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Biosci. Biotech. Res. Comm. BIOSCIENCE BIOTECHNOLOGY RESEARCH COMMUNICATIONS Vol. (2) No. (1) June, 2009(33-39)

EFFECTS OF SALINITY ON THE GROWTH OF MAIZE (*Zea mays* L.) VARIETY SUWAN=1-SR 063802

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ABSTRACT

Investigation into the effects of different concentrations of salinity at 0mM, 90mM, 180mM and 360mM on the growth and development of maize (*Zea mays* L.) variety SUWAN=1-SR 063802 was carried out over a period of six weeks of treatment after the establishment of the crop for three weeks in the screen house in a randomized block design. Salinity effect on maize is concentration dependent. There was no significant difference ($p>0.05$) between the control (0mM) and 90mM treated plants (TP) in terms of leaf number, leaf area, stem girth and senescence, but the control was significantly different ($p<0.05$) from the 180mM and 360mM TP in growth parameters such as leaf number, leaf area, plant height, senescence and stem girth. Plants subjected to 180mM salinity showed significant leaf chlorosis from three weeks after treatment (3WAT) while those of 360mM NaCl treatment had started to senesce and complete death was recorded 6WAT. In spite of the fact that flowering was first observed in the control plants followed by those subjected to 90mM NaCl treatment, there was faster rate of its development in the 90mM TP; an indication that moderate level of salinity promotes flower development in maize, but high salinity causes reduction in leaf number, plant height, leaf area, fresh weight, dry weight and an increase rate of senescence.

KEY WORDS: *Salinity, Zea mays, growth parameters, senescence*

INTRODUCTION

Soil salinity is one of the most important factors that limits crop production in arid and semi arid region (Neumann,1995). Great surface area of the world is affected by soil salinity and there are subsequent losses in crop yield (Kent and Lauchli, 1985). Soil salinity is a measure of the amount of soluble salt in soil. As salinity level increases, plant extracts water less easily from the soil; aggravating water stress conditions. High salinity can cause nutrient imbalances, resulting in the accumulation of elements toxic to plants and reduce water infiltration if the level of one salt element like sodium is high.

Plants have different responses to salinity depending on their stage of development (Kalaji and Pietkiewiez, 1993; Rumbaugh *et al*., 1993; Rogers *et al*., 1995). Salinity has a two phase effect on plant growth, an osmotic effect due to the salt in the outside solution and in toxicity in a second phase due to salt build up in transpiring leaves (Muhammed *et al*., 2006). It is important to know how annual crops established in the field from seeds respond to salinity as weak plants with slow growth competes poorly with weeds and plant pathogens.

Saline environment affects plants in a variety of ways such as injury to leaves manifested as marginal chlorosis of leaves followed by extensive scorching of the leaf blades. Also, leaf mottling and necrotic patches or tip burn (Schaffer *et al*., 1999). Climate and irrigation also influence salinity tolerance. As soil dries up, salt becomes concentrated in the soil solution, increasing salt stress. Therefore, salt problems are more severe under hot, dry conditions than under cool, humid conditions. Increasing irrigation frequency and applying water in excess of plant demand may be required during hot dry periods to minimize salinity stress (Tanji, 90).Salinity is often accompanied by other soil properties such as sodicity, alkalinity or boron toxicity which exerts their own specific effects on plant growth (Munns, 1993). In grasses, stress conditions that decrease leaf elongation rates affect the blade elongation zone, reducing its length and elemental growth rates within it. Reactive oxygen species (ROS) in the apoplast of cells in the growing zone of grass leaves are required for elongation growth. Inhibition of leaf elongation is one of the primary effects of salt stress. The physiological processes underlying leaf growth inhibition are not fully understood (Munns, 1993; Lazof and Bernstein, 1998). Salt stress induced growth might be associated with modifications of apoplast acidification. Some indications suggests possible inhibitor effects of Na^+ and Cl^- on H^+ efflux and apoplast acidification (Ben-Hayyim and Ran,1990; Wilson and Shannon, 1995). This might play a role in growth sensitivity under salt stress, since salinized cell walls contain higher levels of Na^+ and Cl^- than non-stressed walls and cultivar. Salt tolerance sometimes correlates with a high level of exclusion from numerous cell wall and cytoplasm (Hajibagheri *et al.*, 1987; Flowers *et al.*, 1991; Lazof and Bernstein, 1998). Apoplast pH was suggested to play an important role in cell wall loosening and growth (McQueen-Mason *et al.*, 1993) and in plant tissues including leaves of maize (*Zea mays*), increased rate of growth are associated with increasing acidification of the cell wall space (Van-Volkenburgh and Boyer, 1985; John *et al.*, 1996; Peter *et al.*, 1998, Stahlberg and Van-Volkenburgh, 1999). Salts in soils are primarily chlorides and sulphate of sodium, calcium. Magnesium and potassium. Symptoms of soil salinity; slow and spotty seed germination, sudden wilting, stunted growth, marginal burn on leaves (especially lower, older leaves) leaf yellowing, leaf fall, restricted root development and sudden or gradual death of plant (Munns, 2002).

