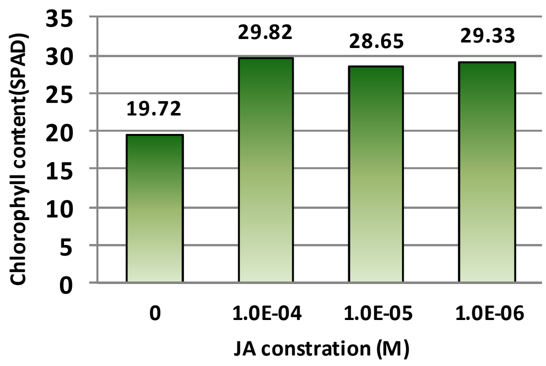

Fig. 2 : Effect of JA on leaf content of Chlorophyll (SPAD)
LSD 0.05 = 1.36

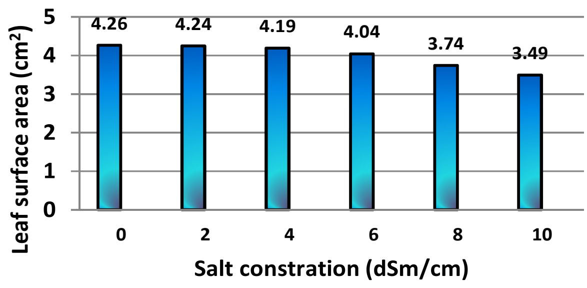

Fig. 3 : Effect of salt concentration on leaf surface area
LSD $_{0.05}$ = 0.25

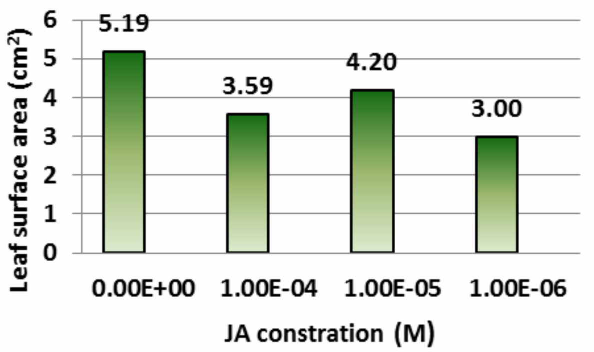

Fig. 4 : Effect of JA on leaf surface area
LSD $_{0.05}$ = 0.21

Plants treated with JA figure (2) had a significant positive effect in increasing chlorophyll content of basil leaves with all concentrations used (10^{-4},10^{-5},10^{-6}) M to be (29.8, 28.6, 29.3) SPAD respectively when compared with the control (19.7) SPAD.

Table (1) elucidated that the treatment of basil with NaCl caused a significant decrease in chlorophyll content especially in the concentration (10) dSm/cm/cm (11.53) SPAD when compared with the control treatment (27.63) SPAD. On the other hand, plants treated with JA (10^{-5}) M showed a significant reduction in chlorophyll content (16.2) SPAD when compared with the control (27.63) SPAD. However, the treatment of the plant exposed to moderate salt stress (2, 4, 6) and sprayed withJAshowed a significantincreased in chlorophyll content, especially the interaction (4 dSm/cm + 10^{-5}M), which gave the highest increase (40.19) SPAD compared with control (27.63) SPAD

Table 1 : The dual interaction between Jasmonic acid and salt concentration on leaf contact of chlorophyll

JA concentration (M) / NaCl concentration (dSm/cm)	0	10^{-4}	10^{-5}	10^{-6}
0	27.63	29.56	16.20	21.76
2	24.5	30.16	36.73	35.13
4	16.46	29.93	40.19	38.23
6	18.26	31.23	32.70	30.70
8	19.93	27.06	25.36	21.70
10	11.53	30.96	20.70	28.43
$LSD_{0.05}$=0.68				

Figure (3) indicated that the plants which exposed to salt stress showed a graduate decrease in leaves area until it become significant at the concentrations (8 and 10 dSm/cm/cm) compared to the control (4.25) cm^2.

Whereas, plants treated with JA showed a significant drop in leaves surface area at all concentrations (3.00, 4.20, 3.58) cm^2 figure (4) when compared with control treatment (5.18) cm^2.

