INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 3, p. 347-353, 2014
http://www.innspub.net

RESEARCH PAPER

OPEN ACCESS

A comparative study of grain yield and yield components of wheat (*Triticum aestivum* L.) in response to waterlogging condition

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Article published on September 25, 2014

Key words: Chlorophyll, grain yield, LAI, waterlogging, wheat.

Abstract

Waterlogging condition is an important abiotic stress that suffers in many parts of global area in each year. For evaluation and comparison of yield and yield components under waterlogging condition a pot experiment was conducted during 2012-2013 crop season. Experimental design was a factorial according to a randomized complete block design (RCBD) with three replications. Treatments were four levels of waterlogging duration include: no waterlogging (control), 7, 14 and 21 days and four height of water above the soil surface namely: 0, 5, 10 and 15 cm. Results showed that increasing of waterlogging duration decreased leaf area index (LAI), chlorophyll a, chlorophyll b, grain yield and all yield components such as 1000-kernel weight, spike per square meter and spikelet per spike, significantly. Average reduction in grain yield for 7, 14 and 21 days waterlogging were 33.2, 47.7 and 68.1% as compared to no waterlogging, respectively. Height of water above the soil surface decreased LAI, chlorophyll a, chlorophyll b, grain yield and all yield components, but it were not significant except chlorophyll a, 1000-kernel weight, spikelet per spike and grain yield. Average reduction in grain yield for 0, 5, 10 and 15 cm waterlogging were 22.2%, 34.8, 42.0 and 50%, as compared to no waterloggin.

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Introduction

Wheat (*Triticum aestivum* L.) is the first cereal grain consumed by humans around the globe. Wheat production suffers from many kinds of abiotic stresses including temperature, air pollution, soil (extreme acidic or alkaline soils), nutrient (deficiencies), wind, fire, radiation and water (drought and/or waterlogging) (Gupta and Gupta, 2005). Waterlogging is the state of land in which the soil surface becomes saturated with water especially due to excessive rainfall or irrigation, particularly in areas with poor drainage or level (Samad, 2001; Ashraf and Harris, 2006). Approximately 10% of the global land area experiences waterlogging stress in each year (Setter and Waters, 2003; Jackson, 2009). Since the speed of oxygen movement in waterlogged soils is about 10,000 times less than normal aerobic soil (Greenwood, 1961; Colmer, 2003), plants and microorganisms experience oxygen deficiency. In waterlogged condition, root growth decreases and gets restricted to small region near the soil surface. Behaviour and perceptible variations of roots under waterlogging appeared after approximately 48 h. (Aslam and Prathpar, 2001; Brisson *et al*., 2002). In the absence of oxygen, root growth and functional relationship between root and shoot is disturbed due to insufficient energy generated by the root respiration. Also under anaerobic conditions, roots generate large quantities of lactic acid, ethanol and carbon dioxide that are phytotoxic to cells (Setter and Waters, 2003; Taiz and Zeiger, 2003; Jin-Woong *et al*., 2006).

The objective of this investigation was to evaluate the effects of waterlogging duration and height of water above the soil surface on yield and its components in bread wheat (*Triticum aestivum* L.).

Materials and methods

Description of experiments

To evaluate effect of waterlogging conditions on wheat a pot experiment was conducted at the Agricultural Research Station, Ahvaz University, Iran during 2012-2013 crop season. Experimental design was a factorial according to a randomized complete block design (RCBD) with three replications. Treatments were four levels of waterlogging duration include: no waterlogging (control) (D0), 7 days waterlogging (D7), 14 days waterlogging (D14) and 21 days waterlogging (D21) and four height of water above the soil surface namely: 0 cm above the soil suface(H0), 5 cm above the soil suface (H10), 10 cm above the soil suface (H10) and 15 cm above the soil suface (H15). In this experiment Chamran cultivar was used as wheat cultivar.

Crop management practices

In order to apply waterlogging treatments, wheat cultivar was 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. 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). Waterlogging treatments were given to the plants at the beginning of stem elongation stage (ZG31).

