Root system plasticity to drought mitigates grain yield depression in wheat

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Telosomic Mapping of Hexaploid 'Chinese Spring' Bread Wheat

- Remove half a chromosome, long or short arm, in the A, B, and D genomes.

- 7 basic chromosomes, 2 arms = 14
- 3 genomes = 42 telosomics

- Ehdaie, B. and J.G. Waines. 1997. Euphytica 96:363-375.

- Waines, J.G., B. Ehdaie, and D.R. Barnhart. Location of genes conferring drought tolerance in rye and braed wheat. 1998. Triticeae III. P 285-292, A.A. Jaradat (ed.) Sci. Publishers Inc. USA.

Distribution of positive (P) and negative (N) effect associate with chromosome arms in the A genome of Chinese Spring bread wheat on days from sowing to maturity (DM), plant height (PH), number of spikes (NS), root dry weight (RDW), shoot dry weight (SDW, excluding grains), and carbon isotope discrimination (Δ).

Character	Chromosome arms of A genome													
	1S	1L	2S	2L	3S	3L	4S	4L	5S	5L	6S	6L	7S	7L
DM				N		N		P	P		N	P		
PH			N		N		N		P	N	N	N	N	N
NS	N		N	N*			P	P						
RDW	N		N	N*				P						
SDW	N		N	N*				P			N			
Δ	N					N					N	P		

* Dimonotelosomic lines that showed effects similar to those of their corresponding ditelosomic lines

Distribution of positive (P) and negative (N) effect associate with chromosome arms in the B genome of Chinese Spring bread wheat on days from sowing to maturity (DM), plant height (PH), number of spikes (NS), root dry weight (RDW), shoot dry weight (SDW, excluding grains), and carbon isotope discrimination (Δ).

Character	Chromosome arms of B genome													
	1S	1L	2S	2L	3S	3L	4S	4L	5S	5L	6S	6L	7S	7L
DM				P			N							
PH				N	N	N		N			N	N	N	N
NS			N*	N						N				
RDW			N		N				N*	N	N			
SDW			N										N	
Δ	N	N			N					N	N		N	

* Dimonotelosomic lines that showed effects similar to those of their corresponding ditelosomic lines

Distribution of positive (P) and negative (N) effect associate with chromosome arms in the D genome of Chinese Spring bread wheat on days from sowing to maturity (DM), plant height (PH), number of spikes (NS), root dry weight (RDW), shoot dry weight (SDW, excluding grains), and carbon isotope discrimination (Δ).

Character	Chromosome arms of D genome													
	1S	1L	2S	2L	3S	3L	4S	4L	5S	5L	6S	6L	7S	7L
DM		N	P	N		N			P			P	P	
PH			N	N	N	N			N		N	N	N	N
NS				N		N			P	N				
RDW				N		N			P	N				
SDW				N		N			P			P		
Δ	N				N	N					N			N

* Dimonotelosomic lines that showed effects similar to those of their corresponding ditelosomic lines

Conclusions from telosomic mapping of A genome

- 1. Loss of whole chromosome arm mostly has negative effects on plant characters
- 2. In a few cases there is a positive effect,
- Days to maturity – 4AL, 5AS, 6AL
- Plant Height – 5AS
- # Spikes – 4AS, 4AL
- Root Dry Wt 4AL
- Shoot Dry Wt 4AL
- Delta – 6AL

Conclusions from telosominc mapping of B genome

- 1. Loss of chromosome arm mostly has negative effects on plant characters
- 2. Only with loss of arm 2BL was there a positive effect on days from sowing to maturity.

