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An assessment of Iranian wheat (*Triticum aestivum* L.) genotypes under saline and waterlogged compacted soil conditions II: Leaf ion concentrations

Hamid Reza Asgari [*1], **Wim Cornelis** [2] **and Patrick Van Damme** [3]

1. Department of AridRegions Management, Gorgan University ofAgricultural Sciences and Natural Resources, Iran
2. Department of SoilManagement,GhentUniversity, Belgium
3. Department of Plant Production,GhentUniversity, Belgium

Corresponding Author email: Hamidreza.Asgari@gau.ac.ir , Hras2010@gmail.com

ABSTRACT: A pot experiment was conducted to study effects of salinity and waterlogging under soil compaction conditions on grain yield and yield components of wheat. Treatments were arranged in a factorial layout assigned to a randomized complete design with three replications. Treatment combinations included: two sets of compaction levels, i.e. non-compacted and compacted soil; four abiotic stresses, i.e. non-saline aerobic (untreated silt loam texture soil having EC_e = 3 dS m^{-1}); saline × aerobic (S) (EC_e 15 dS m^{-1}); saline × waterlogged (S×W); and waterlogged alone (W) were applied; and two Iranian wheat genotypes i.e. Kouhdasht and Tajan. Compaction was achieved by dropping a 5 kg weight, 20 times from 70 cm height on a wooden block placed on top of soil-filled pots. In non-waterlogged treatments, soil water was maintained at 70% of available water holding capacity (AWHC). Waterlogging was achieved by maintaining water up to 110% of the soil's AWHC for 25 days during tillering stage. S×W caused significantly higher reduction in K^+ concentrationfor both genotypes than other treatments. S×W also resulted in higher leaf Na^+ and Cl^- concentrations in comparison to other treatments. Kouhdasht maintained significantly higher K^+ concentration and K^+: Na^+ ratio at S and S×W treatments than that Tajan (under both non-compacted and compacted soil conditions).

Keywords:Abiotic stresses, ecophysiology, plant tolerance to salinity and waterlogging stresses

INTRODUCTION

Soil compaction is defined as: ''process by which soil grains are rearranged to decrease void space and bring them into closer contact with one another, thereby increasing bulk density'' (Soil Science Society of America, 1996). Soil compaction occurs in all continents, under nearly all climates and soil physical conditions (FAO-AGL, 2000). Intensive farming of crops and animals has spread all over the world and involves shorter crop rotations and heavier machinery that lead to an increase in soil compaction (Poesse, 1992). Several plant characteristics are affected when roots are subjected to conditions of high soil strength [defined as a transient localized soil property that is a combined measure of the adhesive and cohesive qualities of the solid phase of a soil subunit (Soil Science Society of America, 2005)] as a result of compaction (Mapfumo et al., 1998).Adverse effects of a compacted soil horizonon plant growth, nutrientsuptake and yields have been studied by many. For example Oussible et al. (1992) reported that compacting a clay loam soilto a density of 1.52Mgm^{-3} from an initial density of 1.33 Mgm^{-3}resulted in 12 to 23% decrease in grain yield and 9 to 20% decrease in straw yield of wheat (*Triticum aestivum L.*). Similarly, Ishaq et al. (2001a) observed 38 and 9% reductions in wheat grain yield and straw yield, respectively (Ishaq et al., 2001a), and also nutrient concentrationreduction amounting to 12-35% for N, 17-27% for P and up to 24% for K when soil was compacted to a bulk density of 1.93 Mgm^{-3} from an initial bulk density of 1.65 Mg m^{-3} (Ishaq et al., 2001b).Soil compaction mayinterfere with salinity and waterlogging stresses thus changing their effects on plant growthand ion uptak. However, consideration of combination effects of soil compaction, soil salinity and waterlogging on plants is lacking, except for Saqibet al. (2004a, b) in Pakistan. They concluded that soil compaction aggravated negative effect of soil salinity on ion uptake of both wheat (*Triticum aestivum* L.) genotypes, i.e. Aqaab and MH-

97. Salinity×compaction treatment caused significant higher reduction in leaf K^+ concentration and K^+:Na^+ ratio, and also significantly increased leaf Na^+ and Cl^- concentrations of both genotypes as compared to salinity alone.The aim of the present study was to quantify soil compaction effects on leaf ion concentrations of two Iranian wheat genotypes i.e., Kouhdasht and Tajan under saline × waterlogged soil conditions in semi-arid area of Golestan province.