Investigation of traits

For investigation of yield and yield components, the plants in each pot were harvested manually and after determine the number of spikelet per spike, the grain yield and other yield components namely kernels number per spike and 1000-kernel weight determined after hand threshing of plants. For determination of leaf area index, total plants from the soil surface harvested in each pot and the laminas of leaves from sheathing base site separated in laboratory and the leaf area was measured by Leaf Area Meter (ADC, Bioscientific Ltd. SKF-103). Then the leaf area index was calculated on basis of seed density (400 seed per square meter). The amount of chlorophyll a and b were determined according to method of Arnon (1949) and using data in formula (1) and (2) below:

(1) Mg chlorophyll a/g tissue = (12.7 A $_{663}$ – 2.69 A $_{645}$) V / 1000*W

(2) Mg chlorophyll b/g tissue = (22.9 A $_{645}$ – 4.68 A $_{663}$) V / 1000*W.

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

Leaf area index (LAI)

Screening of LAI under waterlogging condition showed a significant reduction under durations of waterlogging (table 1). The mean values comparison for LAI (table 2) showed that the LAI after the end of waterlogging durations at stem elongation stage (ZG31) decreased and the plants didn't recover the LAI at booting stage. The maximum LAI observed for no waterlogging (control) and the minimum was under 21 days waterlogging. Pang *et al.*, (2004) reported that reduction of LAI is due to increasing yellowing of leaves. It is reported that waterlogging condition causes a necrotic spots on the lower surface of leaves, also in waterlogged soils, premature senescence of older leaves increased due to reallocation of elements (N, P, and K) to younger leaves (Samad *et al.*, 2001; Taiz and Zeiger, 2003; Gupta and Gupta, 2005). Jiang *et al.* (2002) demonstrated that early senescence of flag leaf after waterlogging is due to decline in activity of some enzymes such as super oxide dismutase, catalase and two key enzymes involving in membrane lipid peroxide elimination in flag leaves.

Table 1. Analysis of variance for LAI, chlorophyll a, chlorophyll b, spike per square meter, 1000-kernel weight, spikelet per spike and grain yield under duration of waterlogging and waterlogging applied at different height of water above the soil surface.

Source of variation	df	LAI		Chlorophyll a		Chlorophyll b		Spike per square meter	1000-kernel weight (g)	Spikelet per spike	Grain yield (kg/h)
		Stem elongation stage	Booting stage	Stem elongation stage	Booting stage	Stem elongation stage	Booting stage				
Replication	2	0.33 ns	1.36 ns	0.01ns	0.04 ns	0.07 ns	0.01ns	17239.5 ns	1.38 ns	1.48 ns	108331.6 ns
Duration of waterlogging (D)	3	3.45 *	1.97 *	0.97**	1.21*	0.53**	0.65**	319791.6**	604.5**	80.68**	17800314.2**
Height of water (H)	3	0.28 ns	0.34 ns	0.12*	0.02 ns	0.02 ns	0.03 ns	15763.8 ns	27.5**	25.19**	3021917.5**
D * H	9	0.08 ns	0.02 ns	0.01ns	0.08 ns	0.01ns	0.01 ns	26643.5 ns	2.96 ns	11.74*	1083061.9*
Error	30	0.81	0.98	0.04	0.09	0.03	0.58	11795.1	7.91	3.864	379586.1
Coefficient of variation %		23.3	21.8	8.2	12.8	11.4	11.2	19.3	10.8	14.6	23.1

