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SALINITY EFFECTS ON SEEDLING GROWTH AND YIELD COMPONENTS OF DIFFERENT INBRED RICE LINES

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Abstract

Water culture studies of short (seedling stage) and long term (maturity) stage were conducted to evaluate the effect of different levels of salinity (0, 50, 75 mM NaCl) on the growth, yield and yield components of different inbred rice lines. Studies at seedling stage showed significant growth reduction in term of leaf mortality and shoot fresh weight in all tested lines under salinity. However, the rate of reduction varied among different lines. Variable responses to salinity have been observed at vegetative and reproductive stages. The lines which have shown tolerance at seedling stage exhibited greater reduction in their grain production. All yield contributing characters like fertility, tiller numbers, panicle number and panicle length were significantly reduced under salinity. Among these contributing characters sterility was found to be major cause of yield losses under saline conditions.

Introduction

Salinity is a major factor reducing plant growth and productivity throughout the world. Approximately 10% of the world's 7 x 10^9 ha. arable land surface consist of saline or sodic soils. The percentage of cultivated land affected by salts is even greater. Of the 1.5 x 10^9 ha. Cultivated lands, 23% are considered saline and another 37% are sodic and it has been estimated that one-half of all irrigated lands (2.5 x 10^8 ha.) are seriously affected by salinity and water logging (Francois & Maas, 1999). This problem is more serious in the agriculture of south and southeast Asia, which accounts for more than 90% of world rice production are worstly affected by salinity (320 mha) (Aslam *et al.*, 1993).

Rice is rated as a salt sensitive crop (Maas & Hoffman, 1977; Shannon *et al.*, 1998). Although, salinity affects all stages of the growth and development of rice plant and the crop responses to salinity varies with growth stages, concentration and duration of exposure to salt. In the most commonly cultivated rice cvs., young seedlings were very sensitive to salinity (Flowers & Yeo, 1981; Lutts *et al.*, 1995). There are other reports where grain yield is much more depressed by salt than the vegetative growth (other than that of very young seedlings). Yield is a very complex character which comprise of many components and these yield components are related to final grain yield which are also severely affected by salinity. Panicle length, spikelets per panicle and 1000-grain weight are significantly affected by salinity (Cui *et al.*, 1995; Khatun *et al.*, 1995; Khatun and Flowers, 1995).

Inspite of these extensive studies of salinity on rice, our knowledge of the quantitative effect of salinity on rice seedling growth and yield components and interrelationship among yield components is limited. The present study was therefore, undertaken to determine the effects of salt levels and stress duration on seedling growth to analyze the salt sensitivity of different yield components and to identify the most important yield component(s) responsible for reduction in grain yield of rice crop.

Materials and Methods

Short and long term water culture experiments were conducted to study the effect of sodium chloride salinity at different growth stages of the rice plants. The seeds of six inbred rice lines of a cross IR55178 were obtained from International Rice Research Institute, Manila, Philippines. Seedlings for two experiments were grown separately. For short duration studies at early seedling stages, seeds of six inbred lines alongwith a known tolerant check a locally developed (Shua-92) were surface sterilized with 1% commercial bleach for 30 minutes. These were then thoroughly washed with distilled water three to four times. After rinsing these seeds were planted on a nylon netted frame (5” x 7”) fitted in 2.5 L solution capacity plastic container filled with culture solution (Yoshida *et al.*, 1971). These boxes were covered and placed for germination in a green house at $35^o C \pm 5$ in the month of May. Transplanting was done when the seedling were of 7 days and salinized at the age of 14 days with appropriate amount of sodium chloride to make a concentration of 50 and 75mM sodium chloride salinity.

After giving an exposure of salinity treatment for the period of one and two weeks, number of dead leaves per plant, were counted and percent increase in mortality of leaves were calculated comparing the plants growing under non-saline conditions. At each harvest, 5 seedlings per treatment were randomly sampled from surviving plant. The fresh weights of seedlings were measured at each harvest. For the second experiment, seeds were sown in normal soil under field condition, where these seedlings were raised for six weeks. The seedlings were then uprooted and transplanted in cemented tanks (9 x 1.2 meters size) filled with river sand. These seedlings were planted at a distance of 30 cm between plants and 15 cm between rows under hydroponically controlled conditions. Nitrogen, Phosphorus and Potassium @ of 120 kg N as urea, 60 kg P as DAP and 60 kg K ha^{-1} as KNO_3 was mixed thoroughly in the upper 6 inches of sand in tanks. These tanks were irrigated with $1/4^{th}$ strength Hoagland solution (Hoagland & Arnon, 1950) and the plants were allowed to grow under these conditions for one week. Thereafter, nutrient solution supplemented with 50mM NaCl (corresponding to EC 6 dS/m) was applied in 4 tanks, whereas the other four tanks were continued to receive non-saline solution which served as control. Electrical conductivity of the nutrient solutions were regularly monitored and adjusted. At maturity the growth, yield and yield contributing parameters such as plant height, number of productive tillers, straw weight, panicle length, number of grains/panicle, sterility %, grain yield and 1000 grain wt. were measured.

