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# EFFECT OF SOME GROWTH REGULATORS ON GROWTH AND PRODUCTIVITY OF MAIZE UNDER WATER STRESS CONDITIONS.

**Abdel-Ati, A. A.*; S. S. Eisa** and Kawthar A. E. Rabie ****

*** Plant Production Dept., Desert Res. Center, El Matareya, Cairo, Egypt.**

**** Agric.Botany Dept., Ain Shames Univ., Shobra El-Khema- Cairo, Egypt.**

## ABSTRACT

Two field experiments were performed during summer seasons of years 2005 and 2006 at El-Nuparia district, the desert backyard of El-Behera Governorate, to investigate the response of maize plant (*Zea mays* L.) hybrid of 30B9 to different growth regulators; Abscisic acid (ABA) at 30 and 50 ppm, Ethephon at 300 and 500 ppm and Cycocel (CCC) at 400 and 600 ppm, under different water stress treatments, which included missing only one irrigation in each water stress treatment after (El-mohayah irrigation) 10 days after germination i.e., the $2^{end}$ irrigation, the $3^{rd}$ irrigation or the $4^{th}$ irrigation beside the normal irrigation as a control treatment.

Results indicated maize plants can tolerate water stress at the vegetative growth period (60 days). Missing the fourth followed by the third irrigation treatment seemed to produce more aggressive water stress for maize plants rather than those produced when missing the second and normal irrigation, respectively.

Spraying growth regulators i.e. (ABA, Ethephon or CCC) on maize plants reduced significantly plant height, fresh weight and leaf area as compared to the control treatment. Vice versa, it increased significantly plant dry weight, number of leaves, total pigments, chlorophyll, free proline, endogenous abscisic acid, osmotic pressure, ear weight, number of grains, 100 grain weight, and both biological and grain yields as compared with the control treatment. Superior results were obtained by applying the higher concentrations of ABA and CCC, and lower concentration of Ethephon compared with the other treatments.

Under normal irrigation conditions, it is not recommended to spray any of the studied growth regulators on maize plants for its negative effects on plant growth, productivity and chemical composition. While, under water stress conditions, applying growth regulators increased the plant tolerance to water stress which led to produce appreciated yields under these conditions after improving the physiological adaptation to water stress, yet, growth characters was declined. Higher observations under severe water stress conditions were obtained from applying abscisic acid, ethephon then cycocel at the higher concentrations, respectively.

**Keywords:** maize, global change, drought, water stress, growth regulators, Abscisic acid, Ethephon, Cycocel , growth characters, total pigments, chlorophyll, ABA, proline, osmotic pressure, biological and grain yield, yield components.

## INTRODUCTION

Drought exists as a result of Global Change which includes serious increment of earth temperature. Therefore, increases the evapo-transpiration rate compared with irrigation water requirement, and thus produces unexpected water stress for several strategic crops at certain growth stages, to decline its growth and productivity, particularly if water stress exists at a critical period of plant growth stage (Wilhite, 2000).

The critical period of plant growth usually starts at the time when reproductive organs are formed, and then pollination and fertilization take place. So it is essential that, each unit of water is used effectively and equitably at these periods (Lawrence 2001). If were taken the bad impacts of the Global Change on crops growth and productivity into consideration, its clear that these bad impacts are always magnified in the new reclaimed lands, where several environmental factors are stressing the plants, yet water is a main stressful and limiting production factors for several strategic crops (Tuner, 1979).

Maize is considered as a very sensitive crop to water stress especially at the reproductive phase. It can tolerate water stress in the vegetative growth period compared with the other growth periods. The total water stress sensitive period equals the last 55 days of the plant growth (Wenmad and Shaw, 1960; Norwood and Dumler, 2001; Nathan *et al.,* 2005 and Abdel-Ati, 2006).

In Egypt, maize plant is one of the main grain crops. During the last decade it became one of the most important goals of the Egyptian government to increase maize production to face the parallel essential needs of both human food and animal feed. In this respect, continuous extension efforts has been made on both horizontal and vertical levels, facing several environmental challenges including higher temperature, sunshine and evapo-transpiration, thus less relative humidity, and therefore water stress which magnifies if irrigation water scarcity is presented (Abdel-Ati, 2006).

Providing physiological adaptation for the stressed plants may play as a key role to facilitate the successful growth and production under these stressful conditions. Growth retardants is one of the growth regulators groups that control plant growth and productivity. It works as gibberellins inhibitor, so that retarding the growth meanwhile providing the physiological adaptation under stress conditions. It encourages the plant adaptation pathway, by encouraging the osmotic regulations, stomatal closer, reducing the transpiration, synthesis of stress proteins and modifying the repetitive DNA, then DNA confirmation, to produce the genetic adaptation at the end (Lashbrook, 2002). In other words, the plant environment is no longer stressing when growth regulators are presented in suitable endogenous concentration. ABA and Ethylene are well known as natural growth regulators that provide physiological adaptation under stress conditions (Lashbrook , 2002), meanwhile CCC (2-Chloroethyltrimethylammonium Chloride) is one of the synthetic growth regulators that provide physiological adaptation, in the meantime it was remarkable by its slight bad effects on environment, so that it should be handled with care, alike all the synthetic materials which is widely used at commercial level (Anonymous, 2000, 2003 and Lashbrook , 2002).

