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Testing of Wheat (*Triticum aestivum* L.) Genotypes Against Salinity and Waterlogging

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Abstract: A pot experiment was conducted to see the effect of salinity and waterlogging on five wheat genotypes. The experiment consisted of four treatments i.e., control (non-saline non-waterlogged), waterlogging, saline and salinity × waterlogging. NaCl salinity was developed prior to sowing and waterlogging was created two weeks after germination. At booting stage fully expanded second to flag leaf was collected for Na^+, K^+ and Cl^- analysis. At harvesting grain and straw yield was recorded. The genotypes SARC-6 and Pasban-90 were found to be tolerant producing high grain and straw yield under all treatments. SARC-6 was able to manage the high concentration of Na^+ and Cl^- while Pasban-90 accumulated low Na^+ and Cl^- concentration possibly due to exclusion of these ions. The sensitive genotype SARC-5 produced low yield and could not manage the high concentration of Na^+ and Cl^-.

Key words: Salinity, waterlogging, wheat jenotypes

Introduction

The incidence of salinity and waterlogging is a common feature of irrigated agriculture in arid and semi-arid regions of the world including Pakistan. It has been estimated that 4×10^8 km^2 of the world's land is salt-affected (Flowers *et al*., 1977), a substantial portion of which is subjected to prolonged, intermittent or occasional waterlogging (Barrett-Lennard, 1986). The salt-affected area in Pakistan is 6.67×10^6 ha (Khan, 1998). Salinity and waterlogging co-exist in an area of 1.16×10^6 ha (Qureshi *et al*., 1993).

In the salt-affected soils of the rice tract, application of irrigation or rains during summer and winter seasons create surface ponding which leads to temporary waterlogging (hypoxia). Wheat is the common crop following rice in these fields. Since wheat unlike rice is sensitive to hypoxia, so its yield is seriously decreased (Parveen *et al*., 1991).

The typical response of wheat to waterlogging includes early leaf senescence, slow shoot growth, cessation of seminal root elongation and/or decreased nutrient uptake (Trought and Drew, 1980). Salinity affects plant growth through numerous complex interactions including specific ion effects, osmotic effects and induced nutrient deficiency (Wyn Jones and Storey, 1981; Flowers *et al*., 1991).

Due to insufficient and poor quality of irrigation water, high cost of amendments and drainage, the reclamation approach is not feasible (Qureshi *et al*., 1990). Effective utilization of salt-affected and waterlogged soils involves the cultivation of salt and waterlogging tolerant crop cultivars/plant species, which produce economic yields under such adverse soil environments. Keeping all this in view the present study was planned to test five wheat genotypes against salinity and waterlogging interaction.

Materials and Methods

Five wheat genotypes (SARC-1, SARC-5, SARC-6, N-30 and Pasban-90) were tested against salinity and waterlogging in soil culture. Experiment included four treatments with three replications. The treatments were; control (EC_e 1.13 dS m^{-1}, non waterlogged), waterlogged, saline (EC_e 15.0 dS m^{-1}) and saline-waterlogged. Soil with an EC_e of 1.13 dS m^{-1} was collected from a field and was ground and sieved through 2 mm sieve. For salinity treatments salinity was developed prior to filling the soil in pots by adding calculated amount of NaCl. While the pots for control and non-saline waterlogged treatment were filled with non-saline soil. Each pot was filled with 10 kg of soil. The seeds were imbibed for 48 hrs. in continuously aerated water Imbibed seeds were sown in pots with soil moisture at field capacity. Fertilizer at 120:60:60: kg ha^{-1} NPK was applied as Urea SSP and K_2SO_4. Half of N and whole P and K were applied at sowing while 1/2 of the N was applied at booting stage. Waterlogging was created two weeks after germination and the soil was kept saturated with a thin layer of water on surface during the whole experimental period, while ambient moisture was kept in non-waterlogged treatments.