Table (2) showed that all concentrations of NaCl affect negatively on plants leaves area compared with non-stressed plants (5.25 cm^2) . And it indicated that non- stressed plants sprayed with JA (10^{-4}, 10^{-6}) Mcaused a significant increase in leaves surface area (5.29, 5.31) cm^2 respectively compared with control (5.25) cm^2. In addition the dual interaction between salt stress and JA showed that the stressed plants sprayed with JA showed a significant decrease in leaves surface area, especially the combination (10dSm/cm/cm +10^{-5}M) which gave the lowest value (2.17) cm^2 .

Table 2 : The dual interaction between Jasmonic acid and salt concentration on leaf surface area

JA concentration (M) / NaCl concentration (dSm/cm)	0	10^{-4}	10^{-5}	10^{-6}
0	5.25	5.29	2.40	5.31
2	5.22	4.37	3.50	4.53
4	5.19	2.67	3.53	4.60
6	5.17	2.51	2.57	4.43
8	4.57	3.63	3.84	2.80
10	4.09	3.10	2.17	3.53
$LSD_{0.05=}$ 0.1				

A graduate significant decrease in wet weight has been occurred in plants irrigated with NaCl (4, 6, 8, 10) dSm/cm/cm which were (1.07,0.96,.86,0.74) respectively figure(5).

Figure (6) shows that the treatment of basil plant with JA led to a gradual increase in the wet weight of basil plants, especially at concentration (10^{-5}) M, that it reached (1.21) g compared with the control treatment (1.03) g. While the wet weight of the plant decreased significantly at the concentration (10^{-6}) M JA to reach (0.90)g when it compared with the control treatment (1.03) g.

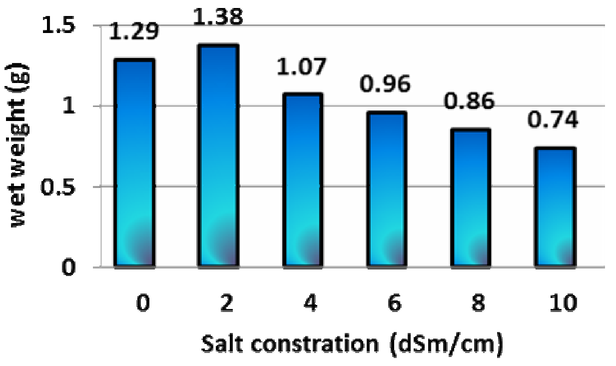

Fig. 5 : Effect of salt concentration on wet weight
LSD $_{0.05}$ = 0.116

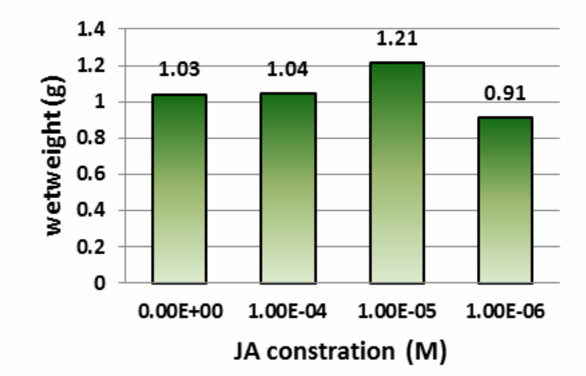

Fig. 6 : Effect of JA concentration on wet weight .
LSD $_{0.05}$ = 0.095

Table (3) showed the dual effect of salt stress and JA on the wet weight of the basil plants. It clarified that stressed plantsshowed a significant decrease in wet weight, especially plants irrigated with the concentration (10) dSm/cm/cm which was (0.71) g compared with non- stressed plants (1.24), While the treatment of the plant with JA (10^{-4} and 10^{-5} M) caused a significant increase in the wet weight of the plantsto be (1.44, 1.61) g respectively compared to untreated plants (1.24) g. Although most of stressed plants which treated with JA appeared to have a significant decrease in wet weight, the concentration (10^{-5}) M of JA showed great effect in increasing the wet weight of the plant to (1.39) g when compared with the plants that are not exposed to stress and untreated (1.24) g .