This study aimed to evaluate the enhancement of maize growth and productivity under water stress conditions as one of the Global Change elements, as a result of using different growth regulators to provide the physiological adaptation needed under these conditions, which normally exists in the new reclaimed areas in Egypt, where the water resources are very limited.

# MATERIALS AND METHODS

Two field experiments were conducted during summer seasons of 2005 and 2006 at El-Nuparia district, the desert backyard of El-Behera Governorate, to investigate the response of maize plant (*Zea mays* L. var. 30B9) to different growth regulators i.e.{ water as a control treatment, Cycocel (CCC) (2- Chloroethyltrimethylammonium Chloride) at 400 and 600 ppm, Ethephon (2-chloroethylphoshonic acid) as Ethylene producer at 300 and 500 ppm , and Abscisic acid (ABA) at 30 and 50 ppm} (Anonymous 2002, 2003); which were sprayed on plants one week before starting each of the water stress treatments. The different water stress treatments included missing only one irrigation after El-mohayah irrigation 10 days after germination i.e.,{the $2^{end}$ irrigation (15 days after El-mohayah irrigation), the $3^{rd}$ irrigation in (30 days after El-mohayah irrigation) , which matched the early juvenile period of plant growth, or the $4^{th}$ irrigation (45 days after El-mohayah irrigation), which matched the end of the juvenility and the starting of maturity periods } beside the normal irrigation as a control treatment.

The experimental sandy soil was tilled, and then calcium superphosphate (15.5% $P_2O$) was added to the soil in the rate of 200 kg/fed along with 20 $m^3$/fed of balady compost during soil preparation. While nitrogen fertilization was added as ammonium nitrate 33.5% N in the rate of 120 kg N/fed., and potassium fertilization was added as potassium sulfate 40% $K_2O$ in the rate of 24 kg $K_2O$/fed., both in two equal dosages were added before the first and second irrigation. Maize hybrid of Pioneer 30B9 were planted in hills at 25 cm distance on $15^{th}$ April at the rate of 15 kg/fed. in the two seasons.

Split plot design in three replicates was used in this experiment, where water stress treatments occupied the main plots, while the growth regulators treatments arranged in the sub-main plots. The experimental plot area was 12 $m^2$ (3 × 4 m) including 6 ridges at 60 cm. The experimental soil chemical and physical properties are presented in tables (1 and 2).

**Table 1: Mechanical properties of El-Nuparia experimental soil (mean of 2005 and 2006 seasons):**

| O.M | Particle size distribution (mm) | | | | |
|---|---|---|---|---|---|
| | Course Sand | Fine Sand | Silt | Clay | Class texture |
| 0.33 | 28.18 | 39.25 | 18.27 | 14.18 | Sandy |

**Table 2: Chemical properties of El-Nuparia experimental soil (mean of 2005 and 2006 seasons):**

| pH | Ca Co3 % | E.C $dsm^{-1}$ | Saturation soluble extract | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Soluble anions (meq/L.) | | | | Soluble cataions (meq/L.) | | | |
| | | | $CO^{-3}$ | $HCO^{-3}$ | $SO^{-4}$ | $CL^{-}$ | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ |
| 7.6 | 17.28 | 0.94 | - | 3.18 | 2.75 | 4.32 | 3.1 | 1.77 | 4.22 | 0.19 |

Samples of ten individual guarded plants were taken from each replicate, two weeks after applying the fourth irrigation to study some growth characters i.e. plant height (cm/plant), fresh and dry weights (g/plant), the fourth upper expanded leaf area ($cm^2$) (using "Li-3000 A" portable leaf area meter), number of leaves/plant. While samples of chemical composition were taken from the upper fourth expanded leaf to determine total pigments using SPDA-502 leaf chlorophyll meter, then converted into chlorophyll (a + b) as µ mole $m^{-2}$ referring to the equation published by John *et al.,*(1988), free proline as (µ mole proline / g dry weight) using the method described by Bates (1973), Abscisic acid (µ mole / g dry weight) using the bioassay technique following the method published by Zeevart (1971) after extracting the endogenous phytohormones in ethyl-alcohol 70% using the method described by Lenton *et al.,* (1975) and Osmotic pressure (bar/ $cm^2$) after determining the cell sap concentration using the refractometer then converting it to osmotic pressure using special conversion tables as described by Gosev (1960).

Similarly, yield and its components were evaluated at harvest time i.e. ear weight (g), number of grains/ear, seed index (as 100 grain weight/g), biological and grain yield (ton/fed.).

Data of all parameters were exposed to the proper statistical analysis of variance according to the ANOVA procedure given by Snedecor and Cochran (1967). After passing the homogenizing test for data of both years, the combined analysis was done following Waller and Duncan (1969). Duncan's multiple range tests was used to verify the significant differences between means of treatments as described by Duncan (1955).