Results and Discussion

Salinity effects on mortality of leaves: The results of short duration studies at early seedling stage showed that salinity caused a significant reduction in seedling growth very soon after transplanting in a saline solution. Depending upon concentration of salt and duration of exposure, an increased mortality of leaves was observed in all the tested lines. The symptoms of leaf necrosis and wilting started to appear from the basal leaf, just after 3 to 4 days of exposure of salinity when compared with non-saline treatments. The percentage of leaf mortality increased from 0-300% in salt sensitive lines just after the exposure of one week to salinity (Table 1). These effects became more pronounced as the duration of exposure was increased (2 weeks).

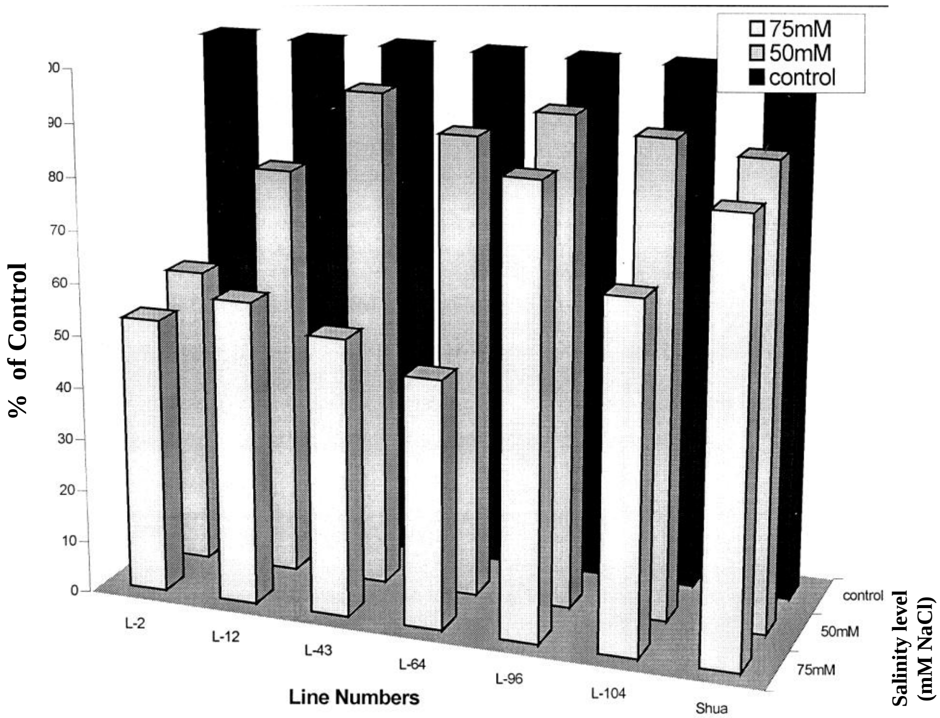

Fig. 1. Shoot growth of different rice lines at the exposure of one week salinity.

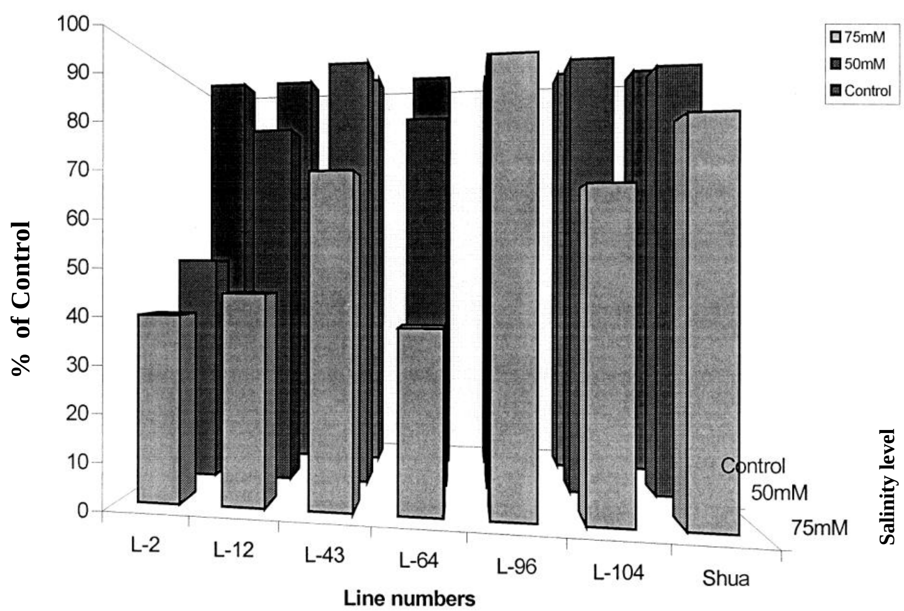

Fig. 2. Shoot growth of different rice lines at the exposure of two week salinity.