* Indicates significance at P=0.05

** Indicates significance at P=0.01.

Chlorophyll a and chlorophyll b

In the present study, the average chlorophyll a and b at the end of waterlogging stress at stem elongation stage and also at booting stag were decreased significantly when waterlogging increased for 7, 14 and 21 days, but the average chlorophyll a and b were not significant when waterlogging were applied for different height of water above the soil surface except chlorophyll a after the end of waterlogging at stem elongation stage (table 1). The minimum chlorophyll a and b observed when waterlogging were applied for 21 days and the height of water was 15 cm above the soil surface (table 2). The results indicated that after the end of waterlogging at stem elongation stage the plants did not recover chlorophylls for booting stage this was due to damage to shoot and root system especially for treatment of waterlogging durations. Many researchers have reported that waterlogging directly affects leaf chlorophylls content, (Musgrave, 1994 ; Yordanova and Popova, 2001; Yordanova and Popova, 2007). When plants are hypoxic or anoxic, the root growth and functional relationship between roots and shoots is disturbed. Thus, carbon assimilation is inhibited (Jin-Woong *et al.*, 2006). Pang *et al.* (2004) observed a reduction in chlorophyll fluorescence in leaves after waterlogging condition due to reduction in chlorophyll content. Collaku and Harrison (2002) and Olgun *et al.* (2008) also suggested to reduction of chlorophyll content under waterlogging condition.

Table 2. Mean values for LAI, chlorophyll a, chlorophyll b, spike per square meter, 1000-kernel weight, spikelet per spike and grain yield under duration of waterlogging and waterlogging applied at different height of water above the soil surface.

Treatments	LAI		Chlorophyll a (mg/g/fw)		Chlorophyll b (mg/g/fw)		Spike per square meter	1000-kernel weight (g)	Spikelet per spike	Grain yield (kg/h)
Duration of waterlogging	Stem elongation stage	Booting stage	Stem elongation stage	Booting stage	Stem elongation stage	Bootin g stage				
Wo (control)	4.525 a	5.083 a	2.89 a	2.68a	1.80 a	1.54 a	762.5 a	36.38 a	17.22 a	4250.0 a
W7	3.942 ab	4.625 a	2.60 b	2.49 ab	1.53 b	1.29 b	600.0 b	24.94 b	12.77 b	2838.5 b
W14	3.750 ab	4.325 ab	2.42 c	2.38 b	1.47 b	1.13 c	504.2 c	21.86 c	11.96 b	2221.2 c
W21	3.225 b	3.958 b	2.22 d	1.93 c	1.30 c	1.00 d	375.0 d	20.98 c	11.62 b	1357.8 d
Height of water										
Ho	3.800 a	4.683 a	2.43 b	2.35a	1.50 a	1.19 a	579.2 a	27.45 a	14.36 a	3307.7 a
H5	4.042 a	4.675 a	2.65 a	2.43a	1.53 a	1.29 a	595.8 a	27.08 a	14.38 a	2771.8 b
H10	3.917 a	4.508 a	2.59 ab	2.37a	1.55 a	1.27 a	554.2 a	25.45 b	13.52 a	2463.1 bc
H15	3.683 a	4.325 a	2.46 b	2.32a	1.52 a	1.20 a	512.5 a	24.17 b	11.30 b	2125.1 c

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

Number of spikes per square meter

Investigation of spike number per square meter showed that duration of waterlogging applied at stem elongation stage reduced the number of spikes per square meter, significantly (table 1). Results also indicated that the height of water above the soil surface namely: 0, 5, 10 and 15 cm above the soil suface were caused a reduction in spike number per square meter, but the reductions were not significant (table 1). The minimum spike number per square meter was observed under 15 cm and the maximum was under 0 cm water above the soil surface (table 2). The reduction of spike number per square meter was as a result of damage to bud located at the coleoptilar node. Therefore the plants produced fewer tillers by aborting initiated tillers. Xiao *et al.* (2007) reported that reduction in grain yield in barley after waterlogging at tillering stage was mainly due to decrease in number of spikes per square meter. Samad *et al.* (2001) reported minimum production of spike number per square meter in wheat (10 to 30 days old) under waterlogging condition as compared to waterlogging at later growth stages.

