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Growth Physiology of Spring Wheat Under Saline Conditions

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Abstract: A hydroponic experiment was carried out to see the effects of salinity by using a randomized complete block design with 4 salinity treatments and 5 replicates. The salinity levels tested were 0, 50, 100 and 150 mol m^{-3} NaCl. $CaCl_2$ was also applied to the salinity treatments. Leaf appearance stage was not significantly affected by salinity. With salinity, no extra tillers were produced and number of tillers decreased as salinity increased. The trends in results for leaf 3 and leaf 4 were inconsistent while leaf extension rate (LER) of leaf 5 and the flag leaf was decreased with increase in salinity. LER of leaf 6 and leaf 7 was significantly decreased with increase in salinity. Final leaf length of all the later appearing leaves was significantly decreased with salinity but the differences between salinity treatments were not always significant.

Key words: Wheat, Salinity, plant growth, leaf and tiller appearance stages, leaf extension rate and duration, final leaf length

INTRODUCTION

Salinity is known to reduce the growth of non-halophytes (Shabala *et al*., 1998). Dry matter formed prior to anthesis has been estimated to contribute 3-30% of the grain dry matter at maturity. Growth and yield in crop plants are affected to varying degrees by salinity (Grant, 1995). The growth of a plant is influenced by leaf area and by amount of dry matter produced per unit leaf area. Changes in the dry fresh weight are other widely used parameters to determine plant sensitivity to NaCl (Seemann and Critchley, 1985). It is known that leaf growth is normally more sensitive to salinity then is root growth (Seemann and Critchley, 1985; Munns and Termaat, 1986; Rawson, 1986). Iqbal and Chuahan (2003) found a positive correlation between leaf extension rate (LER) and final leaf length (FLL), indicating that LER determined the leaf length, which is main factor responsible for leaf area. One of the main objectives of the present work is to study the effects of salinity on growth and dry matter production of wheat. Previous experiments (Iqbal, 1988; 1992) have shown large effects of salinity on leaf expansion. Therefore, this paper examined the effects of NaCl on plant growth and other parameters before anthesis.

MATERIALS AND METHODS

Experimental design and treatments: A hydroponic experiment was carried out to see the effects of salinity at University of Wales, Bangor UK. The experiment was carried out using a randomized complete block design. There were 4 salinity treatments and 5 replicates. The salinity levels tested were 0, 50, 100 and 150 mol m^{-3} NaCl. $CaCl_2$ was also applied to the salinity treatments (50, 100 and 150 mol m^{-3} NaCl) in the ratio of 20:1 (moles Na: moles Ca) as suggested by Gorham *et al*. (1985) in order to increase the potassium/sodium ratio (Hanson, 1984).

Plant material and growth condition: The experiment was initiated on 13 May and terminated on 29 June at University of Wales, Bangor, UK. Spring Wheat variety Wembley was used in this experiment. The experiment was carried out in glasshouse with no control of temperature and without supplementary lighting.

Growth containers and aeration: In this experiment many plants were required for chemical analyses, gas exchange measurements and growth analyses. Therefore, large containers were used. In this experiment 25 L water holding plastic containers (63 x35 cm wide x 18.5 cm deep) were used. Prior to seeding, eight 7 mm (for air supply) and one 9 mm (for solution changes) holes were made in the front, sides and bottom of the containers. The holes were plugged with rubber bungs to facilitate easy changes of nutrient solutions and to fix air supply needles (No. 16: Terumo Europe, Belgium). The containers were arranged along the sides of large work benches, again to facilitate easy access for maintenance and measurements. Instead of polyurethane tubing, silicon tubing (Scientific Services, Chester, UK) was used to facilitate sealing of holes created by needles in it. The silicon tubing (5mm internal diameter (ID), 8 mm outer diameter (OD)) was fixed along the sides of the workbenches and then connected

to the air regulator. Air from the silicon tubing to the containers was supplied via narrow (0.58 mm ID, 0.96 mm OD) polythene capillary tubing (Portex Ltd. Hythe, Kent, England), which was put into the silicon tubing and the bungs fitted in the containers. This system allowed a more uniform and efficient distribution of air in each container and avoided the air blockage problem encountered when using the 3-way air regulators and aerators in previous experiment (Iqbal, 1988).