## RESULTS

### Effect of water stress

Results in table 3 indicated that regarding all the studied characters, normal irrigation treatment gave the highest values comparing to the other water stress treatments i.e. (missing the $2^{nd}$, $3^{rd}$ or $4^{th}$ irrigation) respectively. Missing the $2^{nd}$ irrigation produced 14.8% reduction in the grain yield, while it was 33.3% and 48.1% reduction in case of missing the $3^{rd}$ and $4^{th}$ irrigation, respectively compared to the normal irrigation treatment (control).

Plants under water stress showed significant reduction in all studied growth characters i.e. plant height, fresh and dry weights, leaf area and number of leaves. Similarly, all studied characters of yield and its components i.e. ear weight, number of grains per ear, 100 grain weight, biological and grain yields. Likewise, total pigments and chlorophyll contents were reduced significantly in plants under water stress. On the contrary, the endogenous content of abscisic acid and free proline were increased significantly which cause the increase of osmotic pressure significantly as well, in order to provide the osmotic adjustment needed to mitigate the water stress.

T3-4

It could be understood that, irrigation is a main limiting factor for maize growth, development and productivity. Therefore, plants represented normal growth and productivity under normal irrigation conditions, and could compensate water stress unless it harmonies the reproductive stage. In another words, the elder the plant the hazardous effects of water stress on maize growth, development and productivity.

**Effect of growth regulators**

Results in table 4 showed that spraying growth regulators i.e. (ABA, Ethephon or CCC) on maize plants reduced significantly plant height, fresh weight and leaf area as compared with control treatment. Vice versa, it increased significantly both plant dry weight and number of leaves.

Likewise, higher endogenous concentrations of total pigments, chlorophyll, free proline, abscisic acid and osmotic pressure were obtained by applying the growth retardants treatment. Similarly, ear weight, number of grains, 100 grain weight, and both biological and grain yields were increased significantly compared with the control treatment.

Among the growth regulators treatments, applying the higher concentrations of ABA and CCC, and lower concentration of Ethephon gave in general the higher values of yield and yield components, followed by applying the higher concentration of Ethephon, lower CCC and ABA concentrations, respectively. ABA at 50 ppm concentration seemed to be the superior with no significant difference among the other treatments, which provided valued physiological adaptation, to produce an appreciated yield.

**Effect of the interaction between growth regulators and water stress**

Results in table 5 indicated that, under normal irrigation treatment, when water stress is absent spraying growth regulators at any concentration, led to decrease significantly maize growth characters i.e. plants height, fresh and dry weights, leaf area and number of leaves. Similarly, yield and its components i.e. ear weight, number of grains per ear, 100 grain weight, and both biological and grain yields. On the other hand, it increased significantly each of total pigments and chlorophyll content, proline, abscisic acid and osmotic pressure as compared with spraying water as a control treatment. Higher reduction in most of the studied characters was obtained by spraying ABA in the concentration of 50 ppm compared with the other growth regulators treatments.

When missing the second irrigation, applying the growth regulators on the water stressed maize plants provided the physiological adaptation needed to succeed in growth, development and productivity. Using growth regulators accompanied with missing the 2$^{nd}$ irrigation may lead to reduce plant height, fresh weight, and leaf area, compared with the control treatment but insignificantly in most cases. Nonetheless, it was talented to increase significantly total pigments and chlorophyll, dry weight, proline and abscisic acid content, and osmotic pressure. The latter may provide the osmotic regulation needed to increase ear weight, number of grains per ear, 100 grain weight, and both biological and grain yields, as compared to the control treatment.

T5

Under the relentless water stress when missing the 3rd or the 4th irrigation, the observations of the control treatments indicated that, maize plant defy drought at a very critical growth stages, demonstrated by significant decline in plant growth, higher total pigments and chlorophyll content plus endogenous concentration of ABA, proline were observed as well, therefore osmotic pressure was increased. Hitherto, the highly significant dwindle in the yield and its components. Accordingly, plants dependent on its endogenous physiological adaptation to mitigate such aggressive drought is a big fake. Hence, providing such needed physiological adaptation by spraying the growth regulators into the stressed maize plants is essential, confirmed by the improvement happened in plant dry weight, total pigments, chlorophyll, ABA, proline contents, combined with higher osmotic pressure, which led to elevate yield and its components under such stressful conditions compared to the control treatments. Concerning the grain yield, results indicated that, when missing the 3rd irrigation, higher observations but in no significant differences obtained by using ABA at the concentration 50 ppm followed by 300 ppm concentration of Ethephon then CCC at the concentration 400 ppm respectively. However, higher grain yield was achieved by using it was 600 ppm of CCC followed by 50 ppm of ABA then 500 ppm of Ethephon respectively in the case of missing the 4th irrigation in no significant differences as well.

## DISCUSSION

The Global Change has become one of the main challenges that corrupted human life on earth particularly food security in the new era. This change normally accompanied by critical events of global weather, including critical increment of earth temperature, thus producing unexpected different types of drought cycles in many places, mostly in the new reclaimed lands where the water always is a limiting production factor (Wilhite,2000).

