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MITIGATORY EFFECT OF KINETIN AND SPERMINE ON SEAWATER-STRESSTED WHEAT (TRITICUM AESTIVUM) PLANTS : I- YIELD COMPONENTS AND BIOCHEMICAL ASPECTS OF YIELDED GRAINS

Aldesuquy, H. S.; Baka, Z. A. and Mickky, B. M.

Department of Botany, Faculty of Science, Mansoura University,, Egypt

ABSTRACT

A pot experiment was conducted to evaluate the effect of grain presoaking in kinetin (0.1 mM), spermine (0.3 mM) and their interaction on yield components and biochemical aspects of the yielded grains of wheat plants irrigated with 25% seawater. Seawater salinity caused marked reduction in shoot length, plant height, main spike length, main spike weight, number of tillers per plant, number of spikes per plant, number of spikelets per main spike, number of spikelets per plant, number of grains per main spike, number of grains per plant, grain yield per main spike, grain yield per plant, individual grain biomass, 100-kernel weight, biological yield, economic yield, straw yield, crop yield, mobilization index, crop index, harvest index, as well as relative grain yield and evapotranspiration efficiency. Furthermore, seawater induced marked reduction in biochemical aspects of yielded grains especially carbohydrates content (glucose, sucrose, total soluble sugars, polysaccharides and total carbohydrates), nitrogenous constituents (ammonia, amino, amide, total soluble, total and protein nitrogen), total protein and nucleic acids (DNA and RNA) contents as well as proline and organic acids (citric and keto acids) contents. Conversely, seawater stress increased nitrite nitrogen, phosphorus (inorganic, organic and total) and ions (Na^+, K^+ and Cl^-) contents of the yielded wheat grains.

Treatment with kinetin and spermine appeared to mitigate the effect of seawater stress on wheat yield and the biochemical aspects of yielded grains. The effect was more pronounced with kinetin + spermine treatment. Furthermore, the change in grain yield in response to seawater stress and the used chemicals was strongly correlated with the change in all the estimated yield criteria and biochemical aspects of the yielded grains (r = 0.7 - 1.0).

Keywords: *Triticum aestivum, seawater stress, yield, kinetin, spermine.*

INTRODUCTION

Wheat is a major agricultural commodity and dietary component across the world, where it is the most widely grown crop species in the world (Rezzoug *et al.*, 2008). Moreover, wheat is one of the most important cereals in the view of nutritional value (Abd El-Baky, 2009). Egypt is present in the semi-arid region; seawater therefore has been a recent effort, the possibility of obtaining reasonable yield and quality to products from whole grains (Abd El-Baky *et al.*, 2008).

Yield is the ultimate outcome of all processes involved at all stages in growth and development of a crop, any one of which may limit the yield of a particular crop (Munns *et al.,* 2006). Previous reports have revealed that stressing wheat plants with different levels of saline solution resulted in significant and gradual decline in all yield components, such as the number of tillers, number of spikes per plant, number of grains per plant, straw yield, grain yield, biological yield and harvest index. In addition, the yielded grains contained less carbohydrates, nitrogen, protein, phosphorus, potassium, calcium and magnesium contents, but higher sodium content when compared with control plants (Iqbal *et al.,* 2006b; Khozaei *et al.,* 2006; Ahmed *et al.,* 2008; Aldesuquy *et al.,* 2009).

Seed priming with cytokinins, especially kinetin, is reported to increase plant salt tolerance. It was hypothesized that cytokinins could increase salt tolerance of wheat plants by interacting with other plant hormones, especially auxins and ABA (Iqbal *et al.,* 2006a).

Polyamines have been shown to be an integral part of plant stress response, as they are implicated in senescence and environmental stress (Alcázar *et al.,*2006). Many studies have indicated that stress tolerance of plants is correlated with their capacity to enhance the synthesis of polyamines upon encountering the stress (Kasinathan and Wingler, 2004).

The present work was undertaken to assess up to what extent seed priming in kinetin, spermine or their interaction could ameliorate the deleterious effects of seawater stress on yield components and biochemical aspects of the yielded grains of wheat plants.

MATERIALS AND METHODS

Plant material and growth conditions :

For soaking experiment, a homogenous lot of *Triticum aestivum* L. var. Sakha 93 grains was selected. The grains were surface sterilized by soaking in 0.01 M $HgCl_2$ solution for three minutes, then washed thoroughly with distilled water. The sterilized grains were divided into four sets. Grains of the 1st set were soaked in distilled water to serve as control, while those of the 2nd, 3rd, or 4th sets were soaked in 0.1 mM kinetin, 0.3mM spermine or 0.1mM kinetin + 0.3 mM spermine; respectively, each for about 12 hours.

After soaking, thoroughly washed grains were drilled on 15th November 2008 in plastic pots (20 cm in diameter) filled with 5.5kg soil (clay/sand, 2/1, v/v), where fifteen grains were sown in each pot. The pots were then kept in a greenhouse at Botany Department, Faculty of Science, Mansoura University, Egypt. The plants were subjected to natural day/night conditions (minimum/maximum air temperature and relative humidity were 15/25^{o}C and 35/45%; respectively) at midday during the experimental period. The plants in all sets were irrigated to field capacity with tap water.