Germination and raising of seedlings: Wheat seeds were germinated and grown in P180 Plugtrays (Cookson Plantpak Ltd., Maidon, Essex, UK). Prior to seeding, capillary matting was fixed at the bottom of each plugtray with copydex. Another P180 plugtray was stacked on top with the one containing the capillary matting at the bottom. This provided increased strength to the plugtray to withstand plant weight gained later during the experiment. The pairs of plugtrays were then placed on the top of the 25 L containers, which were filled with nutrient solutions (0.4 g L^{-1} Phostrogen). All the cells of the P180 plugtrays were filled with vermiculite. Initially, after soaking the vermiculite, seeds were sown directly into the trays with one seed per cell and a total of 180 seeds per tray. After 4 days it was realized that using this technique the nutrient solution was creating waterlogged condition for the germinating seeds, even though they were aerated through the air supply. The experiment was therefore re-sown. New seeds were presoaked overnight in a muslin bag suspended under a slow running tap. On next morning the seeds were sown on the moist vermiculate in the P180 plugtrays with one seed per cell and a total of 180 seeds per tray (51.5 x 30.0 cm). The seeds then covered with newspapers and kept moist until the radicles and coleoptiles were seen to be emerging. The newspapers were later removed. The containers were then filled with tap water containing 0.4 g L^{-1} Phostrogen and the trays placed over the containers. The seedlings were later thinned to 90 per tray by uprooting alternate rows along the width of the tray, as 9 rows of 10 plants at a distance of 60 x 30 mm, which is equivalent to a plant population of 583 plants m^{-2}.

Preparation of nutrient based salt solution: In this experiment, for ease of preparation and solution changes, Phostrogen based nutrient and salt stock solution were used for each treatment. After necessary calculations for each salt treatment being made, Phostrogen and all the micronutrients were added to each salt stock solution and the volume was made to 10 L and then stored in a cold room for further use. This technique facilitated the maintenance of a uniform supply of salt stress throughout the course of experiment.

Application of salt stress: Prior to salt stress (12 days after seeding), when the plants had 2 emerging leaves, the containers were drained out and refilled. The stock salt and nutrient solutions were drip fed into the plant containers from polyurethane containers, which were fixed to retort stands. One needle, connected to polythene capillary tubing was inserted into the bottom side of the polyurethane container and the other into the 25 L container holding the plants. The concentration of stock solutions varied for each treatment so that final desired concentration would be achieved. By this method salinity was introduced gradually and continuously over a 2 days period in each treatment. Stalinization was completed at 1+2 leaf stage (one fully expanded and two expanding leaves).

Growth measurements: The 90 plants in each container were divided into 3 groups. The central plants were used for leaf extension growth measurements, the plants to the left side for gas exchange measurements and the plants to the right side for chemical analyses.

Leaf Appearance and Tiller Appearance Stages: For leaf appearance stage (LAS), tiller appearance stage (TAS) and other growth measurements, 4 plants in the center of each tray were marked with small wire rings of different colours. After every second day, the numbers of fully expanded leaves and newly emerged leaves and tillers on the mainstem of these 4 marked plants in each container were recorded to determine LAS and TAS.

Leaf extension growth and final leaf length: Leaf extension growth (LEG) of leaf 3 and subsequent leaves on the mainstem of the 4 marked plants was measured in mm with a rular every day, starting after the initial salt stress and following the procedure described earlier (Iqbal, 1988). After completion of LEG measurements, when the ligule was emerged, final leaf length (FLL) of sheath plus leaf lamina was recorded.

Leaf extension rate and leaf extension duration: Leaf extension rate (LER) and leaf extension duration (LED) were calculated following the procedure described earlier (Iqbal, 1988).

RESULTS AND DISCUSSION

Effect of salinity on las and tas: Generally, LAS was not significantly affected by salinity (Fig. 1). In the majority of

Table 1: Effect of different salinity levels on final leaf length (FLL in mm), leaf extension rate (LER in mm day^{-1}) and leaf extension duration (LED in days) of different leaf insertions on mainstem of spring wheat

	Salinity levels (mol m^{-3} NaCl)					
Parameters	0	50	100	150	SEM	HSD
Final leaf length						
Leaf 3	210.1	208.8	208.6	196.1	11.1	NS
Leaf 4	295.4	290.5	285.0	248.9	8.5	35.7**
Leaf 5	354.4	322.5	307.6	287.9	13.5	56.5*
Leaf 6	352.3	313.8	293.8	260.4	12.1	50.6**
Leaf 7	363.1	313.9	288.6	262.5	11.5	48.4**
Flag leaf	356.7	293.2	279.8	274.6	8.9	37.5**
Leaf extension rate						
Leaf 3	31.0	32.3	29.9	22.4	3.3	NS
Leaf 4	27.3	28.3	27.4	28.8	3.0	NS
Leaf 5	31.9	30.7	30.4	28.0	1.8	NS
Leaf 6	37.8	35.5	33.9	29.7	1.2	5.0**
Leaf 7	42.5	40.7	40.2	26.9	3.5	14.5*
Flag leaf	47.5	35.4	33.1	32.0	5.9	NS
Leaf extension duration						
Leaf 3	6.9	6.9	7.7	8.8	0.8	NS
Leaf 4	10.9	10.7	9.8	9.7	0.8	NS
Leaf 5	11.2	10.5	10.1	10.4	0.3	NS
Leaf 6	9.4	8.9	8.7	8.4	0.3	NS
Leaf 7	9.1	7.9	7.6	7.9	0.7	NS
Flag leaf	7.8	7.6	7.8	6.8	0.8	NS

