The Response of Winter Wheat to Flooding

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Abstract—The effect of flooding can be a serious problem for wheat farmers, even at dry land condition. Amount of flooding damage depends on duration flooding, developmental stage, wheat type and variety. Therefore as a factorial experiment in randomized complete design based on winter bread wheat cultivars (Pishtaz, Marvdasht, Shiraz, Zarin, Shahriar, C-81-4, Sardari, Agosta seed, FGS and Azar2) at stages (Non- flooding stress, flooding at tillering and stem elongation stages for 15 days) carried out in Faculty of Agriculture, Razi University, Kermanshah, Iran. During flooding, soil environment of plant roots were water saturated. Analysis of variance showed that flooding had a significant effect on the number of grains per spike, grain weight per spike and a grain weight. Hence flooding reduces the number of grain per spike between 27.1 to 42.5 percent, grain weight per spike between 34.7 to 54.4 percent and single grain weight between 12.1 to 15.1 percent. Effects of flooding at the tillering stage reduced higher than stem elongation stage on studied traits. The result also showed that flooding at tillering stage delayed spikelet primordial and floret. Between wheat cultivars was significant for traits, but were different reactions. "Shiraz", "Zarin" and "Shahriar" had the most no. grain per spike, but "Zarin" and "Sardari" had the most grain weight per spike and single grain weight, respectively. Also, interaction between start of flooding and cultivar was significant.

***Keywords*—**Flooding, winter wheat, yield components

I. Introduction

FLOODING or waterlogging occurs in many wheat growing regions around the world, especially in irrigated and high rainfall environments. During flooding, the gas exchange between soil and air decreases, O_2 in the soil is depleted rapidly, and the soil may become hypoxic or anoxic within a few hours. When the oxygen is depleted from soil, the roots and aerobic micro-organisms lose almost all capacity to produce energy; hence, they stop growing and may die. Flooding during germination reduced germination percentage and seedling growth but after the wheat established, many cultivar can withstand flooding and increase tolerance [12]. In wheat, flooding reduces leaf elongation, photosynthesis, plant height [10], root and shoot growth [6], number of tiller and leaves, delayed ear emergence [5] - [6], kernel number and final yield [2] - [8] - [13]. Flooding can reduce grain yield of winter wheat by about 20 to 50 % [14]. Also flooding caused increase ethylene production [3] - [5] - [15] and reduce uptake N, P, K and other nutrients [9]. The severity of the effects of flooding can vary depending on the genotype, the growth stage of the plant [7] - [8] - [11], the depth of the water level [3], the duration of the flooding event [1] - [7], the organs directly affected, and external conditions such as temperature [4]- [11] - [12]. Some evidence of genotypic differences in tolerance to flooding exists in wheat [9] - [14] - [15].

The aim of this experiment was to analyze the effects of 15 days flooding events applied during tillering (ZGS13) and stem extension (ZGS31) on yield components (spike number, grain set, grain weight) for 10 winter wheat cultivars.

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II. Materials and Methods

In order to study grain set at flooding conditions (15 days) at growth stages (tillering, stem elongation and control (non-flooding)) on ten winter wheat (*Triticum aestivum* L.) cultivars (Pishtaz, Marvdasht, Shiraz, Zarin, Shahriar, C-81-4, Sardari, Agostaseed, FGS and Azar2) were grown outdoor at, a pot experiment was carried out in Laboratory of the Razi University, Kermanshah, Iran. The experimental design was a factorial according to a CRD with three replications. Seeds of the 10 wheat cultivars were planted in plastic pots (height 60 cm, diameter 16 cm). After emergence, the seedlings were thinned to eight plants per pot. The pots were fertilized pre-plant with 300 kg ha^{-1} N-P-K (100 kg ha^{-1} for each one) at planting, and with later top-dressed N at tillering and stem elongation to equal 100 kg N ha^{-1} (top-dressed) at tillering and stem elongation for each time. Part of the pots, in the start treatment were moved to the a small pool at tillering and stem elongation to maintain the water level at the top of the pots to desired water level with depth 60 cm. At harvest time, the number of grain per spike, the grain weight per spike, and the number of spike per plant were determined measured position of grain (number and weight) per spike and spikelet, also grain yield per plant. Average grain weight and grain yield per spike were then calculated.

III. Results and Discussion

Analysis of variance showed that both the period of flooding and the cultivar had a significant effect on all the yield components analyzed, except for grain yield per plant which was not significantly different among the cultivars (Table I, II and III).

Flooding at tillering and stem elongation stages reduced no. grain per spike (42.5 and 27.1 %), grain weight per spike (54.4 and 34.7 %), average grain weight (15.1 and 12.1 %) and grain yield per plant (41.5 and 31.8 %) compared to the control (Table I).

Ghobadi et al., [8] indicated that waterlogging at tillering stage (double ridge to terminal spikelet stages) reduced spikelet initiation and formation. Waterlogging at stem elongation stage had smaller effects on spikelet development than at tillering stage.

Results indicated that different cultivars responded differently to flooding, which could be linked to variation in morphological traits expression. "Shiraz" and "Zarin" had the highest number of grain per spike and grain weight per spike, but "Sardari" and "Agostaseed" had the highest average grain weight (Table II). Ghobadi et al., [10] observed at tillering (21 – 39 %) and stem elongation (15.8 - 36.8 %) stages reduction in spring wheat cultivars yield from 10 to 30 days flooded treatment.