Table 3 : The dual interaction between Jasmonic acid and salt concentration on wet weight

JA concentration (M) / NaCl concentration (dSm/cm)	0	10^{-4}	10^{-5}	10^{-6}
0	1.24	1.44	1.61	0.88
2	0.92	1.41	1.08	0.87
4	0.73	0.65	1.13	1.34
6	0.76	0.89	1.18	0.59
8	1.87	128	1.39	0.98
10	0.71	0.59	0.87	0.79
LSD $_{0,05}$0. =048				

Figure (7) shows a significant gradual decrease in the dry weight of the basil plant by increasing the concentration of NaCl, where the maximum decrease was at concentration (10) dSm/cm/cm which was (0.13) gas compared with control treatment (0.26) g.

While, the treatment with JA figure (8) had a positive effect in increasing dry weight, especially when treated with concentration (10^{-5}) M, where it reached (0.24) g compared with the control plants (0.213) g.

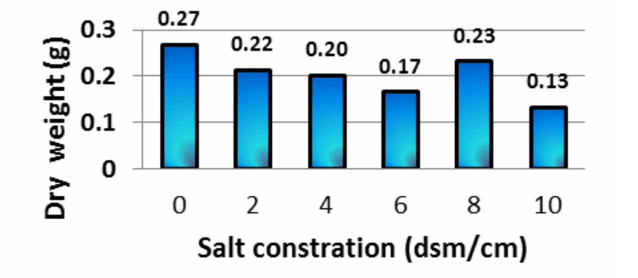

Fig. 7 : Effect of salt concentration on dry weight .
LSD $_{0.05}$ = 0.013

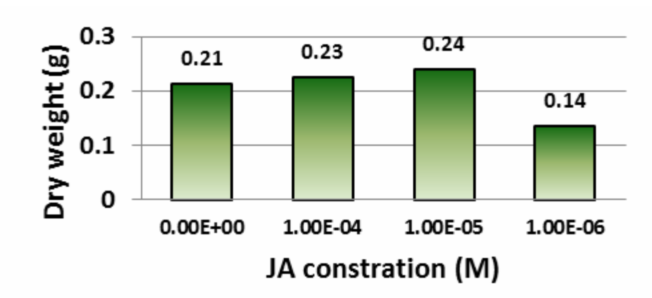

Fig. 8 : Effect of JA concentration on dry weight .
LSD $_{0.05}$ = 0.025

Table (4) shows the dual interaction between salt stress and JA treatment and it clarifies that the natural dry weight of the basil plant was (0.18)g (control treatment) and the exposure of plants to salt stress led to a significant increase in dry weight, especially at the concentration (8)dSm/cm (0.41) g, while it decreased to (0.14) g at the concentration (10)dSm/cm, when compared with the control. However, when the non-stressed plants treated with JA, it caused a significant increase in plant dry weight, especially at the concentration (10^{-5}) M which was (0.46)g. Stressed plants showed an increase in dry weight when treated with JA at the combination (8dSm/cm + 10^{-4}M) and (6 dSm/cm + 10^{-5}M), the dry weight was (0.25 g and 0.24 g) respectively.

Table 4 : The dual interaction between Jasmonic acid and salt concentration on dry weight

JA concentration (M) / NaCl concentration (dSm/cm)	0	10^{-4}	10^{-5}	10^{-6}
0	0.18	0.28	0.46	0.15
2	0.15	0.32	0.24	0.15
4	0.23	0.24	0.18	0.16
6	0.16	0.17	0.24	0.08
8	0.41	0.25	0.14	0.13
10	0.14	0.07	0.17	0.15
LSD $_{0,05}$0. =013				

Figure (9) showed that IAA concentration in the leaves was (0.73) Mm and that the plant treated with NaCl (2, 4, 10) dSm/cm showed a significant decrease in IAA concentrations (0.58, 0.6, 0.4) mM respectively when compared with non-stressed plants (0.73) mM, while the concentration of IAA was significantly increased to (1.08, 0.92) mM when plants treated with NaCl (6, 8) dSm/cm.