At booting stage fully expanded 2nd to flag leaf from each plant was collected in separate Eppendorf centrifuge tubes which were stored at freezing temperature. Frozen samples were thawed and crushed using a metal rod and centrifuged at 6500 rpm for 10 minutes. Leaf sap was diluted as required and Na^+ and K^+ were measured using Jenway PFP-7 Flame Photometer, while Cl^- was determined using Chloride Analyzer (Corning-926). Crop was harvested at maturity and data regarding grain and straw yield per pot were recorded. Statistical analysis was made according to completely randomized design as described by Steel and Torrie (1980), while treatment means were compared using DMR test (Duncan, 1955).

Results

Growth: Hypoxia and salinity reduced the grain yield but their interaction had more pronounced effect. Hypoxia decreased the grain yield of all the genotypes except SARC-6 and N-30 which produced more grain yield compared to their respective controls. Under hypoxia SARC-1 produced the highest while SARC-5 the lowest grain yield. Under both saline and saline × hypoxic treatments, SARC-6 produced the highest while SARC-5 produced the lowest grain yield. However, on relative basis, the grain yield of N-30 was the highest under all three stress levels. The genotype SARC-5 produced the lowest relative grain yield under all the treatments Salinity and hypoxia individually reduced the straw yield while the most adverse effect on straw yield of all the genotypes was observed under salinity × hypoxia interaction. The genotype SARC-6 produced the highest while SARC-5 produced the lowest straw yield under all the stress conditions. On relative basis, the genotype N-30 produced the highest relative straw yield under hypoxia followed by SARC-6 and SARC-1. Under saline treatment the genotype SARC-1 produced the highest

Table 1: Effect of salinity and water logging on growth

Genotypes Grain yield (g per pot)	Control	Hypoxia	Saline	Salinexhypoxia
SARC-1	15.68a	13.45a (86)	7.13 a (46)	3.73 b (24)
SARC-5	15.67a	6.34 b (41)	5.12 b (33)	1.70 c (11)
SARC-6	10.73ab	11.40a (107)	8.51 a (79)	5.46 a (40)
N-30	8.4913	10.19 ab (120)	7.29 a (86)	4.23 ab (50)
Pasban-90	13.73ab	10.81 a (79)	7.33 a (54)	5.70 a (42)
Mean	12.73A	10.49 B	7.08 C	4.13 D
Straw yield (g per pot)				
SARC-1	16.68a	14.01 b (84)	12.28 b (74)	3.18 b (19)
SARC-5	24.2913	11.25 b (47)	11.18 b (46)	2.56 13 (11)
SARC-6	4-4.66a	37.38 a (84)	28.18 a (63)	11.53 a (28)
N-30	21.11 be	18.60 b (88)	12.64 b (59)	3.57 b (17)
Pasban-90	24.04b	17.07 b (71)	13.36 b (56)	3.82 b (16)
Mean	26.17A	19.67 B	15.53 C	4.93 D

Mons with different letters differ significantly according to DMR Test ($p \leq 0.05$) Values in () are % of control
Saline: $EC_e = 15$ dS m^{-1} with NaCl

Table 2: Effect of salinity and water logging on chemical compoisition

Genotypes Na^+ concentration (mol m^{-3})	Control	Hypoxia	Saline	Salinexhypoxia
SARC-1	4.16 b	14.50 ab	26.63 b	35.39 b
SARC-5	4.94 b	15.94 ab	16.00 be	47.49 ab
SARC-6	10.11 a	24.22 a	47.55 a	61.77 a
N-30	9.61 a	17.83 ab	26.3313	45.52 ab
Pasban-90	6.66 ab	9.1613	13.05 c	34.77 b
Mean	7.06 D	16.33 C	25.91 B	44.99 A
K^+ concentration (mol m^{-3}) in expressed leaf sap				
SARC-1	149.66 a	131.38 b	134.72 b	117.52 b
SARC-6	159.99 a	136.98 ab	165.83 ab	88.11 c
SARC-6	161.11 a	122.49 13	199.44 a	80.27 c
N-30	183.83 a	158.61 a	170.14 ab	138.33 ab
Pasban-90	186.10 a	154.39 a	179.30 a	152.22 a
Mean	168.10 A	142.40 B	169.80 A	115.29 C
Cl^{-1} oncentration (mol^{-3}) in expressed leaf sap				
SARC-1	69.55	78.08	85.13	102.96
SARC-5	75.39	63.53	115.88	117.83
SARC-6	71.35	103.75	84.08	155.24
N-30	62.43	76.83	113.45	141.54
Pasban-90	60.28	82.93	95.30	104.53
Mean	67.80 C	80.99 C	98.79 B	124.4 A

