International Journal of Applied Agricultural Research
ISSN 0973-2683 Volume 7, Number 1 (2012) pp. 37-44

http://www.ripublication.com/ijaar.htm

Evaluation of Root System and Mineral Content in Wheat Cultivars under Waterlogging Stress

Seyed Keyvan Marashi[1] and G.S. Chinchanikar[2]

[1]Faculty of Agriculture, Islamic Azad University, Ahvaz Branch, Ahvaz, Iran
[2]Department of Botany, University of Pune-411007, India
**Corresponding Author E-mail: Marashi_47@yahoo.com*

Abstract

Elements toxicities, uptake and transport of them in plants are often a major constraint in waterlogging environments. A pot experiment was performed to attempt to evaluate the effects of waterlogging on root system and mineral content in shoot and root system. This experiment has been conducted by using three wheat cultivars (Chamran, Dez and Verry/nac). The three wheat cultivars are spring wheats with different plant heights. Verry/nac cultivar is early maturing than other cultivars. These were grown under no-waterlogging (control), 7 days and 14 days waterlogging. Waterlogging treatments for each cultivar was given to the plants at the beginning of tillering stage (ZG21), at the beginning of stem elongation stage (ZG31) and at the commencement of booting stage (ZG45), separately. Experimental design was a factorial according to randomized complete block design (RCBD) with three replications. Results showed that dry matter of root was decreased significantly after 7 and 14 days waterlogging. The reduction of root dry matter was significant when waterlogging was applied at ZG21 and ZG31 as compared to waterlogging applied at ZG45. Root system of Verry/nac cultivar grew profusely than other cultivars. In the most situations, the concentration of N, K, Fe, Mn, Cu and Zn in root, peduncle, flag leaf and seed did not affect when waterlogging was applied at different growth stages, significantly. Duration of waterlogging significantly decreased concentration of N, K, Cu and Zn in all parts of plant. The concentration of Fe and Mn in the root increased significantly after duration of waterlogging, but decreased in peduncle, flag leaf and seed.

Keywords: Mineral content, root, waterlogging, wheat.

Introduction

All plants require sufficient supplies of macro and micro nutrients for healthy growth and development. Decrease in yield brought by waterlogging may be caused by changes in soil chemistry (Samad et al., 2001). In waterlogging conditions, the root's energy is limited, hydraulic conductivity of roots is decreased and the root growth cease or died. In waterlogged soils, the activity of anaerobic soil microorganisms increased and some nutrients such as NO_3^- changed to gases and lost to the atmosphere (Ohlsson, 1979; Taiz and Zeiger, 2003). It is reported that some ions such as nitrate and potassium are highly mobile in the soils and waterlogging condition can leach the ions below the crop root zone which make the uptake of nitrogen and potassium difficult (Haynes, 1985). In anaerobic condition due to depletion of redox potential and electron excess, Fe^{+3} and Mn^{+4} are changed to Fe^{+2} and Mn^{+2} , respectively. Thus the availability of these ions is increased in the soil solution. Some plants such as rice can avoid uptake of Fe^{+2} and Mn^{+2} by releasing oxygen into the rhizosphere. But these ions may exhibit toxicity symptom in wheat (Ohlsson, 1979; Steffens et al., 2005). According to Sparrow and Uren (1987) changes in Mn concentration in shoot of wheat and soil is related to seasonal condition. Sharma and Swarup (1988) noted that in waterlogged alkaline soils absorption of N, P, K, Ca, Mg reduced, but absorption of Na, Fe, and Mn increased due to wheat. In waterlogged acidic soils the concentration of Al, Mn and Fe in the shoot of wheat increased. While, in neutral soils these elements decreased or remained the same as in control plants (Khabaz–Saberi et al., 2006). Steffens et al. (2005) reported that uptake and transport of N, P, K, Ca, Mn, Cu, and Zn in shoots of wheat decreased under oxygen deficiency, significantly, but concentration of Fe and Ca were not affected by waterlogging. Also, nutrient deficiency was the main cause for poor plant growth in waterlogged soil rather than toxicity factor.