MATERIALS AND METHODS

A pot study was conducted in 2005-2006 in outdoor conditions in the Aqqalla area of northern Golestan province (37° 07' N, 54° 07' E). Mean annual rainfall and evapotranspiration in the area are 386 and 1445 mm, respectively. Treatments were arranged in a 2×4×2 factorial assigned to a randomized complete design with three replications. Treatment combinations included: (i) two sets of compaction levels, i.e. non-compacted and compacted soil; (ii) four abiotic stresses, i.e. non-saline aerobic (normal soil having EC_e = 3 dS m^{-1}); saline × aerobic (S) (EC_e = 15 dS m^{-1}); saline × waterlogged (S×W), and waterlogged alone (W) were applied; and (iii) two wheat genotypes, i.e. Kouhdasht and Tajan. Kouhdasht yield well under salinity whereas Tajan is more sensitive to saline soil conditions (Asgari et al., 2012a). To characterise soil conditions, fifteen sites were randomly selected on an agricultural field. In each site 2-3 sub-samples with approximately 0.5-0.6 kg (wet) weight, were taken manually using a 4 cm diameter Edelman auger. Sampling depths was 0-30 cm, which coincides with the plough layer in the area. The sub-samples were mixed and sieved through a 2 mm sieve before analysis. Soil texture was determined using hydrometer method (Bouyoucos, 1962). Soil organic matter content was determined by the Walkley and Black method (Nelson and Sommers, 1982). Soil bulk density of the 0–30 cm surface layer was progressively determined using the core method (Blake, 1965). Soil pH was determined in a 1:2 (w:v) soil–water extract. Electrical conductivity was measured on a saturated paste. Water content at field capacity and permanent wilting point were determined using pressure chambers. Some physico-chemical properties of the soil at the study site are presented in Table 1. Fifteen seeds were sown in each pot that filling with 8 lit pot^{-1} soil collected from the study area. After germination, three uniform seedlings were selected whereas the rest was uprooted and discarded. For non-waterlogged treatments, soil water was maintained at 70% of available water holding capacity (AWHC). Waterlogging was imposed by keeping pots (without leaching possibility) in hypoxia conditions at tillering stage by adding water daily (up to 25 days) to 110% of AWHC. To generate soil compaction, a 5 kg weight, that controlled by a tripod stand, dropped for 20 times from a 0.7m height on a wooden block placed inside the pot (as a method described by Saqib et al., 2004a, b). At grain maturity, all plants from each pot were harvested. Wheat leaves dried at 70 ℃ and then ground in a mortar with a pestle. Ground leaves were digested with 1 NHCl for 24 hours at 40 ℃, afterwards shaken for 1.5 hours, and filtered manually. Na^+ and K^+ concentrations were determined by flame photometry (Jenway PFP-7, Essex, UK), whereas Cl^- was measured with a coulometric chloride analyzer (Corning 926, Essex, U.K.).

Table. 1 Some physico-chemical properties of the sampling soil

Soil sampling depth (cm)	Soil texture	Clay 0-2 µm (g kg^{-1})	Silt 2-50 µm (g kg^{-1})	Sand 50-2000 µm (g kg^{-1})	OM (g kg^{-1})	Saturated percent (mass%)	Field capacity (mass%)	ECe (dS m^{-1})	pH
0-30	Si-L	14	72	14	1.52	42	24.0	3.0	7.8
30-60	Si-C-L	33	59	8	-	49	28.5	3.9	8.0
60-90	Si-C-L	33	61	6	-	53	28.8	6.2	7.9

OM is organic matter content (not measured for 30-60 and 60-90 cm depths);
EC_e is electrical conductivity on a saturation extract at 25 ℃;
Si-L and Si-C-L are silt loam and silty clay loam soils, respectively.
- Not measured

Statistical Analysis

Completely randomized design (Steel and Torrie, 1980) data thus obtained were statistically analyzed using SPSS computer software (version 12.0). Treatment means were compared using Duncan's Multiple Range Test (Duncan, 1955). A p level of 0.05 was considered in all statistical tests, except when otherwise mentioned.

RESULTS

Leaf Na^+ Concentration

Under non-compacted as well as compacted soil conditions, significant increase in leaf Na^+ concentration of both wheat genotypes, was observed for S and S×W (with significantly higher Na^+ concentration values at S×W) (Fig. 1a). Soil compaction in combination with all abiotic (except for waterlogging) treatments caused significant higher leaf Na^+ concentrations when compared to control treatment. Tajan showed significantly higher leaf Na^+ concentrations at S and S×W than Kouhdasht, under both non-compacted and compacted soil conditions.