1000-kernel weight

One thousand kernel weight was reduced significantly after increasing of duration of waterlogging for 7, 14 and 21 days (table 1). The maximum one thousand kernel weight obtained under no waterlogging (control) and the minimum was after 21 days waterlogging (table 2). This was due to less photosynthesis at grain filling period for dry matter accumulation in seed as a result of reduction in leaf area and chlorophylls content under waterlogging condition. Yordanova *et al.* (2005) considered stomata closure and stomatal conductance as a reason for reduction in photosynthesis and transpiration under waterlogging condition. Results also showed that reduction in one thousand kernel weight for 10 and 15 cm water above the soil surface was significant as compared to 0 and 5 cm (table 2). According to Soltanzadeh and Lak (2009) the minimum reduction in yield components under waterlogging condition (0, 10, 20 days) during stem elongation stage observed in 1000-grain weight as compared to other yield components. Samad *et al.* (2001) reported that waterlogging before anthesis stage of wheat did not affect on kernel weight. Olgun *et al.* (2008) resulted in reduction of kernel weight from 8.4% to 89.4% after 5 to 50 days waterlogging after flowering stage of wheat, respectively.

Number of spikelets per spike

Investigation of mean values for spikelet number per spike (table 1) after increasing of waterlogging duration showed a significant reduction in spikelet number per spike as compared to no waterlogging condition (control). The maximum reduction in spikelet number per spike was observed when waterlogging applied for 21 days. This was due to more die of spikelet primordia initiation at the double ridge as compared to other treatments of waterlogging durations. Result also showed a reduction in number of spikelets per spike under increasing of height of water above the soil surface, but the reductions were not significant, except 15 cm (table 2). Sheikh *et al.* (2008) reported that effect of 20 days waterlogging on number of spikelets per spike at grain filling stage was not significant. Ghobadi *et al.* (2006) also resulted in more reduction in spikelet number in wheat genotypes after increasing of waterlogging duration for 0 to 14 days at stem elongation stage as compared to later growth stages .

Grain yield

The grain yield was reduced after increasing of waterlogging duration, significantly (table 1). The maximum grain yield was observed under no waterlogging condition (control) and the minimum was when waterlogging was applied for 21 days (table 2). Average reduction in grain yield after 7, 14 and 21 days waterlogging was 33.2, 47.7 and 68.1%, respectively as compared to no waterlogging. Results also showed that the grain yield decreased after waterlogging at different height of water above the soil surface, significantly (table 1). Average reduction in grain yield after waterlogging for 0, 5, 10 and 15 cm water above the soil surface were 22.2%, 34.8, 42.0 and 50%, respectively as compared to no waterlogging. Olgun *et al.* (2008) reported that waterlogging for 5 to 50 days after flowering of wheat reduced grain yield by 3.9% to 88.6%, respectively due to reduction in spike number per square meter, seed number per spike, seed weight per spike. Collaku and Harrison (2002) found that 44% decline in average grain yield after 10-30 days waterlogging at 3-4 leaf stage (5 weeks old) is mainly due to reduction in tiller number and number of seeds per spike. Samad *et al.* (2001) and Ghobadi *et al.*(2011) also suggested to more reduction in grain yield of wheat cultivars after waterlogging applied at early growth stages as compared to waterlogging applied at late stages.

References

Arnon DI. 1949. Copper enzyme in isolated chloroplasts. Polyphenoloxidase in *Beta Vulgaris*. Plant Physiology **24,** 1-15. http://dx.doi.org/10.1104/pp.24.1.1

Ashraf M, Harris PJC. 2006. Abiotic stresses, plant resistance through breeding and molecular approaches. 1st ed Food Product Press, 725 P.

Aslam M, Prathpar SA. 2001. Water management in the rice- wheat cropping zone of Sind, Pakistan. Journal of Crop Production **4,** 249 – 272. http://dx.doi.org/10.1300/j144v04n01_07

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.

Collaku A, Harrison SA. 2002. losses in wheat due to waterlogging. Crop Science **42,** 444-450. http://dx.doi.org/10.2135/cropsci2002.0444

Colmer TD. 2003. Long-distance transport of gases in plants: a perspective on internal aeration and radial oxygen loss from roots. Plant, Cell and Environment **26, 17 – 36.** http://dx.doi.org/10.1046/j.13653040.2003.00846.x

Ghobadi ME, Ghobadi M, Zebarjadi A. 2011. The response of winter wheat to flooding. International Journal of Biological, Veterinary, Agricultural and Food Engineering **5,** 38-40.