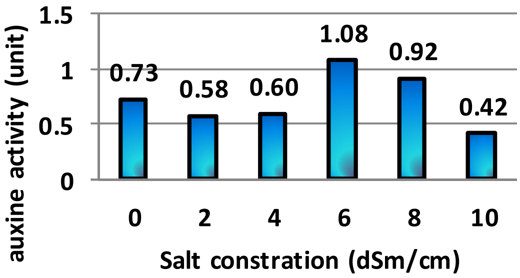

Fig. 9 : Effect of salt concentration on the IAA concentration LSD $_{0.05}$ = 0.118

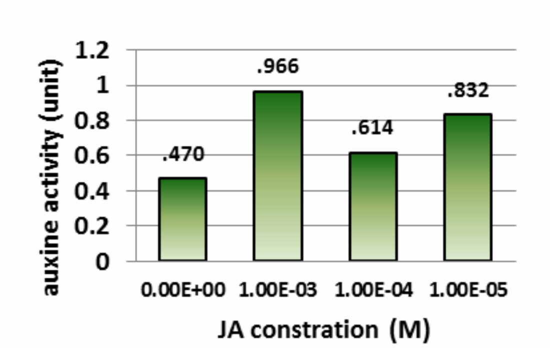

Fig. 10 : Effect of JA concentration on IAA concentration . LSD $_{0.05}$ = 0.097

Figure (10) clarifies that the plants treated with all concentration of JA (10^{-4} , 10^{-5} , 10^{-6}) M showed a significant increase in IAA concentration (0.966, 0.614, 0.832) mM respectively compared with untreated plants (0.470) mM.

Table (5) shows the effect of salt stress and JA and their interaction on the endogenous IAA concentration. This table showed that NaCl caused a significant decrease in IAA concentration, especially the concentration (2, 4, 10) dSm/cm (0.366, 0.179, 0.281) mM respectively, while the concentrations (6,8) dSm/cm were significantly increased to be (0.871, 0.594) mM respectively. The treatment of non-stressed plants with JA (10^{-4}, 10^{-5}) M caused a significant increase in IAA concentration, while the concentration (10^{-5}) Mcaused significant decrease in hormone concentration (0.372) mM when it compared with the control treatment (0.524) mM. This table also indicates that spraying of stressed plants with JA(10^{-4}) mM resulted in a significant increase about two times in IAA concentration, while, the concentration decreased significantly at the concentration (10) dSm/cm. The concentration of (10^{-5}) M was the best in increasing the concentration of internal IAA when exposing the plants to high salt stress (10) dSm/cm (0.913)mM respectively.

Table 5 : The dual interaction between Jasmonic acid and salt concentration on IAAconcentration

JA concentration (M) / **NaCl concentration (dSm/cm)**	**0**	**10^{-4}**	**10^{-5}**	**10^{-6}**
0	0.524	1.1406	0.372	0.8709
2	0.366	1.1806	0.203	0.572
4	0.179	1.390	0.267	0.553
6	0.871	1.264	0.931	1.255
8	0.594	0.661	0.998	1.4186
10	0.281	0.156	0.9136	0.323
$LSD_{0.05}$ = 0.48				

The study of the effect of saline concentrations on GA concentration (Fig. 11) showed that the exposure of basil plants to salt stress (4, 6) dSm/cm did not significantly affect the concentration of GA (0.67, 0.57) mM respectively, while high salt concentrations (8, 10) dSm/cm were caused an increase in the concentration of the hormone up to (0.74 and 0.71) mM respectively if it compared with the control treatment (0.64) mM.