SEM = Standard error of means, HSD = Honestly significant differences, NS = Not significant, *, ** = Significant at 5 and 1% probability levels, respectively

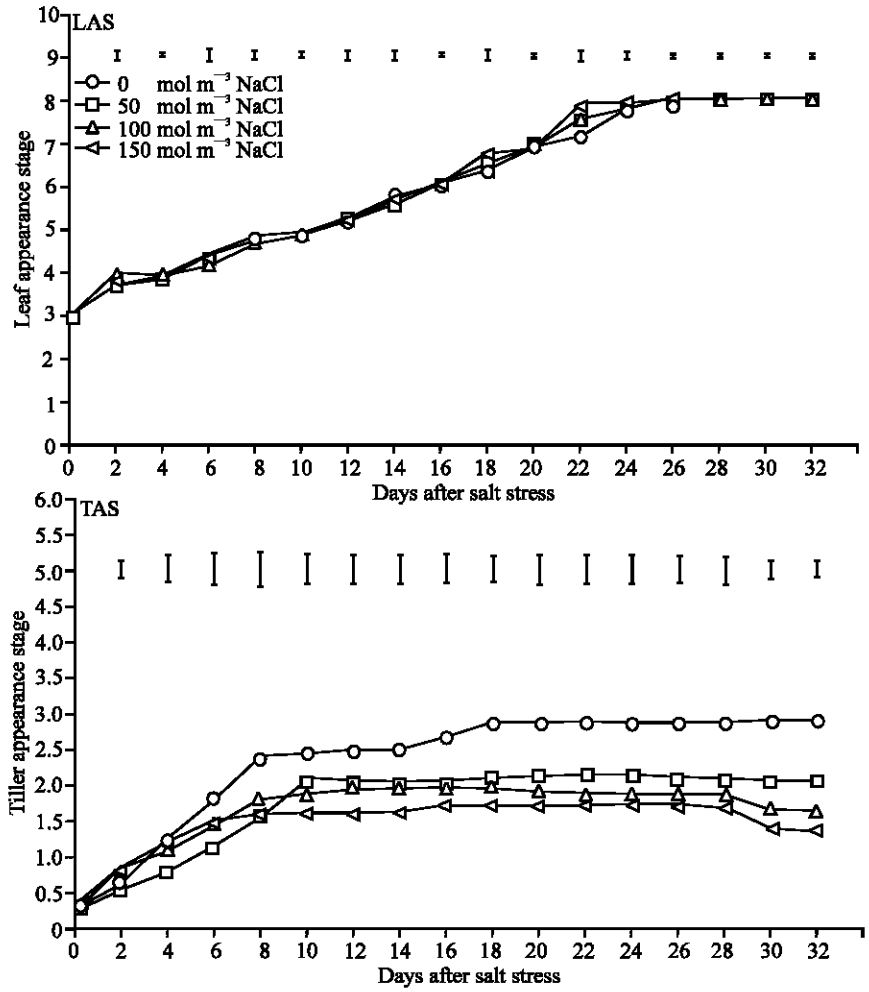

Fig. 1: Effect of salinity levels on leaf appearance stage (LAS) and tiller appearance stage (TAS) of spring wheat. I= standard error of means