Means with different letters differ significantly according to DMR Test ($p \leq 0.05$)
Saline: $EC_e = 15$ dS m^{-1} with NaCl

relative straw yield followed by SARC-6 whose relative straw yield was the highest under salinity × hypoxia treatment. The genotype SARC-5 produced the minimum absolute and relative straw yield under all the stress levels.

Chemical composition: Presence of salts in the growth medium, increased the Na^+ concentration in leaf sap of all the genotypes and the highest Na^+ concentration was observed when hypoxia was imposed in addition to salinity. The genotype SARC-6 accumulated the highest while Pasban-90 the lowest concentration of Na^+ under all the treatments. The Na^+ concentration of N-30 under all treatments while that of SARC-5 under hypoxia and salinity × hypoxia treatments was closer to that found in SARC-6, while under salinity alone N^+concentration in SARC-5 was lower.

The maximum reduction in K^+ concentration was caused by salinity × hypoxia interaction followed by hypoxia and salinity alone. On an over all average basis, Pasban-90 accumulated the highest while SARC-1 the lowest K^+ concentration. The genotype N-30 under hypoxia, SARC-6 under saline and Pasban-90 under saline-hypoxic treatments accumulated the highest K^+ concentration, while SARC-1 under saline and SARC-6 under both hypoxic and saline × hypoxic treatments accumulated the lowest K^+ concentration.

The Cl^- concentration was also the highest under salinity × hypoxia treatment followed by salinity and hypoxia alone. Under hypoxic and saline-hypoxic treatments, SARC-6 accumulated the highest Cl^- concentration. The genotype SARC-5 under hypoxic while SARC-1 under saline-hypoxic treatment accumulated the lowest Cl^- concentration. But under saline treatment SARC-5 accumulated the highest while SARC-6 the lowest Cl^- concentration (Table 1, 2).

Discussion

Growth: Hypoxia generally reduced the grain and straw yield of wheat genotypes except SARC-6 and N-30, whose relative grain yield was higher compared to their respective controls. The better yield of genotypes under hypoxia was perhaps due to the larger percentage of functional aerenchyma in roots (Thomson *et al*., 1992). The genotype SARC-5 produced the minimum grain and straw yield under hypoxia. This was in agreement with the findings of Thomson *et al*. (1992) and Akhtar *et al*. (1994). Reyes *et al*. (1977) reported that reduction in straw yield under hypoxic environment might be due to less oxygen availability that leads to less generation of energy rich compounds like ATP (Tang and Kozlowski, 1982).

Salinity also reduced the grain and straw yield. The genotype SARC-6 was the most tolerant producing maximum and SARC-5 was the most sensitive producing minimum grain and straw yields. This reduction in straw yield under saline conditions could be due to reduced growth as a result of decreased water uptake, toxicity of Na^+ and Cl^- in the shoot cell and reduced photosynthesis (Brugnoli and Lauter, 1991). According to Steppuhn and Wall (1997) root zone salinity affects the growth of wheat and reduces the number of fertile spikes per plant and hence grain yield. The other possible reason of low grain yield could be the reduced grain weight due to poor development of seeds because under saline environment the supply of essential metabolites is limited (Niane, 1987). Data shows that salinity in combination with waterlogging caused a significant reduction in growth of wheat genotypes as compared with individual effects of salinity or hypoxia. Similar effects of salinity and hypoxia on growth of wheat have been observed by Akhtar *et al*. (1994). The genotype SARC-6 was tolerant to salinity or hypoxia alone treatments was also found to be the most tolerant to the interactive effect of these treatments. The genotype SARC-5, sensitive to salinity and hypoxia was also the most sensitive genotype to the combined effect of salinity and hypoxia.