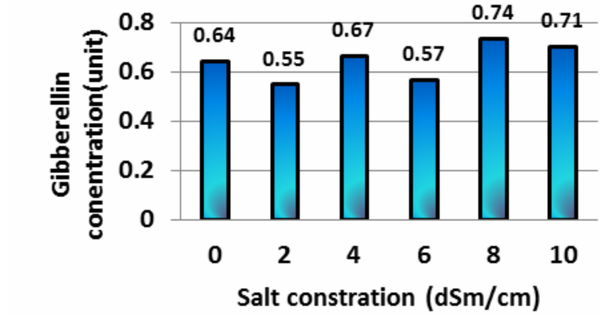

Fig. 11 : Effect of salt concentration on the GA concentration LSD $_{0.05}$ = 0.075

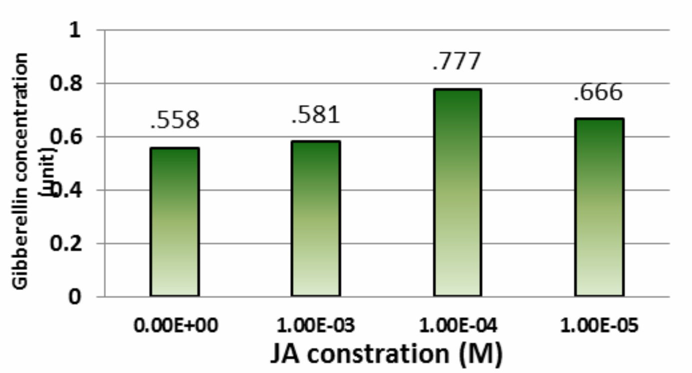

Fig. 12 : Effect of JA concentration on GA concentration $LSD_{0.05}$ = 0.061

Whereas, we found that the plant treated with JA (10^{-5}) M showed a significant increase in GA concentration (0.777) mM comparison with the control treatment (0.558) mM.

Table (6) shows that stressed plants showed a significant decrease in GA concentration , as well as non-stressed plants treated with JA (10^{-4} , 10^{-6}) M. As well as almost stressed plants treated with JA showed a significant decrease in hormone concentration.

Table 6 : The dual interaction between Jasmonic acid and salt concentration on GA concentration

JA concentration (M) / NaCl concentration (dSm/cm)	0	10^{-4}	10^{-5}	10^{-6}
0	0.996	0.222	1.017	0.337
2	0.167	0.19	1.053	0.786
4	0.80	0.91	0.361	0.597
6	0.27	0.86	0.809	0.597
8	0.534	0.58	0.55	1.2783
10	0.577	0.71	0.8729	0.6579
LSD $_{0,05}$0. =031				

Figure (13) shows that the treatment of basil plants with NaCl did not significantly affect the concentration of CK except for the concentration of (8) dSm/cm, which caused a significant increase in the concentration of the hormone (0.47) mM compared with control treatment (0.32) mM.

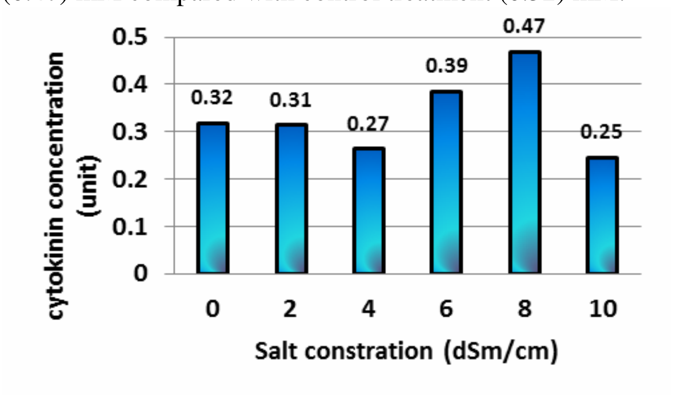

Fig. 13 : Effect of salt concentration on the CK concentration LSD $_{0.05}$ = 0.081

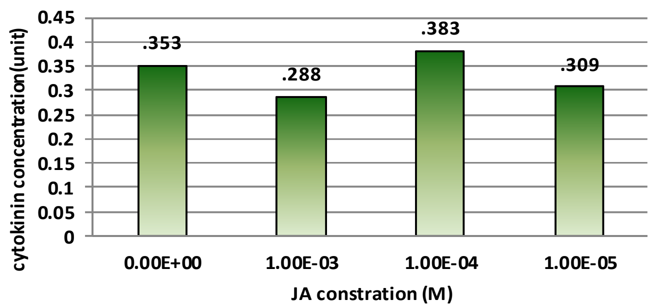

Fig. 14 : Effect of JA concentration on CK concentration LSD $_{0.05}$ = 0.066

In addition, there was no significant difference in the concentration of CK when spraying the plants with all JA concentrations (Fig. 14). All values were close to the normal values of control plants (0.353) mM.

