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Salinity and Waterlogging Interaction in Wheat

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Abstract: Green house studies were conducted to assess the effect of different moisture and salinity regimes on germination; plant height and grain yield of wheat LU 26 S. Four moisture levels (M_1 = 20, M_2 = 40, M_3 = 60 and M_4 = 100% of saturation percentage) and four salinity levels (S_1 = control, S_2 = 10, S_3 = 20 and S_4 = 30dS m^{-1}) were tested. Results indicated that germination, plant height and grain yield decreased progressively with increase in salinity. Total germination percentage increased up to 40% moisture content beyond which it registered a decrease. Maximum plant height and grain yield per plant was noted at 60% moisture combination with all the salinity levels were minimum values were obtained at 100% soil moisture except in case of control. Sodium and chloride concentration in the second leaf exhibited a progressive increasing trend with increase in salinity. Maximum concentrations of these ions were, however, recorded at 100% moisture level followed by 20% soil moisture, while at 40% and 60% soil moisture levels minimum accumulations were observed. Maximum k^+ in leaves was determined at 60% moisture, which decreased with increase in salinity.

Key words: Waterlogging, salinity, wheat growth, ion uptake

Introduction

High salinity and low oxygen/high moisture content in root zone often occur together both in poorly drained irrigated soil and in natural situations of salt marshes, coastal swamps and low lying areas. The responses of plant to high salinity and low soil aeration have been studied separately and reviewed widely (Flowers *et al.,* 1977; Wyne Jones, 1985; Jackson, 1977). Waterlogging results in oxygen deficit, accumulation of toxins and phyto-toxins, decrease in energy dependent ion transport in roots, change in phyto-hormone production by roots and deceased root conductivity to water. The injuries due to these mechanisms include leaf chlorosis, cell-lysis, desiccation, growth inhibition, leaf senescence, epinasty, mineral nutrient deficiency, water deficiency, stomatal closure, reduced photosynthesis and wilting (Drew 1983). A saline environment may expose plants to three types of stresses; osmotic stress, specific ion toxicity and ionic imbalances (Wyne Jones, 1985). But with high external salinity and low root zone oxygen, growth may be seriously reduced and salt uptake may increase. In addition, patterns of ion distribution within the plant may be altered compared with a salinized plant growing in well-aerated conditions, and the plant will be adversely affected. Germination is delayed and decreased with increase in salinity in wheat (Sung, 1981). Aceves *et al.* (1975) reported that soil oxygen and osmotic potential stresses affected germination of wheat. Recent studies of Nawaz *et al.* (2000) indicated that carbon dioxide assimilation rate of wheat varieties (Blue silver & 7-Cerrus) decreased with the imposition of salinity, hypoxia and their combination. Transpiration rate and stomatal conductance also decreased with hypoxia indicating less availability of water but salinity showed no response. Blue silver variety proved more tolerant than 7-Cerrus.

Salinity and waterlogging acting together frequently cause damage in excess of that found with either salinity or waterlogging alone. In *Phaseolus vulgaris* and wheat exposed to 40-120mol m^{-3} NaCl, symptoms of salt damage appeared in the leaves within 2-5 days of the onset of waterlogging (West and Taylor, 1980). Mashhady *et al.* (1982) found that the vegetative growth of wheat and triticale were affected by salinity and waterlogging treatments. Plant takes up Na^+ and Cl^- to the shoot (leaves) at an increased rate under saline- waterlogged conditions (Barret - Lennard, 1986). Saqib *et al.* (2000) reported that salinity as well as sodicity caused a significant reduction in growth parameters like shoot weight and shoot length. Ion uptake of Na and Cl increased while K and K: Na ratio decreased significantly in leaves of all the wheat genotypes.

This experiment was conducted to investigate the combined and separate effects of different salinity and waterlogging levels on the growth and ion uptake of wheat (LU 26 S).

Materials and Methods

The experiment was conducted during the year 1999 in factorial arrangement with completely randomized design (CRD), having four moisture levels (M_1 = 20, M_2 = 40, M_3 = 60 and M_4 = 100% of saturation percentage), four salinity levels (S_1 = control, S_2 = 10, S_3 = 20 and S_4 = 30dS m^{-1}) and four repeats. The experiment was conducted in 4 kg plastic post. Drip irrigation system was followed for a uniform distribution of canal water in the pots. Evaportranspiration losses of water were made up by watering various pots to a constant weight daily. The difference in weight due to plant growth was accounted for by taking the weight of plants from the additional non-planted pots. Seed emergence of wheat cv. LU 26 S was recorded daily for 22 days in each pots. The crop was harvested at maturity for grain yield and chemical analysis. Leaf sampling was done at grain development stage for chemical analysis. All the data were put to statistical processing for testing the significance of differences (Steel and Torrie, 1986).

