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Root Traits Differentiates Osmotic Stress Tolerant and Susceptible Wheat Genotypes under PEG-Treatment †

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Abstract: Wheat is an important cereal crop that often suffers from osmotic stress under various growing conditions. The objective of this study was to investigate the effects of PEG-induced osmotic stress at the phytomer level on root growth and root hair morphology of 22 hydroponically grown wheat varieties. Two treatments, 0% and 10% PEG, were imposed for 15 days duration at 20 days old wheat seedlings. PEG stress significantly reduced plant height, number of live leaves per tiller, chlorophyll content, shoot dry weights, number of root bearing phytomers and roots per tiller. By contrast, PEG stress significantly increased leaf injury scores, root dry weight, main axis length and diameter of developed roots, length and diameter and density of both first and second order lateral roots, density and length of root hairs. An increase in root dry weight in PEG stress tolerant wheat genotypes was achieved through increase in length and diameter of main axis and lateral roots.

Keywords: wheat; PEG; osmotic stress; root traits

1. Introduction

Wheat is one of the major cereal crops that is grown in winter season in Bangladesh [1]. Wheat crops in Bangladesh face moisture deficit in water sensitive stages like booting and flowering [2]. Deficit irrigation may increase wheat production by 11% to 136% [2]. However, a number of traits related to yield of wheat shows adaptive mechanism under drought stress [3]. In a recent study, wheat cultivars showed variability in tolerance level based on leaf morphological traits [4]. In earlier studies, different sets of wheat genotypes showed genetic diversity based on days to maturity and yield contributing traits in Bangladesh [5,6]. None of those studied involved measuring root traits although tolerant crop plants exhibit root adaptive traits under various abiotic stress conditions [7,8]. The present study was therefore planned to investigate detailed root traits of wheat genotypes under osmotic stress.

2. Experiments

A total of 22 wheat genotypes including landraces, obsolete varieties and high-yielding cultivars were selected to impose osmotic stress. Plants were hydroponically cultured following Robin et al. [9,10] for 20 days before imposing 10% PEG induced osmotic stress along with control (Figure 1a). Plants were exposed to 15 days under stressed condition to allow plants to sufficient stress to record morphological difference in root growth (Figure 1b). Chlorophyll content of leaves under control and osmotic stress were recorded (Figure 1c) and leaf injury scores were scored (Figure 1d). A number of root traits including length, diameter and density of root axes, lateral roots and root hairs were measured under a light microscope (Figure 1e–f, [9,10]). In addition, number of live leaves and roots per tiller were recorded at the destructive harvest.