When Global Change exists, date of sowing and zonal agricultural belts of many strategic crops may change to face the unfavorable conditions of such critical events of the global weather. Some crops will not be capable to produce appreciated yields, some varieties will not be adapted to tolerate these stresses and will be disappeared, and many important genera will be sensitive enough to be vanished. If we take into consideration the virtual growth of human population in comparison to the decline happened in the world cultivated areas, global change will be considered as a global warning of famine and death (Tuner, 1979 and Wilhite, 2000).

In the new reclaimed areas many aggressive sequenced types of drought are existed, i.e. metrological, agricultural then hydrological and each has its own consequenced impacts, which plunks the plant with several challenges. Nevertheless, the impacts of the man made drought which called socioeconomic drought exceed the impacts of the other types of drought together, particularly if it happens in a plant sensitive water stress growth stage. The latter is incarnate the failure of providing the irrigation water for several reasons all are man made, yet, the irrigation water is available but not accessible.

As it well known, maize plant is a very sensitive crop to water stress especially at the reproductive phase. Plants can tolerate the water stress in the vegetative growth period compared with the other growth periods (Wenmead and Shaw, 1960 and Abdel-Ati, 2006).

Results indicated, three irrigation treatments out of four were in the vegetative growth, while the fourth one lied between both of the end of the vegetative growth and the beginning of the reproductive growth period. In another words the first three irrigation treatments were done in the juvenile period, while the fourth one was in the beginning of maturity.

Many investigators indicated that plants in juvenility can tolerate and overcome the bad effects of the unfavorable growth conditions such as water stress, salinity or even heat stress rather than those in maturity. Plants in juvenile have high concentration of growth promoters such as IAA, $GA_3$ and CKs, which helps significantly in compensating any decrease may happened in photosynthesis pathway, water and minerals absorption therefore, the plant metabolism as a result of increasing the endogenous levels of growth regulators such as Ethylene and ABA which reach the inhibition levels when severe water stress occurs. (Lashbrook, 2002; Muhammad Ijaz, 2005; Nathan *et al.*, 2005 and Abel-Ati, 2006)

Similarly, at maturity plants generally have high concentrations of the inhibitors comparing with the promoters; the way it encourages assimilates transportation from sources to sinks accompanied with recognizable decay in plant growth and metabolism, to reach early the end of life cycle by producing the fruity parts (Devieln, 1969; Setter *et al.,* 2001; Wang *et al*., 2002; Yiwei and Huang, 2002; and Mahdi and Xinhua, 2005). This can clarify the results obtained in this study when taking into consideration the bad effects of water stress on maize plant growth, chemical composition and yield and its components, especially at the end of the juvenility when compared with the early juvenile growth period (Setter *et al.,* 2001; and Abdel-Ati, 2006) Until genetic scientists published new varieties of strategic crops that adapted to these new environmental challenges, special and intensive efforts of physiologists should be made to provide temporary adaptation in certain growth stages to compensate these stresses hazard impacts on growth and development of such strategic crops. Breeders should not only relay on few screening tests but think in terms of physiological processes related to tolerance. Also, physiologists should keep in mind the integrated behavior of the whole plant rather than isolated processes. Taking into consideration the plant hormonal balance under stress conditions, compared with its balance under normal conditions is a very important subject when studying the plant physiological response to environmental stress such as drought (Tuner, 1979; and Lawrence, 2001).

Drought resistant plant species or varieties seem to accumulate higher content of abscisic acid (ABA) and Ethylene compared with those sensitive ones. ABA is well known as the stress hormone that controls the entire plant metabolism under water stress conditions, which retard plant growth, and drive it to mature earlier than it should be, producing an appreciated yield as described by Amzallag and Lemer (1995). They added that Ethylene may play as a motive for ABA accumulation besides its remarkable role in plant maturity. Yet, the higher resistant plants are capable to increase endogenous ethylene emission, consequently, accumulate ABA faster than the other sensitive species, under stressful conditions, and when stress period is ended they are capable to reduce ethylene and ABA content along with increasing growth promoters such as auxines, gibberellins and cytokinines (Shatters *et al.,*1998; Setter *et al.,* 2001; Lashbrook, 2002; Wang *et al*., 2002; and Yiwei and Huang, 2002).

To understand the physiological adaptation mechanism made by growth regulators under stress conditions, it could be concluded that it plays as gibberellins inhibitor, therefore increase the plant root / shoot ratio, and encourage the osmotic regulations by synthesis of stress proteins which are rich in amino acids such as proline, in order to enhance stomatal closer, reducing the transpiration, modifying the repetitive DNA, then DNA confirmation, to produce the genetic adaptation at the end. In other words, the plant environment is no longer stressing when growth inhibitors are presented in suitable endogenous concentration. ABA and Ethylene are well known as natural growth substances that provide physiological adaptation under stress conditions (Shatters *et al.,*1998; Setter *et al.,* 2001; Wang *et al*., 2002; Yiwei and Huang, 2002 and Anonymous, 2003 ), meanwhile Cycocel is one of the synthetic growth regulators that provide physiological adaptation with showing slight toxic effects on the environments alike all the synthetic chemicals widely used at the commercial level (Anonymous,2000 and 2003) , mean while it is not recommended to use such synthetic material if alternative is available to safe the environment from pollution even it was economically reasonable, yet, it was used only in this work as a comparison substance for its remarkable as stress relief substance.