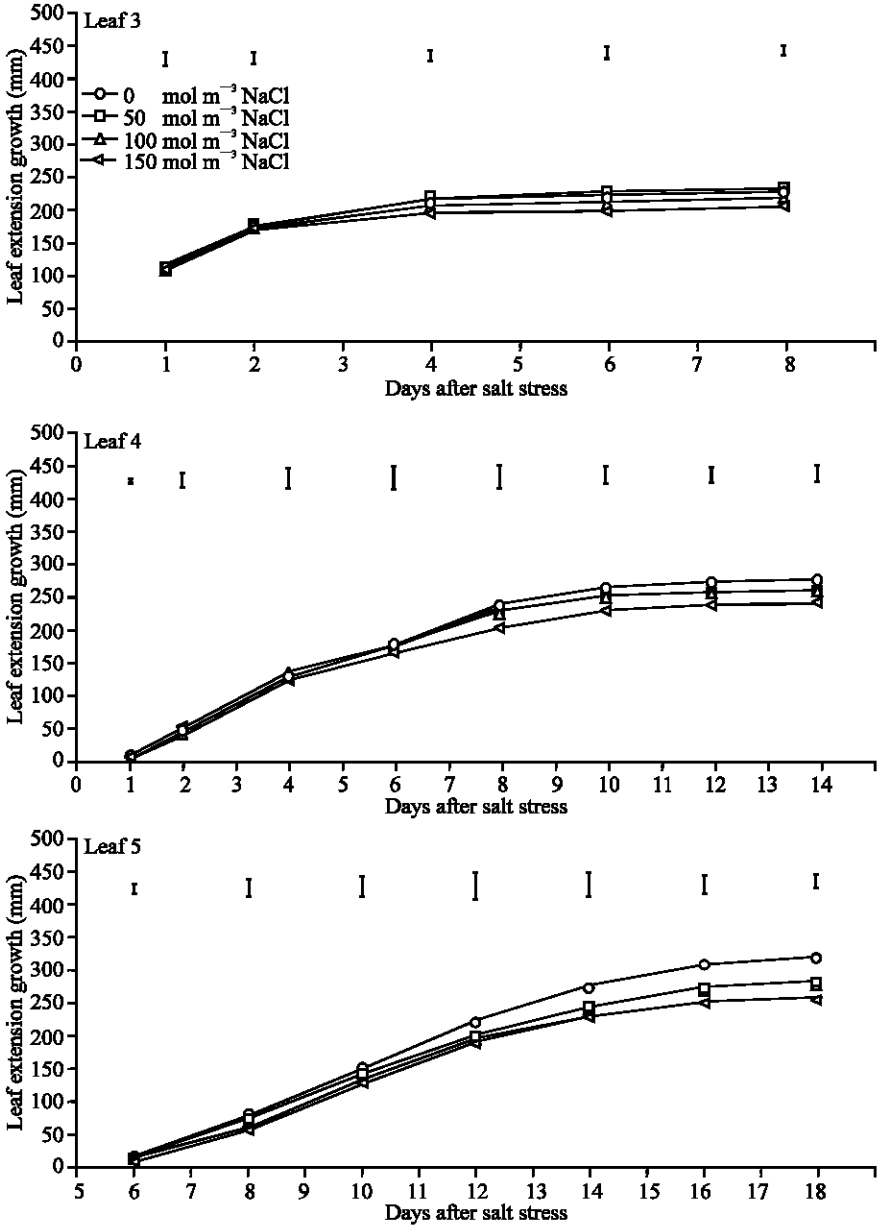

Fig. 2: Effect of salinity levels on leaf extension growth of leaf 3, leaf 4 and leaf 5 of spring wheat. I = standard error of means

plants leaf 8 was the flag leaf but at 0 mol m^{-3} NaCl leaf 9 was the flag leaf in a few plants. TAS was not significantly affected by salinity until 14 DAS, but was higher at 0 mol m^{-3} NaCl than in all other salinity treatments from 6 DAS onwards. With salinity, no extra tillers were produced 10 DAS and number of tillers decreased as salinity increased.

Effect of salinity on LEG, LER, LED and FLL: LEG of leaf 3 and leaf 4 was not significantly affected by salinity (Fig. 2). From 8 DAS onwards, LEG of leaf 4 was higher at 0 mol m^{-3} NaCl than in all other salinity treatments. LEG of all other leaves (leaf 5, leaf 6, leaf 7 and the flag leaf) was decreased as salinity increased but the effects were significant only at one or two sampling dates of each leaf (Fig. 3).

LER of leaf 3, leaf 4, leaf 5 and the flag leaf was not significantly affected by salinity (Table 1). The trends in results for leaf 3 and leaf 4 were inconsistent while LER of leaf 5 and the flag leaf was decreased with increase in salinity. LER of leaf 6 and leaf 7 was significantly decreased with increase in salinity.