The objective of this investigation was to study the effects of waterlogged soil on root system and mineral content status in the shoot and root system of wheat cultivars.

Materials and Methods

To evaluate effect of waterlogging condition, three wheat cultivars namely "Chamran", "Dez" and "Verry/nac" were used. The three wheat cultivars are spring wheats with different plant heights. Verry/nac cultivar is early maturing than other cultivars. These were grown under no-waterlogging (control) (Wo), 7 days (W7) and 14 days (W14) of waterlogging. Waterlogging treatments for each cultivar were given to the plants at the beginning of tillering stage (ZG[1]21), at the beginning of stem elongation (ZG31) and at the commencement of booting stage (ZG45), separately.

The pot experiment was conducted in the Agricultural Research Station, Ahvaz University, Iran during 2006-2007 and 2007-2008 cropping seasons. Experimental design was a factorial according to a randomized complete block design (RCBD) with

---

[1]Zadoks scale (ZG) is a decimal code for the growth stage of cereals (Zadoks et al. 1974).

three replications. In order to apply waterlogging treatments, wheat cultivars were planted in pots made of polyvinylchloride (PVC) (60 cm height, 16 cm diameter and 200 cm^2 soil surface area) and they were waterlogged in a basin filled with water. Water was periodically added to keep the level two cm above the soil surface of pots. The soil of pots contained farm soil and soft sand (passing through 2 mm sieve) in the ratio 1:4, respectively. In each pot 16 seeds were planted and after germination, the seedlings were thinned to 8 plants per pot according to ideal seed density in location (400 seed per square meter).

For investigation of roots system, the pots were placed in the basin full of water for 12 hours. Thereafter, the pots torn and the roots were placed in 0.5 mm sieve and washed thoroughly under running water. Then they were dried to constant weight in an oven. For determination of nutrient ions a sample from different parts of plant (root, peduncle, flag leaf and seed) was taken at ripening stage of plant. Nitrogen concentration analyzed by Kjeldahl method. Concentration of nutrient ions like Mn, Cu, Zn, Fe determined by Atomic absorption (AA 680 model, Varian Co. Australia). Total K were measured by Flame Photometer (Flame Photometer, 115 VAC).

The data collected was analyzed statistically by using computer software “MSTATC”. Duncan's multiple range tests at alpha level 5% was computed to compare the significant differences among means.

Results and Discussion

Effect of Waterlogging on Root System

Root system of plants is affected by many factors such as plant genotype, soil fertility, soil atmosphere and soil water (Taiz and Zeiger, 2003). It was observed that dry matter after waterlogging for 7 and 14 days significantly decreased in wheat cultivars (Table 1) (Figure 1). The maximum reduction was observed after 14 days waterlogging and it was due to the slow growth of root, more death of root tip and failure to recover the stress condition. Malik et al. (2002) suggested to limiting growth of seminal roots after 3, 7, 14, 21 and 28 days waterlogging. Aslam and Prathpar (2001), Brisson et al. (2002) reported that when the soil surface is saturated with water, the root growth decreased and get restricted to small region near the soil surface. According to Li et al. (2000) waterlogging was decreased the dry weight of root in wheat due to rapid senescence of root system. Results showed that the effect of waterlogging was significantly more at ZG21 and ZG31 as compared to ZG45 (Table 1). Watson et al. (1976) observed that the effect of waterlogging on root system in wheat, barley and oat was high when waterlogging was applied after planting stage than ear emergence stage. Ghobadi (2010) indicated that reduction in root system in wheat after waterlogging was more at one leaf and tillering stages as compared to stem elongation stage. Screening of root system in three tested wheat cultivars showed that root system of Verry/nac cultivar with early maturing duration grew profusely as compared to other cultivars (Table 1). It was seen that, a negative correlation existed between root growth rate and duration of maturing in wheat cultivars.

Table 1: Mean values for root dry matter in different wheat cultivars, after waterlogging applied at different growth stages and after duration of waterlogging.