Perhaps growth regulators in a limited endogenous concentration can provide the physiological adaptation needed to relief the pressure from the water stressed plants, however, if it exceeded the permitted endogenous concentration, it terns to be plant growth inhibitors , the way it becomes more hazardous to the plant than the water stress itself. Therefore, it should be handle commercially in an intensive care, with full understand of its recommended dosage and mode of action. (Lashbrook, 2002)

## CONCLUSION

It could be concluded from this study that water stress produced significant reduction in the grain yield ton/fed by 14.8 % and 33.3% when missing the 2nd or 3rd irrigation, respectively; while it produced 48.1% reduction in the grain yield when missing the 4th irrigation, compared to the grain yield under normal irrigation conditions.

Applying ABA at 50 ppm and CCC at 600 ppm was capable to overcome the reduction happened in grain yield when missing the 2nd irrigation and produce 74% of the normal yield. When missing the 3rd irrigation, ABA at 50 ppm, Ethephon at 300 ppm and CCC at 400 ppm were capable to produce 61% of the normal yield. Under severe water stress conditions in case of missing the 4th irrigation, ABA at 50 ppm, Ethephon at 500 ppm and CCC at 600 ppm were talented to produce 48% of the grain yield under the normal conditions.

This study could be considered as preliminary physiological step on the way of breeding maize for multiple environmental stresses. Genetic engineering scientists can identify the gene which responded to the growth regulators application, and provided the water stress tolerance to maize. Hence, drought resistant maize cultivars can come true in the near future.

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## تأثير بعض منظمات النمو علي نمو و إنتاجية الذرة الشامية تحت تأثير ظروف الإجهاد المائي

**أحمد عبد العاطي أحمد* ، سيد شعبان عيسي ** ، كوثر إمام علي ربيع****

*** قسم الإنتاج النباتي – مركز بحوث الصحراء – المطرية - القاهرة - مصر**

**** قسم النبات الزراعي –كلية الزراعة – جامعة عين شمس - شبرا الخيمة – القاهرة – مصر**

أقيمت تجربتان حقليتان خلال الموسمين الصيفيين ٢٠٠٥ ، ٢٠٠٦ علي الترتيب ، بمنطقة النوبارية، الظهير الصحراوي لمحافظة البحيرة ، وذلك لدراسة إستجابة نبات الذرة الشامية للهجين بيونير ٣٠ ب ٩وذلك للمعاملة ببعض منظمات النمو وهي كالتالي ( حامض الأبسيسيك بتركيز ٣٠ ، ٥٠ جزء في المليون ، الإيثيفون بتركيز ٣٠٠ ، ٥٠٠ جزء في المليون ، و السيكوسيل بتركيز ٤٠٠ ، ٦٠٠ جزء في المليون ) ، وذلك تحت تأثير معاملات إجهاد مائية مختلفة والتي تضمنت حرمان رية واحدة في كل معاملة بعد (رية المحاياة ) والتي تعطي للنبات بعد حوالي عشرة أيام بعد الإنبات كالتالي ( حرمان الرية الثانية أو الثالثة أو الرابعة بالإضافة إلي الري العادي كمعاملة مقارنة).

أظهرت النتائج أن نبات الذرة يمكن له مجابهة الإجهاد المائي خلال فترة النمو الخضري من عمره والتي تبلغ إلـ ٦٠ يوماً الأولي من عمر النبات. و أظهرت النتائج أن حرمان الذرة من الرية الرابعة أو الثالثة علي الترتيب قد أحدث إجهاداً مائياً شديداً لنبات الذرة أكثر من حرمان النبات من الرية الثانية أو الري بشكل طبيعي (معاملة المقارنة) علي الترتيب.

أدي الرش بمنظمات النمو (حامض الأبسيسيك ، الإيثيفون ، السيكوسيل) علي نبات الذرة إلي إنخفاض معنوي في إرتفاع النبات ، الوزن الغض للنبات ، ومساحة الأوراق مقارنة بمعاملة المقارنه. إلا أنها قد أدت إلي زيادة معنوية في الوزن الجاف للنبات ، و محتوي النبات من الصبغات الكلية و الكلوروفيل و البرولين ، والتركيز الداخلي من حامض الأبسيسك ، إضافة إلي الضغط الأسموزي. كما أدت إلي زيادة معنوية في وزن الكوز ، عدد حبوب الكوز ، وزن المائة حبة ، وكذلك محصولي الحبوب و البيولوجي قياساً بمعاملة المقارنة. وقد تم التوصل إلي أفضل النتائج من المعاملة بالتركيزات المرتفعة من حامض الأبسيسك و السيكوسيل ، إضافة إلي التركيز المنخفض من الإيسيفون قياساً بباقي المعاملات.