Significant variability in leaf mortality was observed among different lines at each level of salinity (50 and 75mM NaCl). Rice cvs., L-96 and Shua-92 exibited comparatively less mortality in leaves, while L-64, L-2 and L-12 showed the highest mortality at highest salinity level (75mM NaCl), when compared with their respective controls. In addition to this increase over control, when comparison were made with respect to total number of leaves per plant (7 leaves) present at this stage, it was observed that there were less than 40% leaf mortality in rice cvs., L-96 and Shua-92. In L-104 and L-2 almost all leaves began to die at 75mM NaCl at the exposure of two weeks salinity when these plants were 4 weeks old.

Salinity effects on seedling growth: Salinity caused a significant reduction in seedling growth with varying degree of variability among these lines. The fresh weight of all lines decreased as the level of salinity increased from 50 to 75mM NaCl. At 50mM NaCl the highest reduction (50%) was observed in L-2 at the exposure of one week salinity, while other lines exhibited comparatively less reduction at this time (Fig. 1). In salt sensitive lines, this reduction in growth became more pronounced with the passage of time even at the lower level of salinity. After 14 days of salinity treatment, the higher salinity level (75mM NaCl) resulted in a significant reduction in seedling growth when compared with control (Fig. 2) where L. No. 12, L. No. 2 and L. No. 64 exhibited 55, 65 and 62% reduction, respectively, while the least reduction in fresh weight was observed in L. No. 96 (7%).

At lower level (i.e. 50mM NaCl) of salt, the comparatively less reduction in their fresh weights were observed even at the exposure of two weeks salinity. This has indicated that plants affected by salts at lower concentration can tolerate salt stress for longer duration before significant reduction of seedling growth occurs (Zeng & Shannon, 2000).

Salinity reduces the growth of plant through osmotic effects, reduces the ability of plants to take up water and this causes reduction in growth. There may be salt specific effects. If excessive amount of salt enter the plant, the concentration of salt will eventually rise to a toxic level in older transpiring leaves causing premature senescence, and reduced the photosynthetic leaf area of a plant to a level that can not sustain growth (Munns, 2002).

Salinity effects on yield and yield components: Most of the yield contributing components measured were significantly reduced at 75mM NaCl when compared with control (Fig. 3). These components were least affected (10-20%) at 50mM NaCl in all tested lines except in L. No. 64, where an approximate reduction of 50% was observed in all contributing components which resulted in severe reduction in their grain yield (77%) at lower level of salinity. The line Nos. 12, 96 and Shua exhibited less than 10-20% reduction in all yield contributing components, least in their grain yields. Fertility of grain was observed as a very important contributory factor to yield. It was observed that at less than 20% reduction in yield contributing components (other than fertility), only a reduction of 10-15% in fertility caused significant differences in the grain yield (12 – 46% reduction) in line nos. 43 and 104.

At the higher salinity level (75 mM NaCl) when these yield components were compared on the basis of % reduction with their respective controls, a severe reduction in all components was observed in all tested lines. Among all these contributing components studied, the fertility of grain was found most severely affected and thus causing significant reduction in total yield of grain. In addition to fertility, panicle length