Maize plant originated in central and South American and in early times spread to other part of the world. Maize (corn) is an erect, single stem, fast growing, annual grass about 1m - 1.5m tall with fibrous root system some of which arch out from the lower nodes to form stilt roots which acts to support the plant in an upright position. Like other cereals, the leaf consist of sheath and the leaf blade is linear, lanceolate, acuminate and wavy, 50-70cm in length and 8-19cm wide at its broadest point usually with hairs along the upper margin. The maize plant is monoecious with male and female borne separately on the same plant. The male is the tarsel at the terminal position of the main axis while the female is the cob or ear born terminally but on a modified lateral branch developing from the axillary borne on main stem. A corn kernel is caryopsis

Maize is widely cultivated through out the world and a greater weight of maize is produced each year than any other grain. Because it is cold-intolerant. in the temperate zones, maize must be planted in the spring. Its roots system is generally shallow, so the plant is dependent on soil moisture. As a C_4 plant, maize is considerably a more water efficient crop than C3 plant like soybeans. Maize is most sensitive to drought at the time of silk emergence, when the flowers are ready for pollination, the importance of sufficient soil moisture, is shown in many parts of Africa where periodic drought regularly causes famine by causing crop failure (Ferro and Weber, 2002).

Corn is widely cultivated for its edible seed especially in tropical and warm temperature zones of the world. Maize plant prefers light (sandy), medium (loamy), heavy (clay) soils and requires well drained soil. It prefers acid and neutral soils, it cannot grow in shade and requires moist soil. Maize is one of the most commonly grown food crop in the world. The seed can be eaten raw or cooked before it is fully ripe (Hedrick, 1972). The mature seed can be dried and used whole or ground into flour; it has a very mild flavour and is used especially as a thickening agent in foods such as custard. The starch is often extracted from the grain and used in making confectionery, noodles, etc (Facciola, 1990). An edible oil is obtained from the seed, it is an all-purpose culinary oil that is frequently used as food, in salads and for cooking purpose (Bown, 1995).

The seed is widely used in the treatment of cancer, tumours and warts. It contains the cell proliferant and healing substance allantoin, which is widely used in herbal medicine to speed the healing process (Foster and Duke, 1990). A semi-drying oil is obtained from the seed and it has many industrial uses, in the manufacture of linoleum, paints, varnishes, soaps, etc (Lust, 1983).

Salt stress decreases growth of cell as well as adult plant and seedling root and shoot (Viegas *et al.*. 1999; Camara *et al.*, 2000; Murillo-Amador and Troyo-Dieguez, 2000).The objective of this study is to investigate the effect of increasing soil salinity on the growth performance of *Zea mays*.

MATERIALS AND METHODS

Collection of Soil, Polythene Bags and Maize Seeds

Maize seeds; variety SUWAN = 1-SR 063802 (streak resistant) was obtained from the Delta State Agricultural Procurement Agency (DAPA) Limited, Effurun, Delta State, Nigeria. Soil was collected behind the BQ close to Ethiope River Campus II of Delta State University, Nigeria. Black Polythene bags were purchased from Bella Horticultural garden, Sapele, Delta State. Common salt (NaCl) was obtained from the Abraka small market, opposite small gate of Delta State University, Abraka Campus II.

Experimental Design

The experimental design was a completely randomized design with three different concentration of NaCl (90mM, 180mM and 360mM) and a control (0mM). Treatment levels were replicated thrice and a total of twelve experimental units were used in the screen house at Delta State University Abraka; Campus II.