Table (7) shows that the treatment of plants with NaCl (2, 4, 6, 10) dSm/cm affect positively in increasing CK concentration when compared with the control treatment (0.22) mM, in addition, non-stressed plants treated with JA (10^{-4}, 10^{-5}, 10^{-6}) M showed a significant increase in CK concentration (0.424, 0.34, 0.287) mM respectively as compared with the control treatment (0.22) mM. The table also showed that the combination (8dSm/cm + 10^{-5}M) had got the highest hormone concentration which was (0.955) mM compared with the control treatment (0.22) mM,

Table 7 : the dual interaction between Jasmonic acid and salt concentration on CKconcentration

JA concentration (M) / NaCl concentration (dSm/cm)	0	10^{-4}	10^{-5}	10^{-6}
0	0.22	0.424	0.34	0.287
2	0.297	0.425	0.304	0.231
4	0.48	0.217	0.20	0.162
6	0.4619	0.36	0.311	0.407
8	0.243	0.1826	0.955	0.499
10	0.416	0.1176	0.183	0.266
LSD $_{0,05}$0. =033				

The effect of salt concentrations on the ABA concentration was shown in (fig. 15) which clarifies that the plants irrigated with salt (2, 8, 10) dSm/cm showed a dramatic increase in hormone concentration to be (1.06 , 1.11 , 1.25) mM respectively when compared with control treatment (0.95) mM.

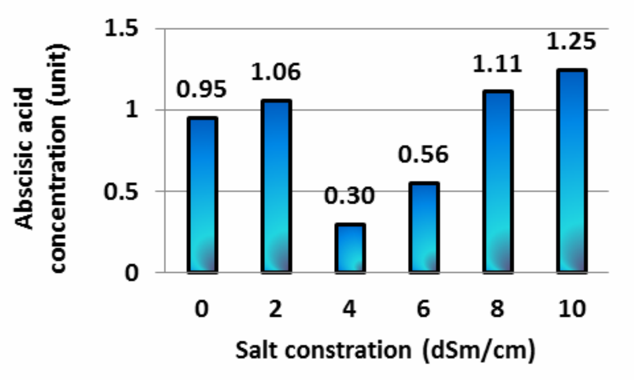

Fig. 15 : Effect of salt concentration on the ABA concentration. LSD $_{0.05}$ = 0.094

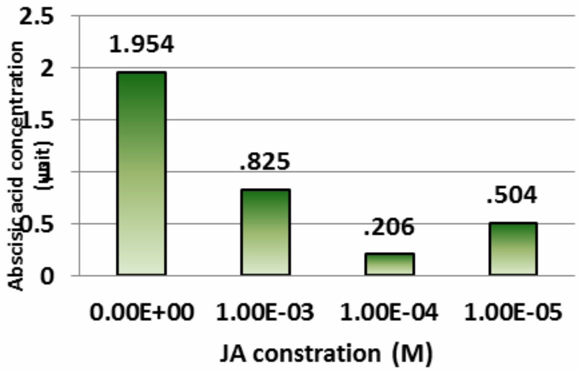

Fig. 16 : Effect of JA concentration on ABAconcentration. LSD $_{0.05}$ = 0.077

But, spraying of plants with all JA concentrations (Fig. 16) showed a significant drop in ABA concentration, especially the concentration (10^{-5}) M, which was (0.206) mM compared to control treatment (0.954) mM.

Table (8) showed that treatment of basil plants with NaCl (8, 10) dSm/cm caused a significant increase ABA (3.63, 3.625) mM respectively. While, the treatment of non-stress plants with JA (10^{-5}, 10^{-6}) M showed a significant decrease in hormone concentration (0.077, 0.13) mM respectively. whereas, stressed plants treated with JA (10^{-4}, 10^{-6}) M caused a significant increase in the concentration of the hormone , while a significant decrease in hormone concentration was observed in treatment with combination (8 dSm/cm, 10 dSm/cm + 10^{-5}) M which were (0.192 and 0.051) mM compared to the control treatment (0.253)mM.