Ghobadi ME, Nadian H, Bakhshandeh M, Fathi G, Gharineh MH, Alami-said K, Ghobadi M. 2006. Study of root growth, biological yield and grain yield of wheat genotypes under waterlogging stress during different growth stages. Seed and Plant improvement Journal **22,** 513-527.

Greenwood DJ. 1961. The effect of oxygen concentration on the decomposition of organic materials in soil. Plant and Soil **14,** 360-376. http://dx.doi.org/10.1007/bf01666294

Grichko VP, Glick BR. 2001. Ethylene and flooding stress in plants. Plant Physiology and Biochemistry **39,** 1-9. http://dx.doi.org/10.1016/s0981-9428(00)01213-4

Jackson MB. 2002. Long-distance signaling from roots to shoots assessed: the flooding story. Journal of Experimental Botany **53,** 175-181. http://dx.doi.org/10.1093/jexbot/53.367.175

Jiang D, Tao Q, Zhang G. 2002. Effect of waterlogging on senescence of flag leaf and root of wheat yangmai. Ying Yong Sheng Tai Xue Bao **13,** 1519-1521.

Jin-woong CHO, Hee Chung JI, Yamakawa T. 2006. Comparison of photosynthetic response of two soybean cultivares to soil flooding. Journal of the Faculty of Agriculture, Kyushu University **51,** 227-232.

Musgrave ME. 1994. Waterlogging effects on yield and photosynthesis in eight winter wheat cultivars. Crop Science **34,** 1314-1318. http://dx.doi.org/10.2135/cropsci1994.0011183x003400050032x

Olgun MA, Kumlaly M, Adiguzel MC, Caglar A. 2008. The effect of waterLogging in wheat (*T. aestivum* L.). Acta Agriculturae Scandinavica **58,** 193-198. http://dx.doi.org/10.1080/09064710701794024

Pang J, Zhou M, Mendham N, Shabala S. 2004. Growth and physiological responses of six barley genotypes to waterlogging and subsequent recovery**.** Australian Journal of Agricultural Research **55,** 895–906. http://dx.doi.org/10.1071/ar03097

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

Setter TL, Waters I. 2003. Review of prospects for germplasm improvement for waterlogging tolerance in wheat, barley and oats. Plant and Soil **253,** 1-34. http://dx.doi.org/10.1023/a:1024573305997

Sheikh F, Kalateh Arabi M, Soghi H, Taghi Bazi M, Abroudi AM. 2008. The effect of waterlogging stress at filling stage on yield and yield component of wheat (*Triticum aestivum*). Electronic journal of crop production **1,** 38-53.

Soltanzadeh Shoshtari M, Lak S. 2009. Effect of waterlogging stress in during stem elongation growth stage on yield and yield components of wheat genotypes. Crop Physiolology **1,** 34-45.

Taiz L, Zeiger E. 2003. Plant physiology. 3rd ed. Panima Publishing Corporation, New Delhi, Banglore 690 P.

Xiao YP, Wei K, Chen JX, Zhou M, Zhang GP. 2007. Genotypic difference in growth inhibition and yield loss in barley under waterlogging stress. Journal of Zhejiang University (Agriculture and Life Science) 33, 525-532.

Yordanova RY, Popova LP. 2007. Flooding-induced changes in photosynthesis and oxidative status in maize plants. Acta Physiologiae Plantarum **29,** 535-541.
http://dx.doi.org/10.1007/s11738-007-0064-z

Yordanova RY, Popova LP. 2001. Photosynthetic response of barley plants to soil flooding. Photosynthetica **39,** 515-520.

Yordanova RY, Uzunova AN, Popova LP. 2005. Effects of short-term soil flooding on stomata behaviour and leaf gas exchange in barley plants. Biologia Plantarum **49,** 317 - 319.
http://dx.doi.org/10.1007/s10535-005-7319-6

Zadoks JC, Chang TT, Konzak CF. 1974. A decimal code for the growth stage of cereals. Weed Research **14,** 415- 421.
http://dx.doi.org/10.1111/j.1365-3180.1974.tb01084.x