Thirty six maize seeds were planted, 3 per hole, 2cm deep in 2kg garden soil placed in black polythene bags of 20.9cm diameter and 25.5cm depth. The maize germinated 4 days after planting within 2 weeks intervals the seedling were thinned down to one seedling per bag. Seedlings of equal growth strength and height were selected. Polythene bags used for the study were perforated, adequately labeled and randomly assigned in the screen house according to the different treatment levels.

Preparation of Treatment Solution

Different salinity concentrations; 90mM, 180mM and 360mM of NaCl (common salt) were made and applied to the growing seedlings using a 100ml beaker every 2 days for 6 weeks and several growth parameter were examined. The maize seedlings were watered at first with tap water for 3 weeks for proper establishment in their environment before they were then subjected to 90mM, 180mM and 360mM NaCl concentration treatments respectively. Control samples (0mM) were not treated with NaCl. There were three replicates per treatment.

The following growth parameters were measured/ noted every week for the period of treatment which lasted 6 weeks.

Determination of Growth Parameters

Plant Height: This growth parameter was obtained using a meter rule and the plants were measured from the base of the stem to the top of the longest leaf.

Leaf Area: This was obtained using a measuring tape because of the nature of maize leaf. The leaf length was taken by measuring the leaf from tip to its point of origin (leaf sheath) while the leaf breadth was taken by measuring the broadest portion of the leaf. The length and breadth were then multiplied to give the leaf area thus: leaf area = leaf length x leaf breadth (mathematically).

Stem Girth/Circumference: This parameter was obtained by using a thread which is passed round the broadest portion of the plant stem and then measured on a ruler.

Fresh Weight: This was obtained using a Harvard trip balance. The plants were uprooted carefully in order not to damage the root and then washed under a running tap to remove soil particles before being weighed.

Dry Weight: The plants were oven dried at a temperature of $60^{\circ}C$ for a minimum of 3 days (Greenwood and MacFarlane, 2009) to get a stable weight.

Senescence: This parameter was obtained by direct counting of the number of dead or dying leaves of the plant.

RESULTS AND DISCUSSION

Various morphological changes were observed in the growth of *Zea mays* variety SUWAN = 1-SR 063802 treated with different concentrations of NaCl. Six weeks after treating the plants with saline water, some abnormal symptoms were observed. These include chlorosis and rapid senescence at 180mM and 360mM NaCl concentrations. Control plants matured first showing the alternate leaf arrangement and flowering also commenced earlier in plants at 0mM NaCl than those of higher salinity levels. This therefore showed that the effect of salinity on *Zea mays* is concentration dependent.

Plant subjected to 360mM NaCl concentration treatment, had already started dying while those of 180mM NaCl had an increased rate of chlorosis three weeks after treatment (3WAT). Total mortality had taken place in 360mM NaCl treated plants 6WAT while 180mM and 90Mm NaCl treated plants has produced flowers but those of 90mM NaCl were more developed 6WAT.

The data obtained from the experiment was subjected to one-way analysis of variance (ANOVA) test, and also post–HOC test using Turkey HSD and LSD. The effects of salinity on the different growth parameters measured are shown in Figures 1 – 7.

Leaf Number: There was a progressive decrease in leaf number with increasing levels of salinity (Figure 1). The variations in leaf number between various salt concentrations was significant ($p<0.05$). Increase in concentration led to decrease in leaf number. A Post-HOC test of means separation using LSD and HSD showed that the control plants were not significantly different ($p>0.05$) from 90mM NaCl TP, but was significantly different ($p>0.05$) from those of 180mM and 360mM NaCl concentrations. The 90mM and 180mM treated plants were not significantly different from each other but significantly different ($p<0.05$) from the 360mM treated plants.

Plant Height: The height of the maize (*Zea mays*) decreased with increased salt concentration (Figure 2). ANOVA test result showed that height was significantly different ($p<0.05$) among the various maize plants exposed to different salt concentrations. Test of multiple comparison using Least significant Difference (LSD) showed that the control plants were significantly different from 90mM, 180mM and 360mM NaCl treated plants but the 90mM and 180mM as well as the 180mM and 360mM were not significantly different from each other respectively. In addition, the 90mM concentration was significantly different from the 360mM concentration but not significantly different from the 180mM NaCl concentration.