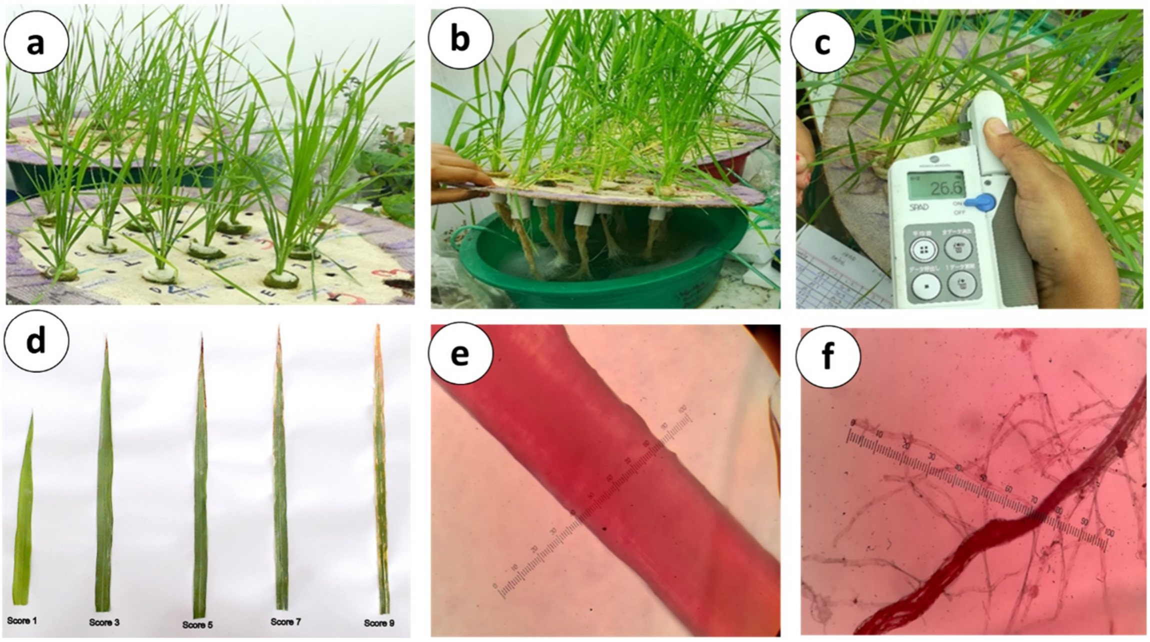

Figure 1. Hydroponic culuture of wheat genotypes and measurements. (**a**) wheat plants at 20 days ready for treatment impostion; (**b**) Root growth of what plants under 10%PEG induced osmotic stress; (**c**) Measurements of chrolophyll content using SPAD meter; (**d**) scoring of damaged leaves under osmotic stress; (**e**) diameter of a root axis and (**f**) length of a root hair.

3. Results

3.1. Effect of PEG Stress

PEG-induced osmotic stress significantly reduced plant height, number of live leaves per tiller, chlorophyll content in the leaf tissues (Table 1). Leaf injury scores was increased at the 5th live leaves (Table 1). Osmotic stress also reduced shoot dry weight per tiller but strikingly root dry weight per tiller increased (Table 1). Despite increase in root dry weight per tiller number of root bearing phytomers and total number of root per tiller decreaed (Table 1). Osmotic stress reduced number seminal roots per tiller but the length of individual seminal roots increased. With the increase of root dry weight per tiller length, diameter and density of lateral roots and root hairs also increased (Table 1).

Table 1. Differce between control and 10% PEG induced osmotic stress among wheat genotypes. Pr, phytomer; MA, main axis; FLR, first order lateral roots; SLR, second order lateral roots; RH, root hairs; d, diameter; Dn, density; L, length.

Traits	Control	10% PEG	*p* Value
Plant height (PH)	42.5 ± 0.71	36.7 ±0.79	<0.001
Live leaves per tiler (LL)	4.76 ± 0.10	3.88 ±0.08	<0.001
Chlorophyll content	29.8 ± 0.46	27.7 ±0.49	<0.001
Leaf injury scores at 5th leaves	5.06 ±0.19	6.94 ±0.19	<0.001
Shoot dry weight (SDW)	0.46 ±0.02	0.32 ±0.01	<0.001
Root dry weight (RDW)	0.05 ±0.00	0.07 ±0.00	<0.001
Total no. of phytomer (TPr)	7.18 ±0.16	5.70 ±0.16	<0.001
Total no. of roots per tillers (TRt)	9.34 ±0.36	7.32 ±0.34	<0.001
No. of seminal roots (SR)	5.59 ±0.16	4.48 ±0.17	0.008
Length of seminal roots (LSR)	2.55 ±0.13	3.23 ±0.17	<0.001
Main axis length at Pr 4 (MALPr4)	47.6 ±1.17	53.2 ±1.3	<0.001
Diameter of main axis (dMA)	0.36 ±0.01	0.50 ±0.01	<0.001

Length of FLR (LFLR, cm)	1.48 ±0.08	3.00 ±0.14	<0.001
Diameter of FLR (dFLR, mm)	0.19 ±0.00	0.27 ±0.01	<0.001
Density of FLR (DnFLR)	4.95 ±0.07	6.60 ±0.08	<0.001
Length of SLR (LSLR, cm)	0.39 ±0.09	0.57 ±0.03	<0.001
Diameter of SLR (dSLR, mm)	3.35 ±0.09	5.13 ±0.09	<0.001
Density of SLR (DnSLR)	6.58 ±0.22	8.18 ±0.23	<0.001
Density of root hairs of MA (DnRH$_{MA}$)	6.70 ±0.22	8.41 ±0.20	<0.001
Density of root hairs of SLR **(**DnRH$_{SLR}$)	7.06 ±0.20	9.15 ±0.20	<0.001
Length of root hairs of FLR **(**LRH$_{FLR}$)	420.5 ±16.5	503.6 ±12.71	<0.001