After two weeks from sowing, thinning was started so that five uniform seedlings were left in each pot for the subsequent studies. The plants of each set were sub-divided into two groups. The 1st group in each set was still irrigated with normal tap water serving as control, whereas the 2nd one was irrigated with 25% seawater. The resulting eight treatments were marked as follows:

Treatments	1	2	3	4	5	6	7	8
SW (%)	0	25	0	25	0	25	0	25
	+	+	-	-	-	-	-	-
K	-	-	+	+	-	-	-	-
Spm	-	-	-	-	+	+	-	-
K + Spm	-	-	-	-	-	-	+	+

Abbreviations: **SW:** seawater, **K:** kinetin, **Spm:** spermine

The choice of the above mentioned doses of the used chemicals (i.e. kinetin and/or spermine) was based on trial experiments for studying the effect of the provided chemicals on the growth of the different seawater-treated wheat plants. Irrigation with seawater was applied after 30 days from sowing with a periodical soil washing (each two weeks) with tap water.

The chemical analyses of the employed seawater, collected from Mediterranean Sea, revealed that it contains Cl^-, 21.6 Kg m^{-3}; Na^+, 11.1 Kg m^{-3}; $SO4^{-2}$, 2.85 Kg m^{-3}; K^+, 0.49 Kg m^{-3} and P^{+3}, 16.6 μg dm^{-3}. Its salinity was found to be 38.5 g kg^{-1}; pH, 8.1 and EC, 47 mmhos cm^{-1}.

For estimation of yield and yield attributes, ten samples of guarded plants were taken from each treatment. Moreover, only three samples were taken from each treatment for biochemical analyses. Data were obtained and the mean values per plant were computed.

Estimation of yield and yield attributes :

Among the different evaluated yield attributes, the following relations were used:

Mobilization index = Crop yield / Straw yield (Ray and Choudhuri, 1980).

Crop index = Economic yield / Biological yield (Beadle, 1993).

Harvest index = Economic yield / Straw yield (Beadle, 1993).

Relative grain yield = (Yield of treatment / Yield of control) X 100 (Beadle, 1993).

Evapotranspiration efficiency = Water use efficiency / Harvest index

(Ehdaie and Waines, 1993).

Water use efficiency = Grain yield / Total water used (Stanhill, 1987).

Estimation of carbohydrates :

Sugars were extracted by overnight submersion of dry tissue of the yielded grains in 80% (v/v) ethanol at 25^{o}C with periodic shaking.

1. Estimation of glucose :

Glucose content was estimated using O-toluidine procedure of Feteris (1965) as modified by Riazi et al. (1985).

2. Estimation of sucrose :

Sucrose was determined using the modification of Handel (1968).

3. Estimation of total soluble sugars :

Total soluble sugars were analyzed according to the modification of Yemm and Willis (1954).

4. Estimation of polysaccharides :

The method used for estimation of polysaccharides was that of Thayermanavan and Sadasivam (1984).

Estimation of nitrogenous constituents :

The method used for the extraction of nitrogenous constituents was essentially that adopted by Yemm and Willis (1956).

1. Estimation of ammonia nitrogen :

Ammonia nitrogen was estimated by the method adopted by Delory (1949) using Nessler's reagent as modified by Naguib (1964).

2. Estimation of amide nitrogen :

The method used with amide nitrogen was that recommended by Naguib (1964).

3. Estimation of amino nitrogen :

The method used in the present study was designed by Muting and Kaiser (1963).

4. Estimation of nitrite nitrogen :

The method described by Snell and Snell (1939) was used to estimate nitrite nitrogen.

5. Estimation of total soluble nitrogen :

Total soluble nitrogen was determined by the conventional semimicro-modification of Kjeldahl method of Pirie (1955).

6. Estimation of total nitrogen :

Total nitrogen was determined by the conventional semimicro-modification of Kjeldahl method of Chinbal et al. (1943).

7. Estimation of protein nitrogen :

Subtracting the total soluble nitrogen from total nitrogen gave the value of protein nitrogen.

Estimation of protein :

The method of protein extraction was adopted by Scarponi and Perucci (1986). Protein content was determined according to the method adopted by Bradford (1976).

Estimation of nucleic acids :

DNA and RNA contents were estimated according to the method of Sadasivam and Manickam (1996) as described by Devi (2000).

Estimation of phosphorus :

The procedures adopted for extraction of different phosphorus compounds were essentially those described by Barker and Mapson (1964). The method of Kuttner and Lichtenstein (1932) as described by Humphries (1956) was adopted to estimate both inorganic and total phosphorus, and the difference between them was equivalent to organic phosphorus.

Estimation of proline :

The method adopted for proline was essentially that of Snell and Snell (1954).