Results and Discussions

Seed Germination: Increase in salinity decreased the mean germination percentage of wheat seed significantly (Table 1). In salinity control pots maximum germination was recorded at M_3, which was at par with M_1 and M_2 but significantly higher than M_4 having only 2.5% germination. With Ec_e 10dS m^{-1} the maximum germination was recorded at M_2 that was significantly greater than all other moisture levels. This was followed by M_1, M_3 and M_4 with 3.8% germination. The highest salinity level created drastic differences in germination percentage and the highest germination obtained in M_2 was only 55% followed by M_1 (12.5%) which was similar statistically with M_3 and M_4, each having germination. It may be inferred that combined effect of salinity and waterlogging proved more severe. Aceves *et al.* (1975) also found that combination of high salinity with low oxygen depressed germination below economic level.

Plant Height: The maximum mean plant height of wheat was recorded in control followed by S_2 which was at par with S_3 whereas minimum was recorded at S_4 (Table 2). Thus, salinity exerted a directly negative effect on plant growth. Ahmad *et al.* (1985) also reported that plant height of rice decreased with increasing salinity levels. Wheat plants had the maximum height at M_3, which was at par with M_2 but significantly greater than M_1 and M_4 where 36 cm and 31.6 cm plant heights were recorded, respectively. Kolbasina and Tsova (1981) concluded that flooding/Waterlogging in spring wheat at tillering or shooting stage decreased plant height.

Table 1: Germination percentage of wheat (LU 26 S) under different soil salinity and moisture regimes (average of 4 repeats)

Salinity levels	Moisture levels (percent of saturation percentage) (dS m^{-1})				
	M_1 = 20	M_2 = 40	M_3 = 60	M_4 = 100	Mean
Control	93.8a	92.5a	98.8a	2.5e	71.9A
10	80.0a	93.8a	78.8ab	2.5e	63.8A
20	38.8d	71.3bc	13.8e	3.8e	31.9B
30	12.5e	55.0cd	2.5e	2.5e	18.1C
Mean	56.3B	78.1A	48.4B	2.8C	

Interactions are non-significant at 5% level of probability.

Table 2: Plant height (cm) of wheat (LU 26 S) under different soil salinity and moisture regimes (average of 4 repeats)

Salinity levels (dS m^{-1}	Moisture levels (percent of saturation percentage)				
	M_1 = 20	M_2 = 40	M_3 = 60	M_4 = 100	Mean
Control	51.4	68.6	77.7	62.5	75.0A
10	41.8	61.6	66.2	30.8	50.0B
20	37.9	41.0	47.2	29.2	38.8B
30	12.9	18.1	29.6	4.0	16.2C
Mean	36.0B	47.3AB	55.2A	31.6B	

Interactions are non-significant at 5% level of probability

Table 3: Grain yield (g plant $^{-1}$) wheat under different soil salinity and moisture regimes (average of 4 repeats)

Salinity levels (dS m^{-1}	Moisture levels (percent of saturation percentage)				
	M_1 = 20	M_2 = 40	M_3 = 60	M_4 = 100	Mean
Control	1.3cd	2.5b	3.6a	1.9bc	2.3A
10	0.7de	1.8bc	2.0bc	0.3e	1.2B
20	0.3e	0.5e	0.6de	0.1e	0.4C
30	0.07e	0.07e	0.11e	0.001e	0.06C
Mean	0.6C	1.1B	1.6A	0.6C	

Significance level= 5%

Table 4: Sodium concentration (mg g^{-1}) dry plant material) in the second leaf* of wheat cv. US 26 S under different soil salinity and moisture regimes (average of 4 repeats)

Salinity levels (dS m^{-1})	Moisture levels (percent of saturation percentage)				
	M_1 = 20	M_2 = 40	M_3 = 60	M_4 = 100	Mean
Control	1.8g	1.1g	0.9g	6.6fg	2.6C
10	3.4g	2.1g	1.5g	11.1ef	4.6C
20	14.8de	3.5g	6.0g	21.5d	11.4B
30	42.7b	33.7c	30.7c	62.8a	42.5A
Mean	15.7B	10.1C	9.8C	25.5A	

Significance level= 5%
*Leaf next to flag leaf.

Table 5: Potassium concentration (mg g^{-1}) in the second leaf* of wheat (LU 26 S) under different soil salinity and moisture regimes (average of 4 repeats)

Salinity levels (dS m^{-1})	Moisture levels (percent of saturation percentage)				
	M_1 = 20	M_2 = 40	M_3 = 60	M_4 = 100	Mean
Control	22.3	26.1	23.7	17.7	22.4 A
10	18.2	20.4	22.1	13.6	18.6 B
20	16.2	20.7	20.9	12.3	17.5 B
30	14.8	9.6	19.1	8.3	12.8 C
Mean	17.9 B	19.1 B	21.5 A	12.9 C	

Interactions are non-significant at 5% level of probability
* Leaf next to flag leaf.