Leaf Area: Leaf area of the exposed plants to various salt concentrations was significantly different ($p<0.05$) from each other using ANOVA. A Post-HOC test of multiple comparison showed that the control was not significantly different from 90mM and 180mM NaCl treated plants but significantly different from those of 360mM concentrations using LSD (Figure 3). The 90mM, 180mM and 360mM NaCl treated plants were not significantly different from each other using LSD multiple comparison test.

Stem Girth: Test for significance using ANOVA and Post-HOC test of multiple comparison showed that the control was significantly different from 360mM NaCl concentration treated plants ($p<0.05$) but not significantly different from 90mM and 180mM treated plants. 90mM and 180mM concentrations were significantly different from 360mM concentration using Turkey LSD (Figure 4).

Fresh Weight: There was a significant decrease in fresh weight of all the treatments with increasing levels of salinity ($p<0.05$) when compared to the control plans. Fresh weight decreased steadily with increased salinity levels such that control plants had the highest fresh weight values while 360mM NaCl TP has no value since mortality has occurred before the weight measurement were taken (Figure 6)

Dry Weight: There was a significant decrease in dry weight with increasing levels of salinity ($p<0.05$). Dry weight decreased steadily with increase in salinity such that the highest value was recorded for control plants while there was no value for 360mM TP as total mortality has occurred since 6WAT before the termination of the experiment (Figure 5).

Senescence: There was a progressive increase in the rate of leaf senescence. Senescence increased with increasing concentration of salinity from 0mM to 360mM NaCl treated plants. ANOVA test showed that senescence was significantly different ($p<0.05$) among the various maize plants exposed to different levels of salinity. A Post-HOC test showed that control plants were significantly different ($p<0.05$) from 180mM and 360mM TP but not significantly different ($p>0.05$) from 90mM TP (Figure 7). The 90mM TP were significantly different ($p<0.05$) from 360mM treated plants, while 180mM treated plants were not significantly different from 360mM treated plants at ($p>0.05$) level of significance, but significantly different ($p<0.05$) from 0mM and 90Mm treated plants.