Estimation of organic acids :

The method used for determining citric acid was that described by Snell and Snell (1949). To estimate keto acids, the method of Friedman and Haugen (1943) was applied.

Estimation of elements :

Flame spectrophotometry was included for determining Na^+ and K^+ contents according to the method designed by Chapman and Pratt (1978). According to Hansen and Munns (1988), Cl- levels were determined.

Statistical analysis :

Using SPSS program, a test for the least significant differences between means at P ≤

0.05 was performed using LSD test (Snedecor and Cochran, 1976). In addition, correlation coefficient between the economic yield and all the estimated criteria was evaluated.

RESULTS

Changes in yield attributes :

Seawater stress at 25% caused significant reduction ($P \leq 0.05$) in all yield components of wheat plants (Table 1). On the other hand, grain presoaking in kinetin, spermine or their interaction caused marked increase ($P \leq 0.05$) in all yield components of wheat plants irrigated with seawater except the number of grains per main spike, crop index and relative grain yield for spermine treatment; and only crop index for kinetin treatment. In consequence to the previous determinations, treatment of kinetin + spermine improved all yield components more than that of kinetin or spermine only. Moreover, kinetin + spermine or kinetin alone induced additional increase ($P \leq 0.05$) in yield components of stressed wheat plants.

Changes in biochemical aspects of the yielded grains :

Changes in carbohydrates content :

Data in table 2 revealed that irrigation of wheat plants with 25% seawater resulted in marked decrease ($P \leq 0.05$) in all carbohydrates fractions (glucose, sucrose, total soluble sugars, polysaccharides and total carbohydrates) in the yielded grains of wheat plants. However, grain presoaking in kinetin, spermine or their interaction induced significant increase ($P \leq 0.05$) in carbohydrates content of the developed wheat grains if compared with untreated stressed plants.

Application of kinetin, whether alone or in combination with spermine, caused additional increase in carbohydrates content of the yielded grains of wheat plants irrigated with 25% seawater in relation to control plants. Generally, the interaction of kinetin and spermine had a more pronounced effect than the other treatments.

Changes in nitrogenous constituents :

As compared to control values, seawater salinity significantly decreased ($P \leq 0.05$) ammonia, amino, amide, total soluble and total nitrogen of yielded wheat grains (Table 2). On the other hand, the applied kinetin, spermine or their interaction generally increased the nitrogenous constituents in the developed grains of seawater-stressed wheat plants.

Seawater stress induced a marked increase ($P \leq 0.05$) in nitrite nitrogen. Application of kinetin, spermine either alone or in combination resulted in an additional increase in nitrite nitrogen. However, insignificant change was observed for protein nitrogen.

Changes in total protein and nucleic acids contents :

The results in table 3 cleared that seawater induced massive decrease ($P \leq 0.05$) in total protein and nucleic acids (DNA and RNA) contents in the developed wheat grains. On the other hand, application of kinetin and/or spermine caused significant increase ($P \leq 0.05$) in total protein and nucleic acids contents of the yielded grains of stressed wheat plants.

The combination of kinetin and spermine was the most effective treatment in mitigating the deleterious impact of salinity on total protein and nucleic acids contents of wheat grains.

Changes in proline and organic acids contents :

Perusal of the data in table 3 showed that seawater stress led to remarkable decline ($P \leq 0.05$) in proline and organic acids (citric and keto acids) contents of the yielded wheat grains. Meanwhile, kinetin, spermine or their interaction seemed to increase tolerance of yielded grains of stressed wheat plants towards seawater salinity by increasing the production of proline and organic acids when compared with stressed plants.

The interaction of kinetin and spermine had the most pronounced effect on increasing proline and keto acids contents in the yielded grains of stressed wheat plants. However, for citric acid, kinetin effect exceeded that of spermine or the combination of kinetin and spermine.

Changes in phosphorus content :

As compared to control values, irrigation of wheat plants with 25% seawater caused noticeable increase ($P \leq 0.05$) in both inorganic and total phosphorus contents of the yielded wheat grains (Table 3). However, the recorded increase in the organic phosphorus content of the yielded grains of stressed wheat plants was insignificant.

Grain priming with kinetin and / or spermine caused additional increase ($P \leq 0.05$) in all phosphorus fractions of the developed grains when compared with control plants.

Changes in ionic content :

It appeared from table 3 that seawater stress significantly increased ($P \leq 0.05$) Na^+, K^+ and Cl^- content of yielded wheat grains. Compared to controls, application of kinetin, spermine or their interaction generally increased ionic content in yielded grains of wheat plants irrigated with 25% seawater. Moreover, grain priming with these chemicals resulted in additional increase ($P \leq 0.05$) in the ionic content in yielded grains of stressed wheat plants.