Treatments Wheat Cultivars	Dry matter of root (g) Harvesting days after germination		
	46 days	70 days	106 days
Chamran	5.056 c	7.126 b	9.281 b
Dez	5.630 b	7.419 b	8.789 b
Verry/nac	7.667 a	9.515 a	11.411a
Stage at which waterlogging started			
ZG21	3.993 b	6.189 c	8.341 c
ZG31	7.304 a	8.393 b	9.830 b
ZG45	7.056 a	9.478 a	11.311a
Duration of waterlogging			
Wo (control)	7.252 a	9.574 a	11.930 a
W7	5.596 b	7.652 b	9.519 b
W14	5.504 b	6.833 c	8.033 c

Means with different letters are significantly different at P=0.05 , using Duncan's Multiple Range Test

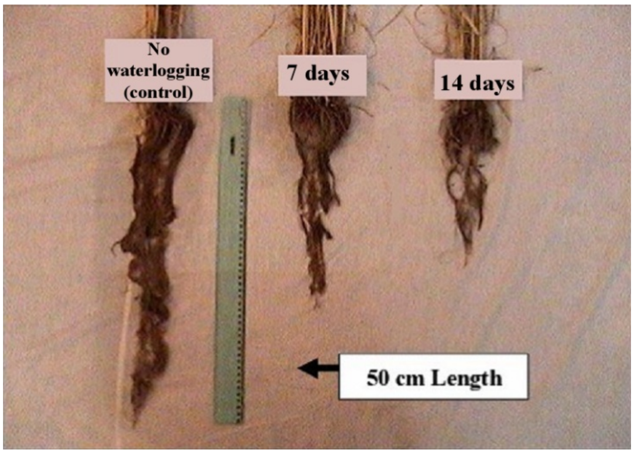

Figure 1: Morphological changes of root system after duration of waterlogging

Effect of Waterlogging on Nutrient Ions in Different Parts of Plant

Nitrogen Concentration

Increasing of waterlogging duration form 7 (W7) to 14 days (W14) significantly inhibited uptake and translocation of nitrogen to root, peduncle, flag leaf and seed (Table 2). It was reported that waterlogging condition causes nitrogen loss through denitrification and leaching of nitrogen out of crop root zone, thus nitrogen uptake is reduced by the plants (Stieger and Feller, 1994; Hill et al., 2004; Steffens et al., 2005). Effect of waterlogging applied at different growth stages were not significant on nitrogen concentration in all parts of plant (Table 2). But investigation of mean values showed that waterlogging applied at ZG21, ZG31 decreased the concentration of nitrogen in all parts of shoot (flag leaf, seed and peduncle). This was due to more reduction in root system (Table 1) after waterlogging at early growth stages (ZG21 and ZG31) as compared to waterlogging applied at ZG45. In other researches reported that injury to root system is more after waterlogging at early growth stages than late growth stages (Watson et al., 1976; Ghobadi, 2010). The concentration of nitrogen in root was increased after waterlogging applied at ZG21, ZG31 as compared to ZG45, but the differences were not significant (Table 2). This was due to long duration after waterlogging applied at ZG21 and ZG31 till ripening stage for absorption of nitrogen by root. But the absorption of nitrogen through roots did not increase nitrogen concentration in all parts of shoot.

Table 2: Means values for concentration of nitrogen, potassium, manganese, iron, copper and zinc in different wheat cultivars, after waterlogging applied at different growth stages and after duration of waterlogging.