Leaf Cl^- Concentration

Under both non-compacted and compacted soil conditions, S and S×W treatments caused significant increase in leaf Cl^- concentration of both Kouhdasht and Tajan (Fig. 1b). Highest Cl^- concentration was promoted by S×W (for both genotypes) as compared to control. Tajan maintained significantly higher leaf Cl^- concentration than Kouhdasht at S and S×W under both non-compacted and compacted soil conditions. Soil compaction significantly aggravated adverse effect of S treatment on leaf Cl^- concentration of both genotypes when compared to salinity treatment under non-compacted soil conditions.

Leaf K^+ Concentration

Except for W, the other abiotic treatments significantly reduced leaf K^+ concentration of both wheat genotypes under non-compacted and compacted soil conditions as compared to control (Fig. 1c). Highest reduction occurred in S×W in comparison to control. Soil compaction significantly accentuated effects of S and S×W on leaf K^+ concentration for both wheat genotypes, as compared to non-compacted soil conditions. Furthermore, soil compaction alone caused a significant leaf K^+ concentration reduction (for both genotypes) as compared to control. Kouhdasht showed significantly higher leaf K^+ concentration than Tajan at S and S×W under both non-compacted and compacted soil conditions.

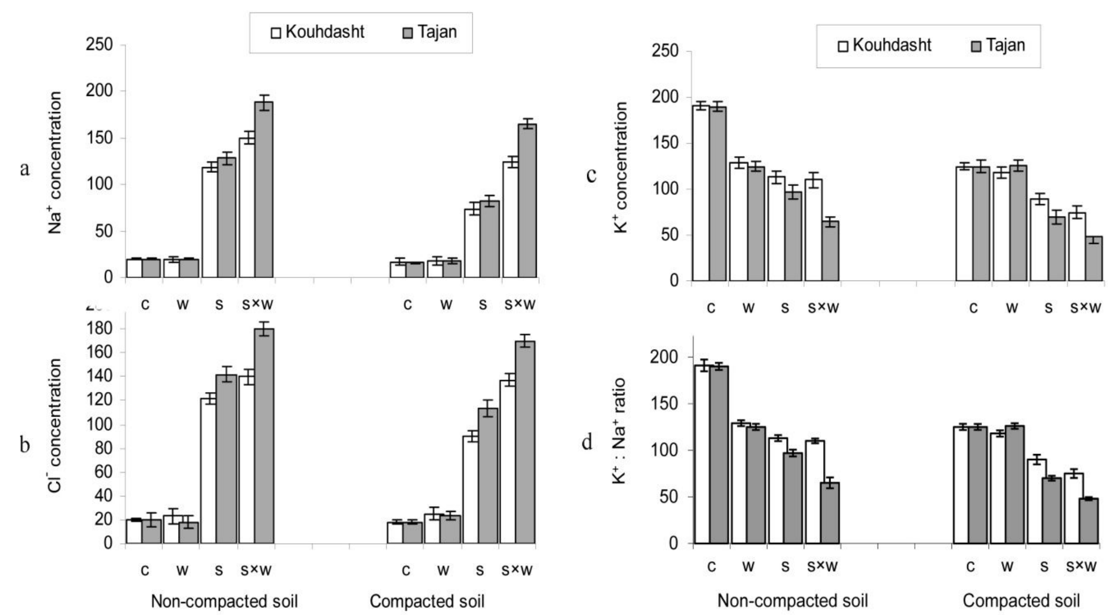

Figure1. Effect of salinity and waterlogging on a) leaf Na^+; b) Cl^- and c) K^+ concentrations; and K^+: Na^+ ratioof two Iranian wheat genotypes under non-compacted and compacted soil conditions. C, W, S and S×W denote relatively control, waterlogging, salinity and waterlogging × salinity respectively; error bars indicate standard deviation.

Leaf K^+: Na^+ Ratio

All abiotic treatments significantly decreased K^+: Na^+ ratio of both wheat genotypes under both non-compacted and compacted soil conditions as compared to control treatment (Fig. 1d). However, similar changes in K^+: Na^+ ratio were caused through S and S×W. Soil compaction significantly aggravated effects of S and S×W in K^+: Na^+ ratio of both wheat genotypes when compared to non-compacted soil conditions. Kouhdasht showed significantly higher K^+: Na^+ ratio than that observed for Tajan at S treatment under non-compacted and at S×W under compacted soil conditions.