In response to the applied seawater and the used chemicals, the grain yield was strongly correlated with all of the estimated yield criteria especially shoot length ($r = 0.96$), main spike length ($r = 0.96$), plant height ($r = 0.96$), main spike weight ($r = 0.89$), number of tillers per plant ($r = 0.87$), number of spikes per plant ($r = 0.91$), number of spikelets per main spike ($r = 0.80$), number of spikelets per plant ($r = 0.85$), number of grains per main spike ($r = 0.88$), number of grains per plant ($r = 0.99$), grain fresh mass ($r = 0.93$), grain dry mass ($r = 0.94$), 100-kernel weight ($r = 0.92$), biological yield ($r = 1$), straw yield ($r = 0.97$), crop yield ($r = 0.98$), crop index ($r = 0.86$), harvest index ($r = 0.87$), as well as relative grain yield ($r = 1$) and evapotranspiration efficiency ($r = 0.70$) for wheat plants. Furthermore, the grain yield was positively correlated with glucose ($r = 0.85$), sucrose ($r = 0.83$), total soluble sugars ($r = 0.87$), polysaccharides ($r = 0.96$), total carbohydrates ($r = 0.96$), ammonia nitrogen ($r = 0.97$), amino nitrogen ($r = 0.97$), amide nitrogen ($r = 0.91$), total soluble nitrogen ($r = 0.93$), total nitrogen ($r = 0.94$), protein nitrogen ($r = 0.92$), total protein ($r = 0.93$), DNA ($r = 0.98$), RNA ($r = 0.94$), proline (r = 0.91), citric acid (r = 0.94) and keto acids (r = 0.98) of yielded wheat grains. On the other hand, weak negative correlation was recorded for the ionic content (P^{+++}, Na^+, K^+ and Cl^-) of yielded wheat grains.

DISCUSSION

It is well documented that all yield components related to final grain yield are adversely affected by salinity (Hasamuzzaman *et al.*, 2009). Thus, in this investigation, irrigation of wheat plants with 25% seawater caused marked reduction in the yield and yield attributes of wheat plants (Table 1).

The results in table 1 showed that irrigation of wheat plants with 25% seawater caused noticeable decrease in shoot length, main spike length and plant height. This was in good agreement with the results of Islam *et al.* (2007). The recorded reduction in the estimated lengths in response to seawater stress could be explained by the fact that salinity may exert negative effect on plant elongation via its reverse effect on cell division, expansion and enlargement during the early growth stages (Hasamuzzaman *et al.*, 2009).

Perusal of data in table 1 revealed that the number of spikes and tillers per plant significantly decreased by the irrigation of wheat plants with 25% seawater. This may be due to the fact that the number of spikes per plant depends on tillering ability of the plant which is negatively affected by salinity (Hasamuzzaman *et al.*, 2009). These results were in accord with the findings of several researchers (Zeng and Shannon, 2000; WeonYoung *et al.* 2003).

Fertile spikelet is well documented to be an important contributory factor to grain yield (Hasamuzzaman *et al.*, 2009). Thus, the results in table 1 showed that seawater stress induced marked decline in the number of spikelets and grains per spike and also per plant. This may be attributed to the reduced spikele t fertility (the failure of grain set in its spikelet) in response to salt stress which may be caused by the lack or reduced pollen viability (Abdullah et al., 2001).

Seawater irrigation induced drastic reduction in grain biomass and 100-kernel weight (Table 1). Similar observations were recorded by Islam *et al.* (2007) and Hasamuzzaman *et al.* (2009). In this connection, Mass and Grieve (1990) mentioned that grain yield decreased as salinity increased by reducing grain number more than grain weight. In addition, salt stress may decrease the yield potential of different plants by reducing the number of tillers.

Grain yield of wheat plants is the ultimate product of almost all yield components which are inversely influenced by salinity levels. Under seawater stress, the loss of grain yield may result from a combination of reductions in plant stand, spikelet number per spike, spike length and fertility (Hasamuzzaman *et al.*, 2009). The reduced grain yield of stressed wheat plants may result from increased Na^+ uptake through root before flowering and its subsequent distribution in different vegetative and floral parts; especially in leaves where it causes leaf mortility and reducing transportation of total assimilates to the growing region (Munns, 2002).

Seawater stress also caused massive reduction in straw yield of wheat plants (Table 1). This result was in accordance with that obtained by Naeem and Muhammad (2006) who ascribed the decrease in straw yield due to salinity to poor water absorption caused by increased solutes in the soil solution. In addition to the direct toxic effects of Na^+ and Cl^-, the increase in ion concentration in the leaf cell sap may retard enzymatic processes. In this regard, Fitter and Hay (1981) postulated that increased straw yield may be due to increasing cell size and activating the enzymatic process.

The harvest index (the proportion of total shoot mass that is found in grain) can vary from 0.2 to 0.5, depending on the timing and severity of the salt treatment (Husain et al., 2003). In this investigation, seawater salinity reduced harvest, mobilization and crop indices of wheat plants (Table 1). Also, Dixit *et al.* (2004) observed that stressing wheat plants with different levels of salinity resulted in great reduction in the harvest index, and this reduction was found to increase with increasing the salt concentration. The decrease in harvest index with salinity may be due to the severe inhibitory effects of salts on fertility.