Different parts of plant	Nutrient ions (mg/kg)	Wheat cultivars			Stage at which waterlogging started			Duration of waterlogging		
		Chamran	Dez	Verry/nac	ZG21	ZG31	ZG45	Control (Wo)	W7	W14
Root	N	91.2 b	62.8 c	106.6 a	89.0 a	86.9 a	85.4 a	102.4 a	82.8 b	75.4 b
	K	196.0 a	197.7 a	171.4 b	186.2 a	188.7 a	190.1 a	197.0 a	186.6 ab	181.4 b
	Mn	116.0 a	116.9 a	118.1 a	114.0 b	117.3 ab	119.7 a	114.6 b	115.3 b	121.1 a
	Fe	255.5 a	241.2 b	262.0 a	250.2 a	252.4 a	256.2 a	245.1 b	253.7 a	260.0 a
	Cu	32.66 a	14.87 c	19.35 b	23.36 a	22.19 a	21.32 a	30.04 a	21.12 b	15.71 c
	Zn	68.58 b	68.75 b	84.46 a	74.42 a	73.93 a	73.44 a	87.71 a	69.20 b	64.89 c
Peduncle	N	24.4 c	27.9 b	38.3 a	29.9 a	30.1 a	31.5 a	32.8 a	30.2 ab	28.6 b
	K	189.7 b	184.7 b	206.8 a	192.4 a	193.9 a	194.9 a	209.1 a	193.0 b	179.1 c
	Mn	18.1 b	20.0 a	19.4 a	18.8 a	19.2 a	19.5 a	20.1 a	19.0 b	18.5 b
	Fe	165.8 c	273.6 a	203.3 b	211.7 a	213.6 a	217.3 a	216.3 a	214.6 a	212.0 a
	Cu	5.02 b	6.21 a	6.00 a	5.77 a	5.75 a	5.72 a	6.02 a	5.72 ab	5.50 b
	Zn	5.84 c	7.76 b	10.61 a	8.24 a	8.04 a	7.94 a	8.72 a	8.11 ab	7.38 b
Flag leaf	N	260.7 a	254.7 a	226.8 b	240.0 ab	251.1 a	261.0 a	266.4 a	247.1 b	228.5 c
	K	290.6 a	262.9 b	252.8 b	261.9a	269.7a	274.7 a	288.4 a	264.8 b	253.1 b
	Mn	35.4 a	25.1 b	23.6 b	27.9 a	28.1 a	28.2 a	34.8 a	27.9 b	21.4 c
	Fe	14.5 a	11.06 b	14.78 a	13.41 a	13.45 a	13.53 a	16.2 a	13.11 b	11.03 c
	Cu	3.66 c	15.71 a	14.98 a	12.38 a	11.14 b	10.83 b	12.9 a	11.44 b	9.96 c
	Zn	50.77 b	46.61 b	58.28 a	52.80 a	51.47 a	51.39 a	60.8 a	51.24 b	43.58 c
Seed	N	163.6 a	151.1 b	147.3 b	150.7ab	155.4 ab	157.2 b	158.0 a	154.4 a	149.6 a
	K	75.3 a	75.5 a	72.6 a	73.0 a	74.8 a	75.6 a	79.8 a	72.3 b	71.3 b
	Mn	14.3 b	15.7 a	12.2 c	13.6 b	13.9 ab	14.7 a	16.6 a	13.2 b	12.4 b
	Fe	66.68 b	75.27 a	67.18 b	69.40 a	69.63 a	70.09 a	73.3 a	69.48 ab	66.28 b
	Cu	4.28 a	4.40 a	4.33 a	4.41 a	4.33 a	4.27 a	4.75 a	4.20 b	4.06 b
	Zn	15.39 b	17.57 a	18.39 a	17.74 a	17.34 ab	16.26 b	20.9 a	15.87 b	14.51 c

Means with different letters are significantly different at P=0.05 , using Duncan's Multiple Range Test.

Potassium Concentration

Potassium concentration was decreased significantly after 7 and 14 days waterlogging in root, peduncle, flag leaf and seed (Table 2). The studies showed that potassium deficiency in the soil highly occurs in sandy soils especially after heavy rainfall due to leaching of potassium (Taiz and Zeiger, 2003). Trought and Drew (1980), Sharma and Swarup (1988), Hussain et al. (2002), Steffens et al. (2005) reported a reduction in potassium concentration in the shoot after waterlogging as a result of reduction in uptake and transport of potassium from root to shoot. Waterlogging applied at ZG21 and ZG31 was decreased potassium concentration in all parts of plant as compared to ZG45, but no significant differences were identified (Table 2). This was because of more reduction in root system after waterlogging applied at ZG21 and ZG31 and consequently more inhibition for potassium uptake through root as compared to waterlogging applied at ZG45.