Table 8 : The dual interaction between Jasmonic acid and salt concentration on ABA concentration

JA concentration (M) / NaCl concentration (dSm/cm)	0	10^{-4}	10^{-5}	10^{-6}
0	0.253	3.351	0.077	0.13
2	3.739	0.339	0.026	0.146
4	0.244	0.464	0.31	0.18
6	0.23	0.346	0.574	1.0706
8	3.63	0.111	0.192	0.515
10	3.625	0.336	0.051	0.98
LSD $_{0,05}$0. =039				

Discussion

Effect of salinity in basil plants

It is clear from the current study that basil is a salt sensitive plant the because plants irrigated with the concentrations (2, 4, 6, 8, 10) showed a gradual decrease in wet and dry weight of the plants (Figure 5,6), which is directly proportional to the increase in salt concentrations, the percent of reduction was (17, 25, 33, 42)% respectively for wet weight and (19, 24, 30, 13, 50)% respectively for dry weight. The plants also showed a significant decrease in the leaf surface area when plants were exposed to high salt concentrations (8 and 10) dSm/cm (Figure 3). This may be due to anatomical changes in xylem vessels , resulting in a decrease in the amount of water transferred from the soil to the shoot system (Jasim *et al.*, 2012) which may be caused a decrease in stored amount of carbohydrates, proteins and carotenoids (Yale and Karim, 2017) or may be because the decrease in the surface area of the leaves (Fig. 3) which may be was one of the defense mechanisms of plant to resist salt stress (Jasim *et al*, 2012) or because the reduction of hormones concentration which were responsible for cellular division (IAA and GA) (Fig. 9 , 11) leading to a decrease in the expansion of the cells thus leading to a decrease in surface area , This finding is compatible with (Jasim *et al*, 2012)who proved the decrease in the surface area of pepper leaves *Capsicum annun* L. was concomitant with the reduction of plant hormones. Vernonx *et al* (2010) mentioned that free IAA plays an important role in dividing meristematic cells of the shoot system to form the whole plant parts. The decrease in leaf surface area of stressed plants were consistent with the studies of (Hirpara *et al.*, 2005; Ziaf*et al.*, 2009).

Effect of JA in basil plants

The results of the current study show that JA plays an important role in improving the physiological and biochemical characteristics of the basil plant, especially the concentration (10-5) M, which increased chlorophyll content of the leaves (Fig. 2), that may be led to increase photosynthesis efficiency which may led to increase the content of carbohydrates and thus increase the wet weight and dry weight (Fig. 6, 8). (Metodiev *et al.*, 1996) showed that JA indirectly affects photosynthesis through its effect on gene expression. Despite the increase in chlorophyll content and wet and dry weight, the surface area of the leaf was significantly decreased (fig. 4) When spraying the plants with JA, especially the concentration (10-5) M, the leaf surface area decreased to 42% compared with the control treatment. These results were consistent with (Liententhaler *et al.*, 2007) showing that thick leaves are characterized by a small surface area with increased chlorophyll and total carotenoids content per unit area compared to thin leaves. This type of leaves possesses the highest rate of photosynthesis, Resulting in linearly increasing dry mass with increasing leaf thickness (Uniinemeta, 1997, 2001), it has been observed that free IAA has increased when spraying the plant with JA. The percentage of increase was (105.5% and 30.6% and 77%) for concentrations (10^{-4}, 10^{-5} and 10^{-6}) M respectively, this may be due to the ability of JA to regulate the bioactivities by increasing the concentration of IAA (figure10). This is consistent with (Huang *et al.*, 2017), who proved that the JA increases the formation of the adventitious roots in the *Arabidobsis* plant by increasing the regulation of the gene expression ERF109 which in turn stimulate the genes responsible for the synthesis of IAA, namely Yucc A and ANTRANILATE (ASA1) SYNTHASE A1, and it is important to mention that the GA increased significantly about (39.2%) (fig. 12) when spraying plants with concentration (10^{-5}) M of JA , this may be due to the important role of JA in the regulation of plant growth (Cheng *et al.*, 2010). Or, it may be related to the role of JA in controlling the effective genes responsible for DELLA proteins inhibition that cause flowering infertility. On the other hand, there were no significant differences in CK concentration (fig. 14) while, the concentration of the ABA was significantly reduced (fig. 16) and there were (57.5%, 89.5% and 74.2%) for concentrations (10^{-4}, 10^{-5} , and 10^{-6}) M respectively . For these reasons we can conclude that the JA acts on controlling of plants enzymatic and hormonal system giving the plant the opportunity to adapt with environmental changes (Song *et al.*, 2013; Song *et al.*, 2014).