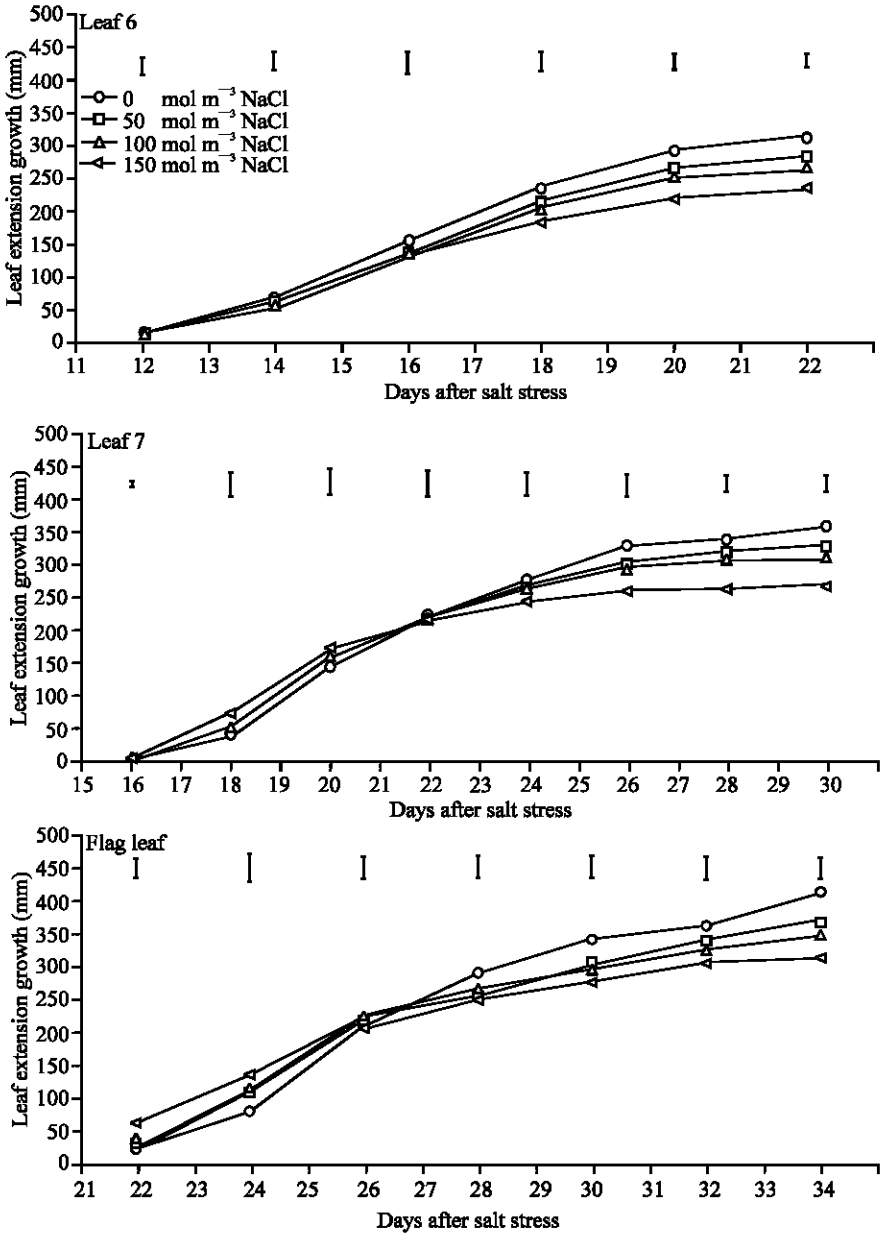

Fig. 3: Effect of salinity levels on leaf extension growth of leaf 6, leaf 7 and flag leaf of spring wheat. I = standard error of means

FLL of leaf 3 was decreased with increase in salinity (Table 1) but not significantly. FLL of all the later appearing leaves was significantly decreased with salinity but the differences between salinity treatments were not always significant.Salinity did not significantly effected LAS but decease in TAS was more prominent with increase in salinity. However, it was observed that salinity slightly enhanced LAS. Therefore, later appearing leaves reached full expansion a few days earlier at high salinity (100 and 150 mol m^{-3}NaCl). In this and the previous experiments (Iqbal, 1988), it was observed that although salinity did not significantly affected number of leaves on the mainstem it decreased total number of leaves by decreasing number of tillers per plant. This resulted in lower leaf area with increase in salinity. Leaf area of plant could be influenced by FLL (Iqbal, 2003; Iqbal and Chauhan, 2003). In previous studies (Kemal-ur-Rahim 1988; Iqbal, 1992), it was observed that FLL was mainly influenced by LER. The present study also confirmed that variation in FLL was not a result of variation in LED but of

LER. Therefore, LER determined FLL, which also determined leaf area and dry weight. Similar results were also observed by Iqbal and Chauhan (2003).

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