DISCUSSION AND CONCLUSION

Salinity × waterlogging caused significantly higher leaf Na^+ and Cl^- concentrations than those documented under salinity and waterlogging treatments, respectively. It also caused significant leaf K^+ concentration and K^+: Na^+ ratio (of both wheat genotypes) reductions as compared to control. In saline × waterlogged soil conditions, the root's ability to exclude Na^+ and Cl^- is reduced because of relatively low energy production following reduced O_2 supply that can also lead to decreased selectivity for K^+ compared to

Na^+(Qureshi and Barrett-Lennard, 1998). These changes result in higher leaf Na^+ and Cl^- and lower leaf K^+ concentration and higher growth reduction under saline × waterlogged conditions when compared to saline or/and waterlogged soil conditions (Hussainet al., 2002; Saqibet al., 2004b). Salinity significantly increased leaf Na^+ and Cl^- concentrations of both genotypes as compared to control. However, waterlogging either under non-compacted and compacted soils did not alter leaf Na^+, Cl^-, K^+ concentrations and K^+: Na^+ ratio in neither of both genotypes as compared to control treatment. Soil compaction significantly aggravated adverse effect of salinity and salinity × waterlogging treatments in leaf Na^+, K^+ concentrations and K^+: Na^+ ratio of both genotypes in comparison to non-compacted soil conditions. Tajan maintained significantly higher leaf Na^+ and Cl^- and less K^+ concentration and K^+: Na^+ ratio than Kouhdasht at salinity and salinity× waterlogging treatments, under both non-compacted and compacted soil conditions. Ability to maintain low Na^+ and high K^+ concentrations in leaves, and K^+: Na^+ discrimination is also correlated with salt tolerance within wheat (Munns and James, 2003; Colmer et al., 2006). Correlations between grain yield and Na^+ exclusion from leaves, along with the associated enhanced K^+: Na^+discrimination, have been shown to occur in wheat (Iqbalet al., 2001; El-Hendawyet al., 2005; Asgari et al., 2012a). Kouhdasht showed better performance than Tajan in saline and saline × waterlogged soil conditions, under both non-compacted and compacted soil conditions. As semi-arid areas of Golestan province often suffer from salt-affected soils and shallow and brackish groundwater, therefore, Kouhdsht would have better survival in this situation in comparison to Tajan.

REFERENCES

Abbasabadi MR.1999. Quantitative assessment of desertification in Aghala-Gomishan plain. M.Sc. Thesis, Department of Natural Resources, University of Tehran (in Farsi).pp: 28-29.

ABS. 2008.http://www.dpi.vic.gov.au. DAV00056 Scoping Study- Final Report.Management options

Akhtar J, Gorham J, Qureshi RH.1994. Combined effect of salinity and hypoxia in wheat (*Triticum aestivum L.*) and wheat-Thinopyrumamphiploids. Plant and Soil, 166, 47-54.

Asgari HR, Cornelis W, Van Damme P. 2012a. Salt stress effect on wheat (*Triticum aestivum* L.) growth and leaf ion concentrations. International Journal of Plant Production, 6 (2), 195-208.

Barrett-Lennard EG. 2003.The interaction between waterlogging and salinity in higher plants: causes, consequences and implications. Plant and Soil, 253, 35-54.

Barzegar AR, Nadian H, Heidari F, Herbert SJ, Hashemi AM. 2006.Interaction of soil compaction, phosphorus and zinc on clover growth and accumulation of phosphorus. Soil and Tillage Research, 87, 155-162.

Blake GR, Hartge KH. 1986. Bulk Density, in A. Klute, ed., Methods of Soil Analysis, Part I. Physical and Mineralogical Methods: Agronomy Monograph, 9, ASA and SSSA, Madison, WI, 363-375.

Bouyoucos GJ. 1962. Hydrometer method improved for making particle size analyses of soils. Agronomy Journal, 54, 464-465.

Castellano MJ, Valone TJ. 2007. Livestock, soil compaction and water infiltration rate: Evaluating a potential desertification recovery mechanism. Journal of Arid Environments, 71, 97-108.

Duncan DB. 1955. Multiple range and multiple tests. Biometrics, 11, 1-42.

FAO-AGL. 2000. Global Network on Integrated Soil Management for Sustainable Use of Salt-Affected Soils. FAO-AGL, Land and Plant Nutrition Management Service(http://www.fao.org/ag/AGL/agll/spush).

Flowers IJ, Hajibagheri MA, Yeo AR. 1991. Ion accumulation in the cell wall of rice plants growing under saline conditions. Plant cell and Environment, 14, 319-325.

Hamza MA, Anderson WK. 2005. Review Soil compaction in cropping systems A review of the nature, causes and possible solutions. Soil and Tillage Research, 82, 121-145.

Hussain N, Khan GD, Tahir M, MujeebArshadullah M, Ahmad A. 2002. Salinity and Waterlogging Interaction in Wheat. Asian Journal of Plant Sciences, 1, 15-17.