There were significant interactions between the stage of development at which the water logging was applied and the cultivar for studied traits that indicated the different cultivars at different stages of flooding had not similar reduction. In our experiment, "Azar2" in flooded at time of tillering had the lowest no. grain per spike, grain weight per spike and average a grain weight with 65.8, 72.0 and 21.9 % reduction compare to control, respectively. Also "Sardari" had the lowest effect from flooding at tillering stage on grain yield (12.5 %) (Table III).

IV. Conclusion

The major results of these studies are: (a) winter wheat cultivars had different tolerance flooding; (b) tillering stage was more sensitive than the stem elongation stage to flooding stress; (at no. grain and grain weight per spike) and (c) grain weight and number grain per spike and also a grain weight per spike had the most decreased.

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Table I
Effect of Flooding Starting Date on Number Grain, Grain Weight and Average Grain Weight per Spike and Grain Yield per Plant also Amounts of their Reduction Compared to Control

Start of flooding	No. grain spike^{-1}	Grain weight (g spike^{-1})	Average grain weight (mg)	Grain yield (g plant^{-1})	Reduction (%)			
					No. grain spike^{-1}	Grain weight	Average grain weight	Grain yield
Control *	38.90^{a}	1.321^{a}	33.1^{a}	15.4^{a}	00.0	00.0	00.0	00.0
T. S.*	22.34^{c}	0.603^{c}	28.0^{b}	9.0^{c}	42.5	54.4	15.1	41.5
S. E. S.*	28.36^{b}	0.863^{b}	29.2^{b}	10.5^{b}	27.1	34.7	12.1	31.8
p-values	<0.001	<0.001	<0.001	<0.001				

*Control = none flooding; T. S. = Tillering Stage; S. E. S. = Stem Elongation Stage
Within each column, mean followed by a different letter are significantly different at 5% level (DMRT).

Table II
Effect of Flooding on Number Grain, Grain Weight and Average Grain Weight per Spike and Grain Yield per Plant for the 10 Cultivars of Winter Wheat Analyzed

Wheat cultivars	No. Grain spike^{-1}	Grain weight (g spike^{-1})	Average grain weight (mg)	Grain yield (g plant^{-1})
Pishtaz	28.78^{e}	0.89^{de}	28.8^{de}	1.42^{a}
Marvdasht	31.30^{d}	0.76^{f}	23.2^{f}	1.41^{a}
Shiraz	44.30^{a}	1.07^{b}	22.5^{f}	1.35^{a}
Zarin	39.67^{b}	1.14^{a}	27.7^{e}	1.53^{a}
Shahriar	28.07^{e}	0.90^{cd}	30.9^{cd}	1.52^{a}
C-81-4	34.04^{c}	1.11^{ab}	31.1^{cd}	1.53^{a}
Sardari	19.30^{h}	0.76^{f}	37.1^{a}	1.73^{a}
Agostaseed	25.63^{f}	0.97^{c}	35.5^{ab}	1.46^{a}
FGS	23.71^{g}	0.86^{de}	33.0^{bc}	1.36^{a}
Azar2	23.84^{g}	0.82^{ef}	31.5^{cd}	1.37^{a}
p-values	<0.001	<0.001	<0.001	<0.253

Within each column, mean followed by a different letter are significantly different at 5% level (DMRT).

TABLE III
INTERACTION BETWEEN FLOODING AND WINTER WHEAT CULTIVARS ON NUMBER GRAIN, GRAIN WEIGHT AND AVERAGE GRAIN WEIGHT PER SPIKE AND GRAIN YIELD PER PLANT FOR THE 10 CULTIVAR OF WINTER WHEAT ANALYZED

Treatments		No.	Grain weight	Average a grain	Grain yield
Start of flooding	Wheat cultivars	Grain spike^{-1}	(g spike^{-1})	weight (mg)	(g plant^{-1})
Control (non flooding)	Pishtaz	38.3	1.30	32.6	1.61
	Marvdasht	42.3	1.10	25.2	1.74
	Shiraz	58.0	1.57	24.8	2.00
	Zarin	46.0	1.50	31.8	2.55
	Shahriar	35.0	1.31	36.2	2.44
	C-81-4	42.3	1.46	32.9	1.85
	Sardari	30.0	1.07	38.0	1.91
	Agostaseed	33.0	1.38	38.5	2.34
	FGS	30.0	1.23	36.1	1.86
	Azar2	35.0	1.29	35.1	1.87
Tillering Stage	Pishtaz	19.3	0.53	25.9	1.30
	Marvdasht	22.3	0.50	22.1	1.32
	Shiraz	35.0	0.77	21.1	0.79
	Zarin	33.3	0.89	25.5	0.87
	Shahriar	19.6	0.63	30.0	0.96
	C-81-4	26.3	0.80	29.2	1.24
	Sardari	16.0	0.48	30.7	1.67
	Agostaseed	17.0	0.57	33.4	0.98
	FGS	15.3	0.50	30.0	1.15
	Azar2	12.0	0.36	27.4	1.13
Stem Elongation Stage	Pishtaz	28.6	0.84	27.8	1.35
	Marvdasht	29.3	0.70	22.2	1.36
	Shiraz	38.3	0.87	21.5	1.64
	Zarin	38.3	1.04	25.7	1.43
	Shahriar	28.3	0.78	26.5	1.48
	C-81-4	33.6	0.08	31.1	1.49
	Sardari	20.3	0.74	37.6	1.21
	Agostaseed	25.3	0.96	34.5	1.05
	FGS	23.0	0.85	33.0	1.09
	Azar2	21.6	0.82	32.0	1.10
$LSD_{0.05}$		0.64	0.036	0.51	0.32
p-values		<0.001	<0.001	<0.001	<0.001

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