Effect of JA in reducing the Salt Stress

This study shows that the JA has a dramatic effect in alleviating salt stress, The results show a gradual decrease in the chlorophyll content (Table 1).This reduction may be due to the effect of salt stress on enzymes activity which is responsible for the bio-synthesis of chlorophyll (Belavari *et al.*, 2010). Or, because the malfunction in grana which is in turn leads to the degradation of the chloroplast , especially in high salt concentrations that are exposed to prolonged salt stress (Wang and Blumwald, 2015) or due to an increase in Chlorophyllase enzyme activity causing chlorophyll degradation (Khamees and Faiath, 2013) which in turn was resulting in lower wet and dry weight (Table 3 and 4) especially when treated with a concentration of (10) dSm/cm (García-Morales *et al.*, 2012) who showed that salt stressed rice plants are less efficient in photosynthesis due to the breakdown of photosynthetic pigments, resulting in lower efficiency of the electron transport system. Almodares *et al.*, (2008) showed that salinity decreased the content of sucrose, glucose and fructose in both roots and leaves of sweet sorghum, resulting in a decrease in the dry weight of saline sensitive plants. Salinity also caused a decrease in the building of amino acids, especially tryptophan, which is considered the precursor in the vital pathway for IAA biosynthesis, as well as young leaves are one of the sources for hormone, which may be adversely affected when the plant exposed to stress. So, its affects on IAA concentration (Munns, 2008; Flowers, 2005; Munns and Tester, 2008). Furthermore, we observed that the decrease in the concentration of IAAwascoincided with ABA increase (Table 7).

Whereas, stressed plants treated with JA showed an increase in chlorophyll content (Table 1) due to its ability in alleviating harmful effect of salt stress through increasing chlorophyll content of *Melissa officinalis* (Pazoki, 2015) which in turn cause an increase in wet weight (Table 2) that increased about 12% for the interaction (8 dSm/cm+ 10^{-5}M) and dry weight that increased about 38% for (8 dSm/cm+ 10^{-4}M) and (8 dSm/cm+ 10^{-5}M) (Table 3). These findings was compatible with (Reiss and Beale, 1995). Or, wet and dry weight increase may be related to the carbohydrate accumulation (Kaur *et al*., 2017).

In this study we proved that JA could affect positively on morphological characteristics through its effect on biochemical properties especially endogenous hormones. Huang *et al*.(2017) proved that JA regulates resistance genes through its interaction with IAA biosynthesis as it works on increasing gene expression of ERF109 which activate IAA-responsible genes promoters SYNTHRANILATE (ASA1), SYNTHAR AL and YUCCA2 gene (Huang *et al*., 2017) led to IAA increase (Table 5). In addition JA caused an increase in GA concentration about 50.7% of the combination(10 dSm/cm+ 10^{-5}M) and about 137.8% for the combination (8 dSm/cm+ 10^{-6}M) (Table 6). it may be related to JA role in controlling DELLA proteins repressor genes formig during salt stress(Cheng *et al*., 2009). Also, JA cause an increase of CK concentration (Table 7) which is considered as an important hormone for cell division (Taiz and Zieger, 2003). It is note worthy that JA caused a considerable decreased in ABA concentration which was estimated about 94% and 98% for the combination (8, 10 dSm/cm+ 10^{-5}M) leading to increase gas exchange and high stomatal conductance sharing in improving plant characteristics and increase its biological activity. So, we concluded that JA achieves a perfect hormonal balance for stressed plants.

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