Iron and Manganese Concentration

Concentration of iron and manganese in root increased significantly after waterlogging duration for 7 and 14 days (Table 2). It is reported that in waterlogged soils, Mn^{+3} and Fe^{+3} altered to Mn^{+2} and Fe^{+2} and become more soluble in the soil. Thus, iron uptake increased by the root and can rise to toxic level (Saqib, 2002; Taiz and Zeiger, 2003). Sharma and Swarup (1988) observed more absorption of iron in waterlogged alkaline soils (pH 8.9). Concentration of iron and manganese significantly decreased in peduncle, flag leaf and seed after increasing waterlogging duration, except iron concentration in peduncle which was not significant (Table 2). This was because of reduction in root system after waterlogging condition (Table 1) and consequently reduction in translocation of iron and manganese from root to shoot. Steffens et al. (2005) reported that under oxygen deficiency uptake and transport of manganese decreased in aerial parts of wheat, but concentration of iron was not affected by waterlogging. Khabaz–Saberi et al. (2006) indicated that in waterlogged acidic soils the concentration of Mn and Fe in shoot of wheat increased, while in neutral soils these elements decreased or remained the same as in control plants. Results also showed that concentration of iron and manganese in root was less after waterlogging applied at ZG21 and ZG31 as compared to waterlogging applied at ZG45. But it was not significant for concentration of iron (Table 2). The reduction of iron and manganese in root was due to long duration after waterlogging applied at ZG21 and ZG31 till ripening stage of plant for reduction of iron and manganese from toxic level to sufficiency in the plant. Concentration of iron and manganese in peduncle, flag leaf and seed was decrease after waterlogging applied at ZG21 and ZG31 as compared to waterlogging applied at ZG45, but no significant differences were observed, except manganese concentration in seed which was significant (Table 2). This was due to more reduction in root system and transport of iron and manganese from root to all parts of shoot.

Copper and Zinc Concentration

Copper and zinc concentration in all parts of plant significantly decreased after waterlogging duration (Table 2). This was due to reduction in root system and leaching of copper and zinc in soil under waterlogging condition (Table 1). It is reported that in waterlogged soils the availability of copper in soil reduced, but after waterlogging condition the availability of copper increased in the soil (http://www. spectrumanalytic.com). Steffens et al. (2005) and Chang (2000) reported a reduction in uptake and transport of Cu, Zn in shoots of wheat under oxygen deficiency. Result also showed that the concentration of copper and zinc in different parts of plant was more after waterlogging applied at ZG21 and ZG31 as compared to waterlogging applied at ZG45, but it was not significant except flag leaf copper concentration and zinc concentration in seed which was significant (Table 2). This was due to long duration after waterlogging applied at ZG21 and ZG31 till ripening stage of plant for uptake and translocation of copper and zinc from root to shoot.

Acknowledgements

Express my sincere thanks to all the faculty members of Botany Department, University of Pune, India and Agricultural Faculty, Ahvaz Azad University, Iran including the teaching and non-teaching staff members for their direct and indirect help rendered from time to time.

References

[1] Aslam, M., Prathpar, S.A. ,2001, "Water management in the rice - wheat cropping zone of Sind, " Pakistan. J. Crop Produc., 4: 249– 272.

[2] Brisson, N., Rebiere, B., Zimmer, D., Renault, P. ,2002, "Response of the root system of winter wheat crop to waterlogging, " Plant and Soil, 243: 43-55.

[3] Chang, J., 2000, "Nutrition of wheat wet injury and its regulation," Ying Yong Sheng Tai Xue Bao, 11(3): 373-376.

[4] Haynes' R.J., 1985, "Principles of fertilizer use for trickle irrigated crops, " Nutri. Cycl. Agroeco, 6: 235-255.