Grain Yield: Increase in salinity decreased the mean grain yield of wheat per plant significantly (Table 3). With no artificially created Salinity (S_1= control) and moisture level M_3 wheat gave significantly the highest grain yield followed by M2 which was at par with M4 producing 1.9 g, grains. The grain yield at M_1 was the least of all but it was at par with M_4. At EC_e 10ds m^{-1} the recorded grain yield was 2.0 g, which remained at par with M_2 but significantly greater than M_1 and M_4 both the latter were assessed as similar. At EC_e 20dS m^{-1}, wheat gave 0.6 g grain yield per plant when combined with M_3, followed by M_2 which was statistically similar to M1, and M_4 having 0.3 g and 0.1 g grain yields, respectively. The highest salinity level with M_3 cut the grain yield to only 0.11g that was non-significantly different from M_1, M_2 and M_4 giving 0.07 g; 0.07 g and 0.001 g grain yields per plant respectively. Hence, an increase in moisture beyond 60% or less than that was injurious for wheat plant. When the salinity level was too high the vegetative growth retards at increased levels of salinity and moisture (Mashhady *et al.*, 1982) which affects the grain yield in wheat and Triticale also due to adverse effect on N, P and K uptake. Cannell and Belford (1992) said that yield was depressed by waterlogging in winter wheat. Data of the experiment being reported and results of earlier worker thus agree and it may be safely concluded that combination of salinity with the excessive or restricted moisture proves harmful to the plant growth as well as grain production in wheat crop.

Table 6: Chloride concentration (mg g^{-1} dry plant material) in the second leaf* of wheat (LU 26 S) under different soil salinity and moisture regimes (average of 4 repeats)

Salinity levels (dS m^{-1})	Moisture levels (percent of saturation percentage)				
	M_1 = 20	M_2 = 40	M_3 = 60	M_4 = 100	Mean
Control	9.4h	9.0h	11.2gh	10.9gh	10.2D
10	15.2fgh	11.4gh	11.6gh	17.5fg	13.9C
20	26.9e	14.9fgh	21.8ef	38.6d	25.5B
30	62.8b	55.9c	59.7bc	82.8a	65.3A
Mean	28.6B	22.8C	26.1B	37.5A	

Significance level= 5% * Leaf next to flag leaf.

Sodium concentration in second leaf of wheat: Each increase in salinity level above EC_e 10dS m^{-1} resulted in a significant increase in sodium concentration in second leaf of wheat (Table 4). It has also been reported by earlier workers that higher salinity produced greater leaf concentration of sodium in certain wheat and wheat seedlings (Carlos and Bingham, 1973). In control, the maximum sodium concentration was found when combined with M_4 followed by M_1, M_2 and M_3 in the descending order, the differences being non-significant statistically. At EC_e 10ds m^{-1} the maximum sodium concentration was obtained at M_4 that was significantly higher then all other moisture levels at this salinity level. The combination of EC_e 20dS m^{-1} and M_4 moisture gave the maximum sodium that was at par with M_1 but significantly higher than M_3 and M_2 which were similar statistically. At the highest salinity the maximum sodium accumulation was observed at M_4, which was significantly higher than M_2 with 33.7mg g^{-1} and M_3 with 30.7mg g^{-1} leaf sodium. Letey *et al.* (1965) concluded that sodium concentration in leaves of wheat increased significantly due to decreased soil oxygen. Hence, there was an agreement in between the results of present studies and those of past workers.

Potassium concentration in the second leaf of wheat : Mean potassium concentration in second leaf of wheat (Table 5) was the maximum in control, which was significantly higher than all other salinity levels. This was followed by S_2 and S_3 with 18.6 and 17.5 mg g^{-1} leaf potassium. The minimum leaf potassium was found in S4 that was significantly lower than all other salinity levels. Maximum concentration of this ion was found with moisture percentage of 60%, which was followed by 40 and 20% when different moisture levels were considered. The 100% level induced the highest harmful effect because minimum K was taken up here. Results of Rashid (1978) also supported these findings.

Chloride concentration in the second leaf of wheat: Mean chloride concentration increased significantly as the salinity increased (Table 6). At S_1 and S_2, the differences in chloride concentration at various moisture levels were non-significant while in S_3 and S_4 significantly highest Cl^- concentrations in wheat leaf were recorded under saturated soil conditions (M_4). This was followed by $M_1 > M_3 > M_2$. The differences between M_2 and M_3 were statistically non-significant. Letey *et al.* (1965) found that chloride concentration in barley decreased with increasing oxygen supply. West and Taylor (1980) reported that in barley shoots anaerobiosis increased Na^+ and Cl^- concentration at high salinity.

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