FAO publication number 56 (Allen *et al.,* 1998) provided a very important guideline for calculating crop evapotranspiration under water and salinity stresses. It was assumed that reduction in available water, either physical (drought) or physiological (salinity), may limit evapotranspiration and consequently reduce yield (El-Mesiry *et al.,* 2007). Irrigation of wheat plants with 25% seawater significantly reduced evapotranspiration efficiency (Table 1). Salts in the soil solution can reduce evapotranspiration by making water less available for plant root (Ouda, 2006). However, under saline conditions, many plants are able to compensate for low osmotic potential of the soil solution by building up higher internal solute contents (Ouda, 2006), and this may explain the improvement of evapotranspiration efficiency with the application of kinetin, spermine or their interaction, where it was found that these chemicals caused marked increase in osmotic pressure and different osmotically active metabolites in water extract of flag leaves of stressed wheat plants (unpublished data).

The reduction in wheat yield and yield components in response to seawater stress might be attributed to the inhibiting effects of salinity on plant growth due to the suppression of many metabolic processes including protein, nucleic acids and polyamine synthesis (Reggiani *et al.,* 1994), activity of mitochondria and chloroplasts (Singh and Dubey, 1995), decreasing transpiration, stomatal conductance and photosynthesis (Sharma, 1995), the toxic effects of certain ions present in soil solution and/or imbalance in phytohormone levels through its effects on either the biosynthesis or the destruction of the plant hormones (Nesiem and Ghallab, 1999). Shani and Dudley (2001) related the yield loss to reduced photosynthesis, high energy and carbohydrates expenses in osmoregulation and interference with cell functions under saline conditions.

Cytokinins are known to be involved in various processes of plant growth and development such as cell division, apical dominance,

Table 1: Effect of grain presoaking in kinetin, spermine or their interaction on yield and yield attributes of wheat plants irrigated with seawater.

Parameters / Treatments	Shoot length (cm)	Main spike length (cm)	Plant height (cm)	Main spike weight (g)	No of tillers / plant	No of spikes / plant	No of spikelets / main spike	No of spikelets / plant	No of grains / main spike	No of grains / plant	Grain yield / main spike (g)	Grain yield / plant (g)
Cont	50.83	13.80	64.63	3.68	2.33	2.00	15.33	28.00	41.67	75.67	2.47	3.70
SW	46.50	11.07	57.57	3.19	0.67	0.33	13.33	14.67	30.33	31.00	1.59	0.93
K	54.00	15.70	69.70	4.09	4.67	4.00	19.33	79.00	52.67	102.67	3.48	4.89
SW + K	51.33	14.07	65.40	3.46	2.67	2.33	15.67	38.00	42.67	72.33	2.52	3.60
Spm	52.83	14.83	67.67	3.94	4.00	3.33	17.33	65.33	45.33	93.00	2.86	4.26
SW + Spm	48.50	12.60	61.10	3.28	2.00	1.67	13.67	23.67	36.67	60.67	2.16	2.45
K + Spm	55.83	17.17	73.00	4.28	6.67	5.33	23.00	87.67	62.33	105.00	3.83	4.91
SW + K + Spm	51.83	15.13	66.97	3.60	3.00	2.67	15.67	37.67	42.33	83.00	2.45	4.03
LSD at P ≤ 0.05	1.18	0.46	1.27	0.11	0.69	0.76	0.98	5.81	3.70	14.45	0.21	0.28

Continued: Effect of grain presoaking in kinetin, spermine or their interaction on yield and yield attributes of wheat plants irrigated with seawater.

Parameters / Treatments	Grain biomass (mg)		100-kernel weight (g)	Biological yield / plant (g)	Economic yield / plant (g)	Straw yield / plant (g)	Crop yield / plant (g)	Mobilization index	Crop index	Harvest index	Relative grain yield (%)	Evapo-transpiration efficiency
	Fresh mass	Dry mass										
Cont	59.67	51.67	5.13	7.82	3.70	4.12	6.26	1.517	0.473	0.897	100.00	5.69
SW	54.67	46.67	4.72	3.28	0.93	2.35	3.19	1.357	0.283	0.395	25.16	5.64
K	65.00	57.67	5.66	9.86	4.89	4.97	7.59	1.526	0.496	0.983	132.28	6.87
SW + K	60.33	53.67	5.25	7.50	3.60	3.90	6.39	1.638	0.480	0.923	97.39	5.69
Spm	63.33	56.00	5.48	8.79	4.26	4.53	7.07	1.561	0.485	0.940	115.24	5.85
SW + Spm	57.00	49.00	4.88	5.13	2.45	2.68	5.62	2.096	0.478	0.915	66.37	5.63
K + Spm	68.00	60.33	5.91	9.84	4.91	4.93	8.30	1.682	0.499	0.995	132.82	6.88
SW + K + Spm	60.67	53.67	5.24	8.13	4.03	4.10	6.69	1.633	0.496	0.985	109.11	5.94
LSD at P ≤ 0.05	1.75	1.52	0.15	0.31	0.28	0.15	0.19	0.07	0.024	0.08	17..39	0.03

leaf senescence, stomatal behavior and chloroplast development (Brault and Maldney, 1999). Therefore, an adequate cytokinins supply is essential for normal plant development (Takei *et al.*, 2002). The results in table 1 indicated that application of kinetin, either alone or in combination with spermine, enhanced all yield components of stressed or unstressed wheat plants. In accordance with these findings, it was earlierly noticed that presoaking of wheat grains in phytohormones before subjection to salinity stress increased the plant yield (Salama and Awadalla, 1987; Farida *et al.*, 2003).