أظهرت النتائج أنه تحت ظروف الري العادي ، لا يجب رش نبات الذرة بأي من منظمات النمو المستخدمة في البحث لتأثيراتها السلبية علي نمو النبات و إنتاجيته و التركيب الكيميائي الداخلي له. بينما تحت ظروف الإجهاد المائي ، أدت المعامله بمنظمات النمو المستخدمة إلي زيادة أقلمة النبات للإجهاد المائي ، والتي أدت إلي إنتاج محصول مناسب تحت هذة الظروف نتيجة للتطور الذي حدث في فسيولجي التأقلم للإجهاد المائي بالنبات ، علي الرغم من كون ذلك مصحوباً بنقص معنوي في صفات النمو النباتية الأخري. وقد تم التوصل إلي أفضل النتائج من المعاملة بالتركيزات المرتفعة من حامض الأبسيسك ، ثم الإيثيفون ثم السيكوسيل علي الترتيب.

وتوصي هذة الدراسة بعدم تعريض نبات الذرة الشامية للإجهاد المائي خاصة بعد فترة النمو الخضري ، أما إذا حدث الإجهاد المائي لظروف ما فإن الرش بإحدي المركبين حامض الأبسيسك أو الأثيفون بتركيزات ٥٠ ، ٥٠٠ جزء في المليون علي الترتيب خاصة قد يحد معنوياً من النقص الحادث في المحصول نتيجة لذلك.

**Table 3: Effect of Irrigation treatments on maize growth, chemical composition, yield and its attributes (combined analysis of 2005 and 2006 growing seasons).**

| Studied Characters | Irrigation Treatments | | | |
|---|---|---|---|---|
| | Normal Irrigation | Missing 2end irrigation | Missing 3rd irrigation | Missing 4th irrigation |
| **Growth Characters :** | | | | |
| Plant height (cm) | 190 A | 175.9 B | 164.7 C | 148.9 D |
| Fresh weight (g / plant) | 702.93 A | 514.51 B | 405.28 C | 308.17 D |
| Dry weight (g / plant) | 130.11 A | 94.27 B | 71.57 C | 49.87 D |
| Leaf Area ($cm^2$) | 424.4 A | 360.5 B | 305 C | 236.6 D |
| Number of leaves /plant | 14.6 A | 12.6 B | 11.3 C | 10.1 D |
| **Chemical Composition :** | | | | |
| Total pigments | 44.1 A | 39.9 B | 35.1 C | 30.1 D |
| Chlorophyll µ mole $m^{-2}$ | 615.9 A | 517.7 B | 417.9 C | 330.7 D |
| Proline (µ mol/ g dry.weight) | 17.6 D | 29.3 C | 37.6 B | 49.6 A |
| Abscisic acid (µ mol/ g dry. weight) | 7.2 D | 23 C | 50.8 B | 80.7 A |
| Osmotic pressure (bar/ $cm^2$) | 21.4 D | 31.4 C | 33.5 B | 35.1 A |
| **Yield and Its Components :** | | | | |
| Ear weight (g) | 284.6 A | 239.7 B | 191.2 C | 148.4 D |
| No. grains / ear | 442 A | 372.8 B | 303.7 C | 205.1 D |
| 100 grain weight (g) | 227.7 A | 191.7 B | 152.9 C | 118.8 D |
| Biological yield T/fed | 6.7 A | 5.4 B | 4.2 C | 3.2 D |
| Grain yield T/fed | 2.7 A | 2.3 B | 1.8 C | 1.4 D |

**Means having the same capital letters in the same row are not significantly differed at P≥ 0.05**

**Table 4: Effect of Growth regulators treatments on maize growth, chemical composition, yield and its attributes (combined analysis of 2005 and 2006 growing seasons).**