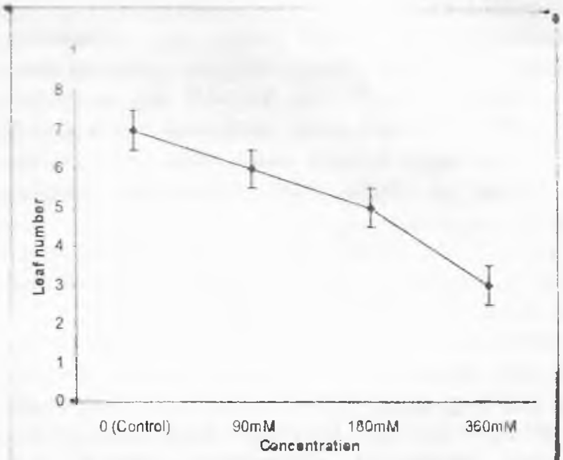

Figure 1: Effect of salinity on leaf number of *Zea mays*

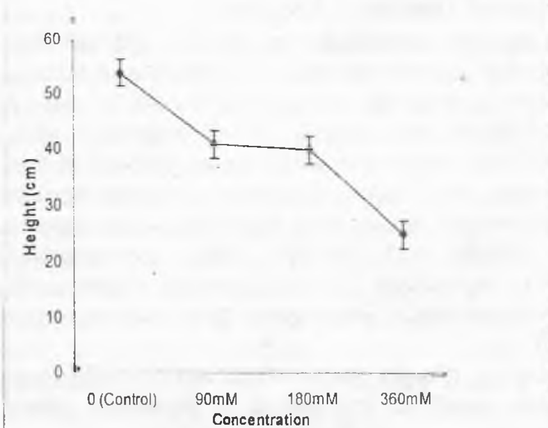

Figure 2: Effect of salinity on height of *Zea mays*

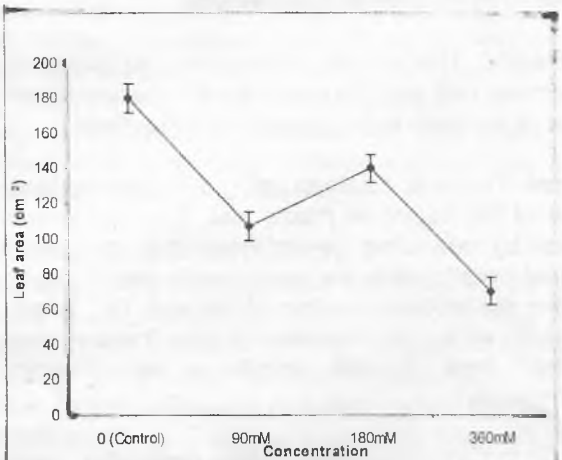

Figure 3: Effect of salinity on leaf area

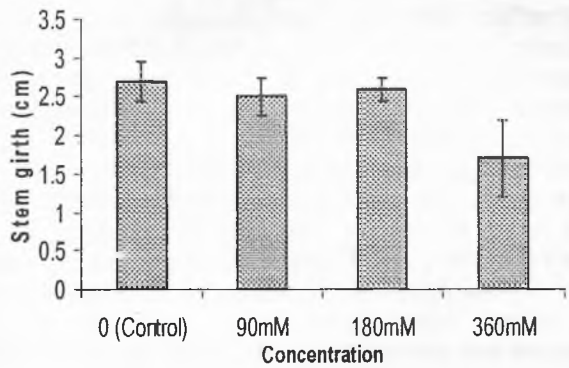

Figure 4:Effect of salinity on stem girth of Zea mays

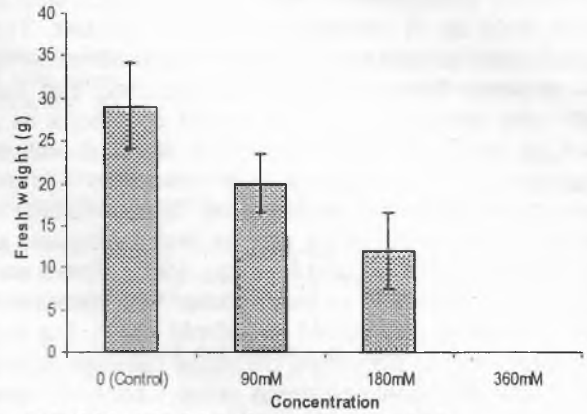

Figure 6: Effect of salinity on fresh weight of Zea mays

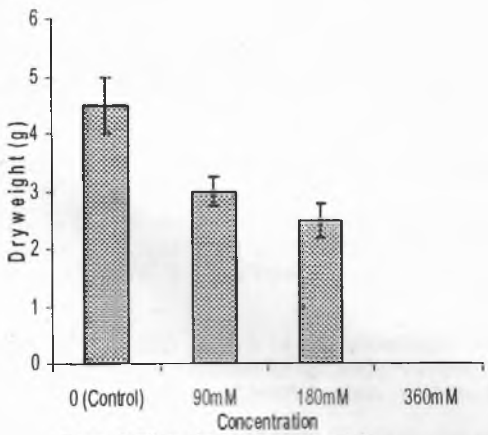

Figure 5: Effect of salinity on dry weight

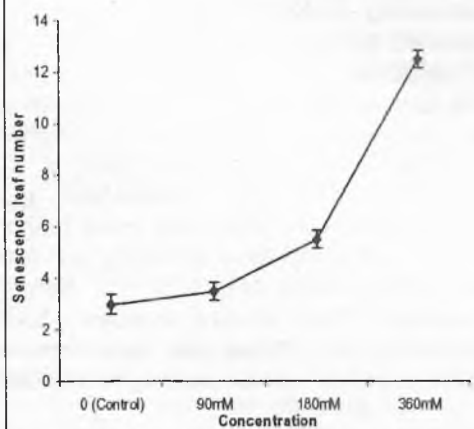

Figure 7: Effect of salinity on leaf senescence in Zea mays

The effect of salinity on the growth of *Zea mays* variety SUWAN = 1-SR 063802 was concentration dependent. This fact was corroborated by Bamidele *et al.* (2007) who reported a progressive decrease in plant growth parameters such as plant height, leaf number, fresh and dry weights, leaf area, and stem girth in *Talinum triangulare* with increasing salinity. These results are in consonance with the investigations of Rajpar *et al.* (2006).They observed adverse effects of NaCl salinity at higher concentrations of NaCl.