It is possible that under salt stress, the amount of naturally occurring cytokinins are suppressed; probably through the inhibition of their de novo synthesis, conversion from active to inactive or bound form, or the acceleration of their degradation (Iqbal and Ashraf, 2006). In addition, it was previously postulated that salinity stress could reduce cytokinins export from the plant root, where they are synthesized, into the shoot of most plants (Kuiper *et al.*, 1990). These two reasons may explain why the exogenous application of kinetin could alleviate the inhibitory effect of seawater stress on wheat yield.

An improvement in wheat productivity due to increased rates of photosynthates translocation from leaves to grains caused by hormone pretreatment had also been suggested by Aldesuquy and Ibrahim (2001). It was proposed that under salt stress conditions, the thickness of assimilate-conducting pathway is reduced, and leaves start behaving as sinks rather than sources (Arbona *et al.*, 2005). This causes inhibition of assimilate movement towards the developing reproductive organs, which might be the reason for the observed decrease in yield. On the other hand, these adverse effects of high salinity were alleviated by the hormone treatment, primarily by rejuvenation of sink potential and enhancement of the duration or rate of dry mass accumulation in developing reproductive organs (Shah, 2007).

Aldesuquy and Ibrahim (2001) proposed that hormones used during salt stress may reduce water loss rates and cause a concomitant increase in leaf water potential and carbon gain rates which are all reflected in the enhanced yield. Angrish *et al.* (2001) further assumed that the plant growth regulator induced salinity stress alleviation by a concomitant increase in the tissue nitrogen content and nitrate reductase activity.

Seed priming with cytokinins has been reported to have beneficial effects on wheat under salt stress (Iqbal and Ashraf, 2005; Iqbal *et al.*, 2006a). These findings indicated that relief of damage and restoration of normal conditions was maintained either partially or completely by application of kinetin. This recovery may be a consequence of several roles played by such hormones, which can cause triggering of the internal cellular metabolism and also induce alterations in the ratios of growth regulators (Younis *et al.*, 2003).

Polyamines play very important role in many physiological processes (related to yield quality) such as reproductive organ development, floral initiation and development, as well as fruit development and ripening (Bais and Ravishankar, 2002; Tiburcio *et al.*, 2002).

Therefore, the results clearly indicated that application of spermine was significant in ameliorating the adverse effects of seawater on yield and yield components of wheat plants irrigated with seawater at 25% (Table 1). Similar results were obtained by Iqbal and Ashraf (2005) and also by El-Bassiouny *et al.* (2008).

In this respect, Davies (1995) reported that polyamines play a critical role in different biological processes, including cell division, growth, somatic embryogenesis, floral initiation as well as the development of flowers and fruits. This could be explained by the fact that polyamines, and spermine with special concern, have the ability to increase the efficiency of solar energy conversion into different photosynthetic outputs which maximized the growth rate of wheat plant and consequently increased its productivity and yield components. In addition, spermine may exert a stimulatory effect on stressed or unstressed wheat plants through their role in increasing the endogenous phytohormones (in particular cytokinins) which in turn increase the yield components by breaking the apical dominance of wheat plants leading to the increase in flowering tillers and consequently the number of spikes and their weight and/or through increasing the assimilates and their translocation from leaves to spikes as the spike weight increased (El-Bassiouny *et al.*, 2008).

Hussein *et al.* (2006) reported that pea plants treated with putrescine gave the highest values of total pod yield and its components as compared with the control. Also, the lowest values were recorded with high level of salinity, and the plants treated with putrescine under salinity stress condition gave the best yield as compared with plants under salinity stress without putrescine spraying. They postulated that these results may be due to the role of putrescine as a growth regulator which promotes the plant growth and increasing photosynthetic pigments content of pea plants as well as increasing the endogenous phytohormones (IAA, GA3 and cytokinins) and decreasing ABA which turn on increasing the total pod yield and its components.

As an explanation to the ability of exogenously-applied polyamines to ameliorate the ill effects of salt stress, Liu *et al.* (2006) suggested that polyamines are highly protonated at a physiological pH, which favors electrostatic binding of polyamines to negatively charged components of membranes, leading to membrane stabilization through ionic interactions. In addition, polyamines may be effective in scavenging free radicals. Recently, several reports suggested that exogenous polyamines could activate the antioxidant systems, thereby controlling free radical generation and preventing membrane lipid peroxidation, which resulted in improved cell growth under stress (Tang and Newton, 2005; Verma and Mishra, 2005).