Ionic relations: Waterlogging initially affects root growth and disturbs ion discrimination at the root level, which leads to increased salt uptake and decreased nutrient uptake (Barrett Lennard, 1986). In all the wheat genotypes, presence of salts in the growth medium increased the Na^+ concentration in the leaf sap and imposition of hypoxia over salinity increased further the concentration of Na^+ in leaf sap. This increased salt uptake due to combined effect of salinity and hypoxia is likely to be caused by increased diffusion through damaged membranes and restricted outward active exclusion of Na^+ (Nawaz *et al*., 1998; Barrett-Lennard *et al*., 1999). The genotype SARC-6 accumulated the highest Na^+ concentration in leaf sap under all the treatments, however salinity × hypoxia increased the uptake of Na^+ in this genotype. The genotype N-30 under all stresses and SARC-5 under hypoxia and salinity x hypoxia also accumulated high Na^+ concentration. The leaf Na^+ concentration of SARC-5 under salinity was low. It means hypoxia increased the permeability of root membranes for N^+ in this genotype. Barrett-Lennard *et al*. (1999) reported that hypoxia causes root death and consequent disorganization allows Na^+ and Cl^- to move into the xylem by apoplastic pathways.

Hypoxia also caused a significant decrease in K^+ concentration compared to the aerated conditions. However, K^+ concentration was much more depressed when salinity was combined with hypoxia. The reduction in K^+ concentration under hypoxic conditions in both saline and non-saline environment may be due to limited amount of energy produced due to ethanolic or lactic fermentation in the absence of free O_2 as potassium selectivity is an energy (ATP) consuming process (Akhtar *et al*., 1994). Tolerant genotype SARC-6 accumulated the highest concentration of K^+ under saline treatment and accumulated the lowest concentration of K^+ under saline-hypoxic treatment. This indicated that hypoxia drastically reduced the K^+ selectivity of this genotype. The sensitive genotype SARC-5 showed almost the similar trend of K^+ accumulation as was observed in tolerant SARC-6.

High external salinity also increased the Cl^- concentration in all the genotypes and a further increase was found with the imposition of hypoxia. Increase in chloride concentration under saline hypoxic treatment may result from passive influx of Cl^- due to less generation of ATP under anaerobiosis which is essential for active exclusion of chloride (Barrett-Lennard, 1986; Francois *et al*., 1986).

The tolerant genotype SARC-6 produced the highest grain and straw yield even accumulating high Na^+ and Cl^- concentration under all the treatments. It could be attributed that this genotype managed its Na^+ and Cl^- concentration in a better way either in vacuoles or tissues. Munns *et al*. (1995) reported that tolerant plants can accumulate the toxic ions in the vacuoles of their expanded or expanding tissues and prevent their built up in cytoplasm and thus do not become toxic to enzymes. The genotype Pasban-90 was also tolerant to salinity, hypoxia and their interaction and produced better grain and straw yield maintaining low Na^+ and Cl^- concentration possibly due to exclusion of these ions.

References

Akhtar, J., J. Gorham and R.H. Qureshi, 1994. Combined effect of salinity and hypoxia in wheat (*Triticum aestivum* L.) and wheat-*Thinopyrum amphiploids*. Plant Soil, 166: 47-54.

Barrett-Lennard, E.G., 1986. Effects of waterlogging on the growth and NaCl uptake by vascular plants under saline conditions. Reclamat. Revegetat. Res., 5: 245-261.

Barrett-Lennard, E.G., P. van Ratingen and M.H. Mathie, 1999. The developing pattern of damage in wheat (*Triticum aestivum* L.) due to the combined stresses of salinity and hypoxia: Experiments under controlled conditions suggest a methodology for plant selection. Aust. J. Agric. Res., 50: 129-136.