| Studied Characters | Growth Regulators Treatments | | | | | | |
|---|---|---|---|---|---|---|---|
| | Control (Water) | ABA 30 ppm | ABA 50 ppm | Ethephon 300 ppm | Ethephon 500 ppm | CCC 400 ppm | CCC 600 ppm |
| **Growth Characters :** | | | | | | | |
| Plant height (cm) | 176.4A | 170 C | 161.9 E | 173.8 B | 167.7 D | 172.4 B | 167.1 D |
| Fresh weight (g / plant) | 559.7A | 476.3 D | 410.3 F | 530.3 B | 458.7 D | 503.7 C | 440.2 E |
| Dry weight (g / plant) | 85.18C | 87.12 B | 87.03 B | 84.08 C | 89.95 A | 84.27 C | 87.58 B |
| Leaf Area ($cm^2$) | 369.7A | 327.6 D | 301.4 F | 349.5 B | 321.3 DE | 337 C | 314.9 E |
| Number of leaves /plant | 11.9 B | 12 B | 12.1AB | 12.1 AB | 12.3 A | 12.3 A | 12.3 A |
| **Chemical Composition :** | | | | | | | |
| Total pigments | 34.9 D | 38.3 A | 38.2 A | 37 C | 37.7 ABC | 37.2 BC | 37.8 AB |
| Chlorophyll µ mole $m^{-2}$ | 428.2D | 493.3 A | 484.2AB | 466.9 C | 474.7 BC | 471.1 C | 475.4BC |
| Proline (µ mol/ g dry. weight) | 28.3 G | 32.9 D | 39.5 A | 29.6 F | 35.3 C | 31.1 E | 37.9 B |
| Abscisic acid (µ mol/ g dry. weight) | 30.8 G | 39.3 D | 50.4 A | 33.5 F | 44 C | 37.4 E | 47.7 B |
| Osmotic pressure (bar/ $cm^2$) | 9.7 G | 30.7 D | 50.2 A | 17 F | 38.1 C | 24.4 E | 42.3 B |
| **Yield and Its Components :** | | | | | | | |
| Ear weight (g) | 209.2C | 213.6BC | 219.8 A | 218.6 AB | 216.1 AB | 216.7AB | 218 AB |
| No. grains / ear | 308.1C | 324.6 B | 341.3 A | 337.1 A | 333 AB | 335.6 A | 337 A |
| 100 grain weight (g) | 167.4C | 170.9BC | 175.9 A | 174.9 AB | 172.9 AB | 173.4AB | 174.4AB |
| Biological yield T/fed | 4.75CD | 4.70 D | 4.96 AB | 4.92 AB | 4.85 BC | 4.90 B | 5.02 A |
| Grain yield T/fed | 2.00 C | 2.05 BC | 2.11 A | 2.09 AB | 2.07 AB | 2.08 AB | 2.09 AB |

**Means having the same capital letters in the same row are not significantly differed at P≥ 0.05**

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**Table 5: Effect of the interaction between irrigation and growth regulators treatments on maize growth, chemical composition, yield and its attributes (combined analysis of 2005 and 2006 growing seasons).**