[5] Hill, N., Moyes, N., McTaggart, R., Anderson, W.K., Tugwell, R., 2004, "Waterlogging and nitrogen management for wheat in high rainfall cropping areas of southern western Australia, " 4 th International Crop Sci. Cong., Brisbane, Australia.

[6] http://www.spectrumanalytic.com/support/library/ff/Cu_Basics.htm.

[7] Hussain, N., Khan, G.D., Tahir, M, Mujeeb, F., Arshad Ullah, M., Ahmad, A., 2002, "Salinity and waterlogging interaction in wheat, " Asian J. Plant Sci., 1:15-17.

[8] Ghobadi, M.E. , Ghobadi, M., 2010, Effect of anoxia on root growth and grain yield of wheat cultivars. World Acad. Sci. Engin. Techn, pp. 85-88.

[9] Khabaz–Saberi, H. , Setter, T.L., Waters, I., 2006, "Waterlogging induces high to toxic concentrations of iron, aluminum, and manganese in wheat varieties on acid soil, "J. Plant Nutri., 29: 899-911.

[10] Li, J., Wei, F., Yu, S., Yu, Z., 2000, "Effect of waterlogging on senescence of winter wheat root system at booting stage, " Ying Yong Sheng Tai Xue Bao, 11:723-726.

[11] Malik, A.L., Colmer, T.D., Lambers, H., Setter, T.L., Schortemeyer, M., 2002, " Short-term waterlogging has long-term effect on the growth and physiology of wheat, " New Phytologist, 153: 225-236.

[12] Ohlsson, T., 1979, "Redox reactions in soils sequence of redox reactions in a waterlogged soil, "Nordic Hydrology, pp. 89-98.

[13] Samad, A., Meisner, C.A., Saifuzzaman, M., Van Ginkel, M., 2001, "Waterlogging tolerance, " In Reynolds MP, Ortiz-Monasterio JI, Mc Nab A (ed) Application of physiology in wheat breeding. CIMMYT- Mexico, pp. 136-144.

[14] Saqib, M., 2002, "Selection and characterization of wheat genotypes against salinity and waterlogging, " Ph.D dissertation. Dep. Soil Sci. Agri. Uni., Faisalabad, Pakistan.

[15] Sharma, D.P., Swarup, A., 1988, "Effects of short-term flooding on growth yield mineral composition of wheat on sodic soil under field conditions, " Plant and Soil, 107: 137-143.

[16] Sparrow, L.A., Uren, N.C., 1987, "The role of manganese toxicity in crop yellowing on seasonally waterlogged and strongly acidic soils in north-eastern Victoria, " Austr. J. Experi. Agri., 27: 303-307.

[17] Steffens, D., Hutsch, B.W., Eschholz, T., Losak, T., Schubert, S., 2005, "Waterlogging may inhibit plant growth primarily by nutrient deficiency rather than nutrient toxicity, " Plant Soil Envi., 51(12):545-552.

[18] Stieger, P.A., Feller, U., 1994, "Nutrient accumulation and translocation in maturing wheat plants growth on waterlogging soil, " Plant and Soil., 160: 87-95.

[19] Taiz, L., Zeiger, E., 2003, "Plant physiology," 3rd ed. Panima Publishing Corporation, New Delhi/Banglore, pp. 690.

[20] Trought, M.C.T., Drew, M.C., 1980, "The development of waterlogging damage in wheat seedlings (Triticum aestivum L.) II. Accumulation and redistribution of nutrients by the shoot, " Plant and Soil, 56: 187- 199.

[21] Watson, E.R. , Lapins, P., Barron, R.J.W., 1976, "Effect of waterlogging on the growth, grain and straw yield of wheat, barley and oats, "Austr. J. Exp. Agr. Animal Husbandry, 16(78): 114-122.

[22] Zadoks, J.C., Chang, T.T., Konzak, C.F., 1974, "A decimal code for the growth stage of cereals, "Weed Res., 14: 415- 421.