Brugnoli, B. and M. Lauter, 1991. Effect of salinity on stomatal conductance, phtosythetic capacity and carbon isotope discrimination of salt tolerant cotton and *Phaseolus vulgaris*. Plant Physiol., 95: 628-635.

Duncan, D.B., 1955. Multiple range and multiple F tests. Biometrics, 11: 1-42.

Flowers, T.J., M.A. Hagibagheri and A.R. Yeo, 1991. Ion accumulation in the cell wall of rice plants growing under saline conditions: Evidence for Oertill hypoptesis. Plant Cell Environ., 14: 319-325.

Flowers, T.J., P.F. Troke and A.R. Yeo, 1977. The mechanism of salt tolerance in halophytes. Ann. Rev. Plant Physiol., 28: 89-121.

Francois, L.E., E.W. Maas, T.J. Donovan and V.L. Youngs, 1986. Effect of salinity on grain yield and quality, vegetative growth and germination of semi-dwarf and durum wheat. Agron. J., 78: 1053-1058.

Khan, G.S., 1998. Soil Salinity/Sodicity Status in Pakistan. Soil Survey of Pakistan, Lahore, pp: 59.

Munns, R., D.P. Schachtman and A.G. Condon, 1995. The significance of two-phase growth response to salinity in wheat and barely. Aust. J. Plant Physiol., 22: 561-569.

Nawaz, R.H.Q., M. Aslam, J. Akhtar and S. Parveen, 1998. Comparative performance of different wheat varieties under salinity and waterlogging II: Ionic relations. Pak. J. Biol. Sci., 1: 357-359.

Niane, A.B., 1987. Response of rice to nitrogen split application on a salt-affected soil. Int. Rice Res. Newslett., 12: 27-27.

Parveen, S., R.H. Qureshi and M. Aslam, 1991. Growth response of wheat to salinity and hypoxia. Pak. J. Agric. Sci., 28: 195-198.

Qureshi, R.H., A. Rashid and N. Ahmad, 1990. A Procedure for Quick Screening of Wheat Cultivars for Salt Tolerance. In: Genetic Aspects of Plant Mineral Nutrition, Elbasam, N., M. Damborth and B.C. Laughman (Eds.). Kluwer Academic Publishers, Amsterdam, The Netherlands, pp: 315-324.

Qureshi, R.H., S. Nawaz and T. Mahmoud, 1993. Performance of Selected Tree Species under Saline-Sodic Field Conditions. In: Towards the Rational Use of High Salinity Tolerant Plants: Agriculture and Forestry under Marginal Soil Water Conditions, Lieth, H. and A.A Al Masoom (Eds.). Vol. 2, Kluwer Academic, Netherlands, pp: 259-269.

Reyes, D.M., L.H. Stolzy and C.K. Labanauskas, 1977. Temperature and oxygen effects in soil on nutrient uptake in Jojoba seedlings. Agron. J., 69: 647-650.

Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2nd Edn., McGraw Hill Book Co., New York, USA., ISBN-13: 9780070609266, Pages: 633.

Steppuhn, H. and K.G. Wall, 1997. Grain yield from spring sown Canadian wheat grass grown in saline rooting media. Can. J. Plant Sci., 77: 63-68.

Tang, Z.C. and T.T. Kozlowski, 1982. Some physiological and growth responses of *Betula papyrifera* seedlings to flooding. Physiol. Plant., 55: 415-420.

Thomson, C.J., T.D. Colmer, E.L.J. Watkin and H. Greenway, 1992. Tolerance of wheat (*Triticum aestivum* cvs Gamenya and Kite) and triticale (*Triticosecale* cv. Muir) to waterlogging. New Phytol., 120: 335-344.

Trought, M.C.T. and M.C. Drew, 1980. The development of waterlogging damage in young wheat plants in anaerobic solution cultures. J. Exp. Bot., 31: 1573-1585.

Wyn Jones, R.G. and R. Storey, 1981. Betains. In: Physiology and Biochemistry of Drought Tolerance, Paleg, L.G. and D. Aspinal (Eds.). Academic Press, Sydney, pp: 204.