Generally, seawater stress resulted in marked reduction in carbohydrates, nitrogenous constituents, total protein, nucleic acids, proline and organic acids contents of the yielded wheat grains (Table 2). The reduction in different organic constituents of developed wheat grains in response to seawater stress may be attributed to the fact that salt stress could increase ABA levels in flag leaves which

Table 2: Effect of grain presoaking in kinetin, spermine or their interaction on carbohydrates content and nitrogenous constituents (mg^{-1} d wt) in yielded grains of wheat plants irrigated with seawater.

Parameters / Treatments	Carbohydrates content (mg g^{-1} d wt)					Nitrogenous constituents (mg g^{-1} d wt)						
	Glucose	Sucrose	Total soluble sugars	Polysaccharides	Total carbohydrates	Ammonia nitrogen	Amino nitrogen	Amide nitrogen	Nitrite nitrogen	Total soluble nitrogen	Total nitrogen	Protein nitrogen
Cont	0.53	13.03	15.56	704.69	721.50	2.96	3.22	2.72	0.041	14.60	20.81	6.21
SW	0.40	11.97	14.31	677.19	691.50	2.27	2.84	2.42	0.045	13.66	19.45	5.79
K	0.86	17.69	18.03	732.50	750.53	3.19	3.56	2.96	0.046	16.34	22.94	6.60
SW + K	0.55	13.58	15.97	704.84	720.81	2.99	3.27	2.60	0.049	15.22	21.55	6.33
Spm	0.73	16.92	17.84	721.09	738.94	3.07	3.42	2.90	0.044	15.45	21.73	6.28
SW + Spm	0.41	12.61	15.69	694.22	709.91	2.84	3.05	2.54	0.046	14.42	20.67	6.25
K + Spm	0.89	17.89	19.38	739.53	758.91	3.31	3.68	3.10	0.047	16.61	23.24	6.63
SW +K + Spm	0.54	13.81	16.47	714.69	731.16	3.04	3.32	2.75	0.048	15.72	22.09	6.37
LSD at $P \leq 0.05$	0.03	0.25	0.52	0.69	6.96	0.13	0.09	0.06	0.003	0.62	0.13	0.62

in turn induced stomatal closure and consequently decreased photosynthetic activity in flag leaves, this effect may result in a decrease in biochemical aspects of the yielded grains. Also, salinity stress may stimulate the early senescence in wheat flag leaf which may affect the translocation of photoassimilates to the developing grains. These results were in good accordance with those obtained by Elhakem (2008) and El-Sawy (2009).

Seed priming with kinetin and/or spermine appeared to alleviate either partially or completely the noticeable decrease in all biochemical aspects of yielded wheat grains in both stressed and unstressed plants (Table 2). Matching this, grain priming with kinetin increased carbohydrates and protein contents in yielded grains of stressed sorghum plants (Aldesuquy *et al.*, 2005). Moreover, Suleiman *et al.* (2002) and Zeid (2004) mentioned that putrescine application resulted in increased in the biosynthesis of nucleic acids, synthesis of macromolecules particularly protein and photosynthetic pigments.

The decrease in protein contents in yielded grains of stressed wheat plants may be due to less transport of protein from source (flag leaf) to the sink (grain). In support to this finding, water stress induced remarkable decrease in total protein of the flag leaf at heading stage (unpublished data). Application of kinetin under seawater salinity was found to synergistically increase seed protein content, being in accordance with the results of Aldesuquy and Ibrahim (2001) and Shah (2007). Hormone pretreatment is known to have a secondary enhancing effect on protein content through the intensification of nitrate reductase activity (Shah, 2004). Stimulation of the enzymes involved in protein synthesis by GA3 stimulates the overall protein synthesis (Premabatidevi, 1998).

Phosphorus, sodium, potassium and chloride levels in yielded wheat grains were increased in response to seawater stress (Table 3). These results match those obtained by Elhakem (2008) and El-Sawy (2009) working on wheat plants subjected to different types of stress. The increase in ionic content of developed grains is a logic consequence to the irrigation using seawater which is rich in different ionic components. This increase in ions level may result from transportation of these elements from root to shoot through the transpiration stream to the developing grains.

Application of kinetin and spermine caused additional increase in phosphorus, sodium, potassium and chlorides contents of yielded wheat grains (Table 3). As a similar trend, grain priming with kinetin increased ion contents in yielded grains of stressed sorghum plants (Aldesuquy *et al.*, 2005). Moreover, polyamines increased water uptake by root and consequently increased the uptake and translocation of Na^+, K^+ and Cl^- contents which were driven by transpiration (Alcázar *et al.*, 2006).

Table 3: Effect of grain presoaking in kinetin, spermine or their interaction on total protein, nucleic acids, proline, organic acids, phosphorus contents (mg g^{-1} d wt) and ionic content (mmole g^{-1} d wt) in yielded grains of wheat plants irrigated with seawater.