| Treatments | | Studied characters | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IRR | GR | Plant height /cm | Fresh weight (g/ plant) | Dry weight (g/ plant) | Leaf area ($cm^2$) | No. leaves /plant | Total pigm. | Chloro -phyll μ mole $m^{-2}$ | Proline (μ mol/ g d .w) | Abscisic (μ mol/ g d .w) | O. P. ( bar/ $cm^2$) | Ear weight (g) | No. grains / ear | 100 grain weight (g) | Bio yield T/fed | Grain Yield T/fed |
| Normal Irrigation | Control(Water) | 199.5A | 874.4A | 159.5A | 507.1A | 17.2A | 43.6BC | 602.4D | 12.18Y | 3.46U | 6.1W | 334.6A | 520.9A | 267.6A | 7.82A | 3.21A |
| | ABA 30 ppm | 189.4C | 674.9D | 129.6D | 409.8D | 13.6DE | 47A | 687.6A | 18.15V | 7.22S | 21.3R | 267DE | 409.4DEF | 213.7DE | 6.17DE | 2.56DE |
| | ABA50 ppm | 183.4DE | 607.4F | 110G | 383.7EF | 13.4DEF | 41.9DEF | 562.3E | 22.18S | 10.83QR | 36.9J | 261.8E | 407.3EF | 209.5E | 5.98E | 2.51E |
| | Ethephon300 ppm | 195.2B | 771.9B | 139.4B | 450.3B | 14.8C | 46.1A | 664.4B | 14X | 4.83TU | 10.8V | 284.8C | 446.1BC | 227.9C | 6.96B | 2.73C |
| | Ethephon500 ppm | 185.3D | 650DE | 122.1E | 399.9D | 13.9D | 43.2CD | 591.9D | 19.47U | 8.18S | 30.2N | 270.3DE | 414.9DE | 216.3DE | 6.28D | 2.59DE |
| | CCC400 ppm | 192.7B | 722.7C | 132.7C | 425.4C | 15.6B | 44.8B | 632.7C | 16.24W | 6.82ST | 17.8T | 297.1B | 464.1B | 237.7B | 7.18B | 2.85B |
| | CCC 600 ppm | 184.5D | 619.4EF | 117.5F | 394.6DE | 13.9D | 42.2DE | 569.9E | 20.78T | 9.07RS | 26.5P | 276.9CD | 431.3CD | 221.5CD | 6.63C | 2.66CD |
| Missing 2end irrigation | Control(Water) | 180.4EF | 569.4G | 86.8M | 377.2FG | 12HI | 38.5K | 491.5I | 24.15R | 12.30PQ | 10V | 227.7H | 357.3J | 182.2H | 5.10H | 2.19H |
| | ABA 30 ppm | 176.8G | 511.4HI | 92.8K | 359.8HI | 12.3GH | 39.9HIJ | 517.1GH | 29.81O | 22.28O | 32M | 244.1FG | 377.2GHIJ | 195.3FG | 5.39G | 2.34FG |
| | ABA50 ppm | 168J | 463.8JK | 100.7I | 348.1I | 12.8FG | 41.4EFG | 550.3EF | 33.43M | 33.48L | 52.7C | 249F | 387.6FG | 199.2F | 5.68F | 2.39F |
| | Ethephon300 ppm | 180.4EF | 561.7G | 90.2L | 366.7GH | 12.3GH | 38.9JK | 497.9HI | 25.55Q | 14.48P | 17.16T | 233.9GH | 363HIJ | 187.2GH | 5.19GH | 2.24GH |
| | Ethephon500 ppm | 179.9H | 482.4IJ | 104.7H | 357.5HI | 13.1EF | 40.3GHI | 527.4G | 31.99N | 25.92N | 38.9I | 247.1F | 382.1GHI | 197.7F | 5.64F | 2.37F |
| | CCC400 ppm | 179.9F | 543.9GH | 87.5M | 363.1GHI | 12.3GH | 39.3IJK | 503.8HI | 27.43P | 21.51O | 23.6Q | 227.9H | 358.9IJ | 182.4H | 5.15GH | 2.19H |
| | CCC 600 ppm | 172.2HI | 468.9JK | 97.2J | 351.3HI | 13.1EF | 40.7FGH | 536.1FG | 32.5N | 30.92M | 45.8F | 248.2F | 383.8GH | 198.6F | 5.69F | 2.39F |
| Missing 3rd irrigation | Control(Water) | 169.7IJ | 437.9KL | 64.5R | 324.7J | 9.7K | 33.5NO | 385.3KL | 33.89M | 35.44L | 10.16V | 158.6LMN | 248.2N | 126.9LMN | 3.55MN | 1.52LMN |
| | ABA 30 ppm | 164K | 402.6LM | 72.4PQ | 304KL | 11.5I | 35.5LM | 424.8J | 36.79J | 49.66I | 33.9L | 196.5IJ | 313.3KL | 157.2IJ | 4.19JKL | 1.89IJ |
| | ABA50 ppm | 163.5K | 364.6MNO | 77N | 281.9MN | 11.5I | 36.6L | 446.2J | 42.37G | 65.01G | 54.66B | 207.4I | 331.3K | 165.9I | 4.55I | 1.99I |
| | Ethephon300 ppm | 164K | 437.4KL | 66.9R | 318.2JK | 11.5I | 33.9NO | 394.1KL | 34.90L | 39.88K | 19.3S | 204.5I | 324.7KL | 163.6I | 4.41IJ | 1.96I |
| | Ethephon500 ppm | 164K | 397.7M | 74.2OP | 298.9L | 11.5I | 35.9L | 432.9J | 38.42I | 57.77H | 40.8H | 188.9JK | 304.2LM | 151.1JK | 4.13KL | 1.81JK |
| | CCC400 ppm | 164K | 403.4LM | 69.9Q | 311.6JKL | 11.5I | 34.5MN | 404.6K | 35.76K | 44.21J | 27.73O | 201.7I | 321KL | 161.4I | 4.28JK | 1.94I |
| | CCC 600 ppm | 164K | 393.3MN | 76NO | 295.7LM | 11.5I | 36.1L | 437.3J | 40.84H | 63.48G | 47.7E | 180.7K | 282.6M | 144.5K | 4.01L | 1.74K |
| Missing 4th irrigation | Control(Water) | 155.8L | 356.9NO | 29.9W | 270.1NO | 8.7L | 24.1T | 233.7O | 43.16FG | 71.94F | 12.5U | 115.9P | 105.8Q | 92.7P | 2.54Q | 1.11P |
| | ABA 30 ppm | 149.8L | 316.2PQ | 53.7T | 236.6PQ | 10.4JK | 30.7R | 343.6M | 46.96D | 78.20D | 35.43K | 146.8NO | 198.4P | 117.4NO | 3.06P | 1.41NO |
| | ABA50 ppm | 132.6N | 205.3R | 60.3S | 191.7S | 10.7J | 33.1OP | 378.1L | 60.03A | 91.75A | 56.56A | 160.9LM | 238.9N | 128.8LM | 3.62M | 1.54LM |
| | Ethephon300 ppm | 155.8L | 350.1OP | 39.9V | 262.8O | 9.8K | 29.3S | 311.4N | 43.79F | 74.92E | 20.76R | 151.1MNO | 214.3OP | 120.9MNO | 3.11OP | 1.45MNO |
| | Ethephon500 ppm | 147.6M | 304.8Q | 58.8S | 228.6QR | 10.7J | 31.3QR | 346.4M | 51.23C | 84.20C | 42.33G | 157.9LMN | 230.7NO | 126.4LMN | 3.34NO | 1.52LMN |
| | CCC400 ppm | 153L | 344.5OP | 46.9U | 247.9P | 9.8K | 30.2RS | 343.4M | 44.93E | 76.89DE | 28.53O | 140.2O | 197.6P | 112.2O | 2.97P | 1.35O |
| | CCC 600 ppm | 147.6M | 279.4Q | 59.6S | 218.1R | 10.7J | 32PQ | 358.2M | 57.48B | 87.25B | 49.23D | 166.2L | 250.1N | 132.9L | 3.76M | 1.59L |

**Means having the same capital letters in the same coulmn are not significantly differed at P≥ 0.05**