In this study, *Zea mays* variety SUWAN = 1-SR 063802 was found to tolerate low or moderate concentration (0 to 90 mM NaCl). This could be seen in the results of the data analysis which showed that there was no significant difference between control and 90mM concentration but salinity had a significant influence on the growth of plants under 180mM and 360mM NaCl concentrations. This finding is similar to that reported by Morris and Grant (2001) on *Bolboschoenus medianus*. Camara *et al.* (2000) also discovered that high salinity levels such as 137mol.m^{-3} NaCl decreased maize callus relative growth rate. Murillo-Amador and Troyo-Dieguez (2000) also revealed that salinity inhibits cowpea shoot and root growth decreasing drastically at EC higher than 0.785m^{-1}

From Figures 1 and 3, it is evident that leaf number and leaf area decrease with increasing levels of salinity. This reduction may be as a result of accumulation of ions especially sodium and chloride which may have been toxic to the leaves turning them chlorotic and leading to loss of leaves and reduced growth. This is corroborated by the work of Bamidele *et al.* (2007) on *Talinum* *triangulare* and that of Munns (1993) in which they stated that continuous salt accumulation combined with limited production of new volume could lead to earlier build up of excess (toxic) levels of salt. This might further accelerate the onset of leaf senescence and necrosis. Munns (1993) also reported that leaf death was obvious under high saline conditions as a result of rapid salt concentration in the cell wall or cytoplasm when the vacuole can no longer compartmentalize the salts. This fact resulted in reduced photosynthesis as well as leaf abscission as reported by (Kozlowski and Pallardy, 1997). There was a significant decrease in leaf number with increasing levels of salinity (from 0mM to 360mM NaCl). For leaf area there was no significant decrease between 90mM and 180mM concentrations but control was significantly different from 90mM to 360mM concentration thus leaf area was affected by higher levels of salinity.

There was significant difference ($p<0.05$) in plant height with increasing levels of salinity. Increasing salinity was reported by Gupta and Sharma (1990) to progressively decrease plant height and yield compared to the control. The adverse effect according to them was associated with significantly higher concentration of Na^+ and lower concentration of K^+ determined in the seedling sap. Greenwood and MacFarlane (2009) observed decreased plant height and total biomass with increasing salinity in two species of *Juncus*; *J. kraussii* and *J. acutus*. Sprent (1984) also observed that salinity reduces shoot growth by suppressing leaf initiation and expansion as well as internodes growth of leaves leading to reduced plant growth.

There was no significant difference in the stem girth among various salt concentrations (Figure 4), although control was significantly different from 360mM, there was no significant difference ($P>0.05$) among control and 90mM and 180mM NaCl TP.

Dry weight decreased with increasing levels of salinity from 0mM to 360mM NaCl (Figure 5). This fact was corroborated by Olusola and Okusanya (1990) who reported a gradual decrease in dry weight, culm length and tiller number in *Paspalum obiculare* as salinity levels increased. Similarly, Anthraper and DuBois (2003) reported reduced dry tissue mass and percentage of nitrogen in *Leucaena leucocephala* using NaCl concentration as low as 0.025mol/L. Dry matter accumulation was best under non-saline conditions (0mM NaCl). Declining productivity of many plant species subjected to excess salt is often associated with a reduction in photosynthetic capacity (Rivelli *et al.*, 2002; Pagter *et al.*, 2009)

There was a significant decrease in fresh weight with increasing levels of salinity. Thus, the control plants had greater fresh weight than those grown in saline conditions (Figure 6).

The rate of senescence increased with increasing levels of salinity. This is in agreement with the work of Munns (1993) in which he stated that NaCl accumulation in plant may lead to toxicity which further accelerates the onset of leaf senescence and necrosis. Munns (2002) also reported sudden wilting, stunted growth, marginal burn on leaves (especially lower and older leaves), leaf yellowing, leaf fall, restricted root development and sudden or gradual death of plant/plant parts as some symptoms of the effect of soil salinity.

Subsequently, the effect of salinity on the growth of *Zea mays* variety SUWAN = 1-SR 063802 was observed on flowering of the plant. Flowers first appeared ion plants under control (0mm NaCl), followed by those treated with 90mM NaCl concentration. Although flowers appeared first on control plants, those of 90mM NaCl concentration grew or developed faster than those of control. Thus, it is obvious that moderate levels of NaCl promote rapid development of maize flowers.

From the various statistical analysis on the effect of salinity on growth parameters of *Zea mays* variety SUWAN = 1 – SR063802, it was evident that there was no significant difference between control and 90mM NaCl TP. It is therefore apparent that this variety of *Zea mays* can withstand or tolerate moderate levels of salinity.

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