Parameters / Treatments	Total protein (mg g^{-1} d wt)	Nucleic acids (mg g^{-1} d wt)		Proline (mg g^{-1} d wt)	Organic acids (mg g^{-1} d wt)		Phosphorus content (mg g^{-1} d wt)			Ionic content (mmole g^{-1} d wt)		
		DNA	RNA		Citric acid	Keto acids	Inorganic	Organic	Total	Na^+	K^+	Cl^-
Cont	86.67	0.176	0.074	0.792	0.289	0.167	0.108	0.509	0.617	1.53	2.03	0.056
SW	81.46	0.160	0.068	0.714	0.258	0.140	0.164	0.530	0.695	1.69	2.59	0.085
K	89.84	0.184	0.081	0.896	0.336	0.180	0.159	0.533	0.693	1.62	2.54	0.075
SW + K	87.40	0.177	0.076	0.818	0.305	0.170	0.207	0.554	0.761	1.78	2.91	0.096
Spm	87.33	0.181	0.076	0.831	0.313	0.173	0.132	0.552	0.684	1.59	2.38	0.066
SW + Spm	86.98	0.164	0.070	0.779	0.281	0.160	0.190	0.540	0.730	1.73	2.76	0.094
K + Spm	89.97	0.185	0.082	0.948	0.328	0.187	0.150	0.541	0.692	1.65	2.67	0.080
SW + K + Spm	87.58	0.179	0.078	0.831	0.297	0.173	0.192	0.556	0.747	1.80	2.93	0.113
LSD at $P \leq 0.05$	0.50	0.003	0.003	0.028	0.018	0.014	0.022	0.028	0.032	0.08	0.42	0.010

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الملخص العربى

التأثير المخفف للكينيتين والإسبرمين على نباتات القمح المجهدة بماء البحر :

١- مكونـات الإنتـاج والسـمات الكيموحيويـة للحبوب الناتجـة من المحصـول

حشمت سليمان الدسوقى زكريـا عـوض بقـا برديس محمد مكى

قسـم النبـات - كلية العلـوم - جامعـة المنصـورة - مصـر

لقد أجريت تجربة أصص لتوضيح الدور الذى يلعبه نقع حبوب القمح صنف (سخا ٩٣) فى كل من الكينتين (١ر٠ ملى مول) أو الإسبرمين (٣ر٠ ملى مول) أو كليهما معاً فى تخفيف حدة الإجهاد الناتج عن الرى بماء البحر (٢٥٪) على إنتاجية نباتات القمح وكذلك السمات الكيموحيوية للحبوب الناتجة من المحصول، وأمكن الحصول على النتائج التالية :

١- أدى الرى بماء البحر إلى نقص ملحوظ فى إنتاجية نباتات القمح من خلال طول المجموع الخضرى، طول السنبلة الرئيسية، إرتفاع النبات، وزن السنبلة الرئيسية، عدد الأشطاء والسنابل لكل نبات، عدد السنيبلات والحبوب ووزنها لكل سنبلة رئيسية ولكل نبات، الكتلة الحية للحبة الواحدة ووزن مائة حبة وكذلك وزن القش، هذا بالإضافة إلى الإنتاج النسبى للحبوب وكفاءة النتح البخرى، وقد تبين أن المعاملة بالكينتين أو الإسبرمين أو كليهما تعمل على تحسين إنتاجية نباتات القمح موضوع الدراسة من خلال الزيادة المعنوية فى مكونات المحصول، وكان التأثير أكثر إيجابية مع المعاملة بالكينتين والإسبرمين معاً.

٢- اتضح أن رى نباتات القمح بماء البحر أدى إلى نقص معنوى فى محتوى الحبوب من السكريات العديدة والمواد الكربوهيدراتية، المواد النيتروچينية، البروتين، الأحماض النووية، البرولين والأحماض العضوية؛ بينما أدى إستخدام ماء البحر إلى زيادة ملحوظة فى كل من الفسفور العضوى والغير عضوى والكلى وكذلك أيونات الصوديوم والبوتاسيوم والكلور فى حبوب القمح الناتجة، كما أدى نقع الحبوب فى الكينتين أو الإسبرمين أو كليهما إلى زيادة واضحة فى كل السمات الكيموحيوية سالفة الذكر، وكان التأثير أكثر إيجابية مع المعاملة بالكينتين والإسبرمين معاً.

٣- تبين أن هناك إرتباطاً وثيقاً بين إنتاجية الحبوب ومكونات الإنتاج المختلفة وكذلك السمات الكيموحيوية للحبوب الناتجة (نسبة الارتباط تتراوح بين ٧ر٠ - ١).

JOESE 5

MITIGATORY EFFECT OF KINETIN AND SPERMINE ON SEAWATER-STRESSTED WHEAT (TRITICUM AESTIVUM) PLANTS : I- YIELD COMPONENTS AND BIOCHEMICAL ASPECTS OF YIELDED GRAINS

Aldesuquy, H. S.; Baka, Z. A. and Mickky, B. M.

Department of Botany, Faculty of Science, Mansoura University,, Egypt

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