3.2. Correlation among Selected Root Traits

Inspite of increasing trend of all root traits upon PEG-induced osmotic stress, only main axis length showed significant association with root dry weight (Table 2). Number of root bearing phytomers, number of roots per tiller and number of seminal roots per tiller showed strong positive association among each other (Table 2). Total number of roots per tiller negative assocation with density of primary leteral roots per unit main axis length (Table 2).

Thus, the genotypes produced higher root dry weight and main axis length were more tolerant to osmotic stress compared to contrasting genotypes.

Table 2. Correlation among root dry weight (RDW), total number of root bearing phytomers (TPr) and total number of roots (TR) per tiller and with other root morphological traits of wheat genotypes under PEG induced osmotic stress.

Traits	RDW	TPr	TR
Total no. of phytomer (TPr)	0.379 ^{NS}		
Total no. of roots per tillers (TRt)	0.492 ^{NS}	0.92 ***	
No. of seminal roots (NSR)	0.405 ^{NS}	0.754 **	0.867 ***
Main axis length at Pr 4 (MALPr4)	0.664 *	−0.101 ^{NS}	0.091 ^{NS}
Diameter of main axis (dMA)	0.34 ^{NS}	−0.383 ^{NS}	−0.358 ^{NS}
Length of FLR (LFLR, cm)	0.481^{NS}	−0.381 ^{NS}	−0.149 ^{NS}
Diameter of FLR (dFLR, mm)	0.073 ^{NS}	−0.612 *	−0.528 ^{NS}
Density of FLR (DnFLR)	−0.145 ^{NS}	−0.759 **	−0.634 *
Length of SLR (LSLR, cm)	0.162 ^{NS}	−0.067 ^{NS}	−0.068 ^{NS}
Diameter of SLR (dSLR, mm)	0.257 ^{NS}	0.309 ^{NS}	0.266 ^{NS}
Density of SLR (DnSLR)	0.448 ^{NS}	−0.337 ^{NS}	−0.262 ^{NS}
Density of root hairs of MA (DnRH$_{MA}$)	0.392 ^{NS}	−0.032 ^{NS}	−0.113 ^{NS}
Density of root hairs of SLR (DnRH$_{SLR}$)	0.205 ^{NS}	−0.186 ^{NS}	−0.125 ^{NS}
Length of root hairs of FLR (LRH$_{FLR}$)	0.334 ^{NS}	−0.374 ^{NS}	−0.447 ^{NS}

*, ** and *** indicate significance at 5%, 1% and 0.1% level of significance, respectively.

4. Discussion

Production of large root system associated with elongation of main axis and lateral branches under drought stress condtion is believed to a characteristic feature of drought tolerant plants [8]. Tall fescue plants produced extensive root hairs under drought stress similar to this study but the root dry weight per plant was decreased under stress condition [11]. In cron, a kind of genotypic diversity was observed where increasing root dry weight in the tolerant genotypes was associated with yield [12] and these results are consistent with our observations. However, none of the previous studies observed root traits at the phytomer level and in detail similar to this study.

5. Conclusions

This study explored the effects of PEG-induced osmotic stress on root development at the phytomer level. A strong positive association between root dry weight and main axis length was observed. The results indicated that tolerant wheat genotypes increases length and density of main axis and lateral branches as an adaptive mechanism to cope the osmotic stress.

Author Contributions: A.H.K.R. and S.G. conceived and designed the experiments; S.G. performed the experiments; S.G. and M.A.S. analyzed the data and prepared tables and figures. A.H.K.R. wrote the paper.

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Conflicts of Interest: The authors declare no conflict of interest.

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