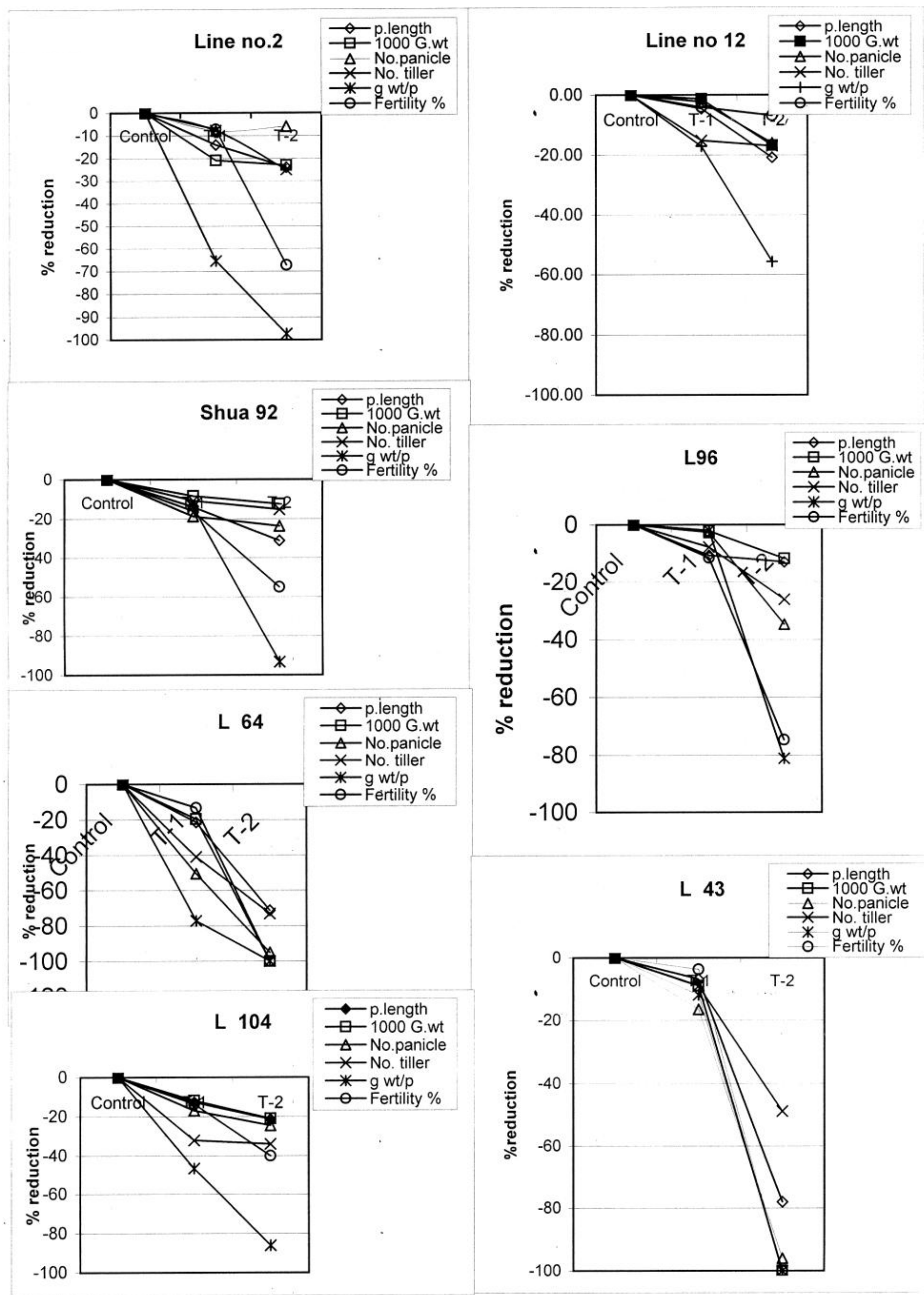

Fig. 3. Salinity effects on yield and yield components in different inbred rice lines.

and panicle numbers were two important affected characters contributing in grain yield. Comparison among the lines have shown that the highest reduction in yield contributing components were observed in L. No. 64 and L. No. 43 (i.e. > 50%) with 100% sterility in grain weight (producing no fertile grains) at 75mM NaCl salt level (Fig. 3), which resulted in sharp decline in their grain weights (Table 2). Most of the lines, which were exhibiting tolerance at early seedling stage (Fig. 2) suffered greater than 80% reduction in their grain yield at higher salinity level (75mM NaCl). This suggests that rice is more sensitive to salt at the reproductive stage than at the vegetative stage and these observed effects of salinity on yields were functions of both salt level and duration of exposure.

The magnitude of salt induced yield losses could not be attributed to single factor. Different physiological, biochemical factors at different stages of rice plants may be involved. One factor may be the over all control mechanism (before flowering) of sodium uptake through root properties and its subsequent distribution in different vegetative and floral parts especially in leaves where it causes leaf mortality thereby reduces transportation of total assimilates to the growing region (Munns, 2002).

The severe inhibitory effects of salts on fertility may be due to the differential competition in carbohydrates supply between vegetative growth and constrained its distribution to the developing panicles (Murty & Murty, 1982), whereas other is probably linked to reduce viability of pollen under stress condition, thus resulting failure of seed set (Abdullah *et al*., 2001). The decreased harvest index with the increase of salinity was consistent with this hypothesis (Table 2).

It may be concluded that the reduction in panicle numbers, panicle length and sterility were the major causes of yield loss as a significant positive correlation exists between panicle length (0.714) number of panicle (0.745) and fertility % (0.717) with grain yield.

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