Ishaq M, Ibrahim M, Hassan A, Saeed M, Lal R. 2001b. Subsoil compaction effects on crops in Punjab, Pakistan. II. Root growth and nutrient uptake of wheat and sorghum. Soil and Till Research, 60, 153-161.

Joseph L, PikulJr, Aase JK. 2003.Water Infiltration and Storage affected by Subsoiling and Subsequent Tillage. Soil Science Society of America Journal, 67, 859-866.

Jury WA, Horton R. 2004. Soil physics. New York: John Wiley and Sons, 370p.

Kalateh M, Dehghan MA, Jafarbai J, Nourinia A, Abroudi A, Soghi H, Kia S, Fallah HA, Nazari A. 2001. Some wheat genotypes characteristics in Golestan province and technical suggestions. Gorgan Agricultural Research Centre, unpublished (in Farsi).

Mapfumo E, Davids S, Chanasyk M, Anne N, Vern SB. 1998. Forage growth and yield components as influenced by subsurface compaction. Agronomy Journal, 90, 805-812.

Munns R, James RA. 2003. Screening methods for salinity tolerance: a case study with tetraploid wheat. Plant and Soil, 253, 201-218.

Munns R, Richard A, Lauchli A.2006. Approaches to increasing the salt tolerance of wheat and other cereals. Journal of Experimental Botany, 57, 1025-1043.

Nevens F,Reheul D. 2003. The consequences of wheel-induced soil compaction and subsoiling for silage maize on a sandy loam soil in Belgium. Soil and Tillage Research, 70, 175-184.

Nhantumbo ABJC, Cambule AH. 2006. Bulk density by Proctor test as a function of texture for agricultural soils in Maputo province of Mozambique. Soil and Tillage Research, 87, 231-239.

Oussible M, Crookston PK, Larson WE. 1992. Subsurface compaction reduces the root and shoot growth and grain yield of wheat. Agronomy Journal, 84, 34-38.

Panayiotopoulos KP, Papadopoulos CP, Hatjiioannidou A. 1994. Compaction and penetration resistance of an Alfisol and Entisol and their influence on root growth of maize seedlings. Soil and Tillage Research, 31, 323-337.

Pietola L, Horn R, Yli-Halla M. 2005.Effects of trampling by cattle on the hydraulic and mechanical properties of soil. Soil and Tillage Research, 82, 99-108.

Poesse GJ. 1992. Soil compaction and new traffic systems. In: Pellizzi, G., Bodria, L., Bosma, A.H., Cera, M., BaerdemaekerJde, Jahns G, Knight AC, Patterson DE, Poesse GJ, Vitlox O. (Eds.), Possibilities Offered by New Mechanization Systems to Reduce Agricultural Production Costs. The Netherlands. pp. 79-91.

Saqib M, Akhtar J, Qureshi RH. 2004. Pot study on wheat growth in saline and waterlogged compacted soil: II. Root growth and leaf ionic relations. Soil and Tillage Research, 77, 169-177.
Saqib M, Akhtar J, Qureshi RH. 2004. Pot study on wheat growth in saline and waterlogged compacted soil: I. Grain yield and yield components. Soil and Tillage Research, 77, 179-187.
Saqib M. 2002. Selection and characterization of wheat genotypes against salinity and waterlogging.Ph.D Thesis, Department of soil and environmental sciences.University of Agriculture, Faisalabad (Pakistan).pp: 110-132.
Soil Science Society of America. 1996. Glossary of Soil Science Terms. Madison, WI, USA.
SPSS (2000).Statistical Package for Social Sciences. Windows Version 11.0. SPSS: Chicago, IL.
Steel RGD, Torrie JH. 1980. Principles and Procedures of Statistics. 2nd ed. McGraw Hill Book Co. Inc., New York.
Stenitzer E, Murer E. 2003. Impact of soil compaction upon soil water balance and maize yield estimated by the SIMWASER model.Soil and Till. Res., 73, 43-56.
Tyerman SD, Skerrett IM.1999. Root ion channels and salinity. SciHortic., 78, 175-235.
USDA.1954. Diagnosis and improvement of saline and alkali soils in Saskatchewan soils. Can. J. Soil Sci. 64:669–704. Agric. Handb. no. 60. United States Salinity Laboratory, RiverHolliday, G., and L.E. Deuel, Jr. 1997.Soil Remediation for the side, CA.
Zhou W, Lin X. 1995. Effects of waterlogging at different growth stages on physiological characteristics and seed yield of winter rape (Brassica napus L.). Field Crops Research, 44, 103-110.