Conclusions from telosomic mapping D genome

- 1. Loss of chromosome arm mostly has negative effects on plant characters.
- 2. In a few cases loss of arm had a positive effect:
- Days to Maturity - 5DS, 6DL, 7DS
- # Spikes – 5DS
- Root Dry Wt. - 5DS
- Shoot Dry Wt. - 5DS, 6DL

Conclusion from telosomic mapping

- **In all cases, loss of a chromosome arm had a negative effect on grain yield.**
- **What is the genetic basis of the positive effect on roots of removal of some teleosomes in polyploids?**

Root Plasticity

- **Muller-Thurgau, 1875, found that growing plant seedlings in drying soil increased the size of the root system compared with that of seedlings in irrigated soil.**

Our Hypothesis

- **Root phenotypic plasticity may reduce the negative impacts of drought on grain yield in wheat.**

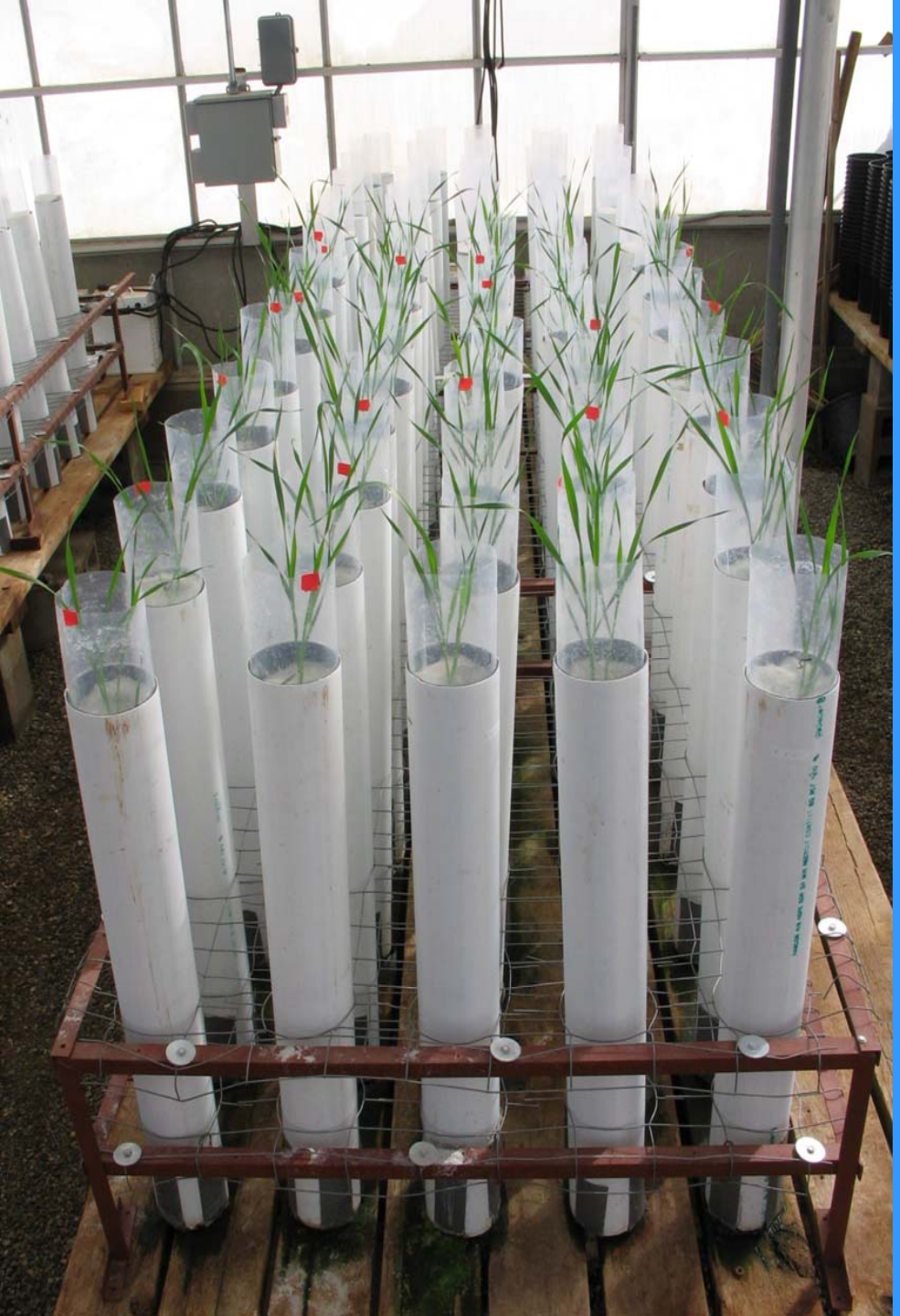
In the 20th century

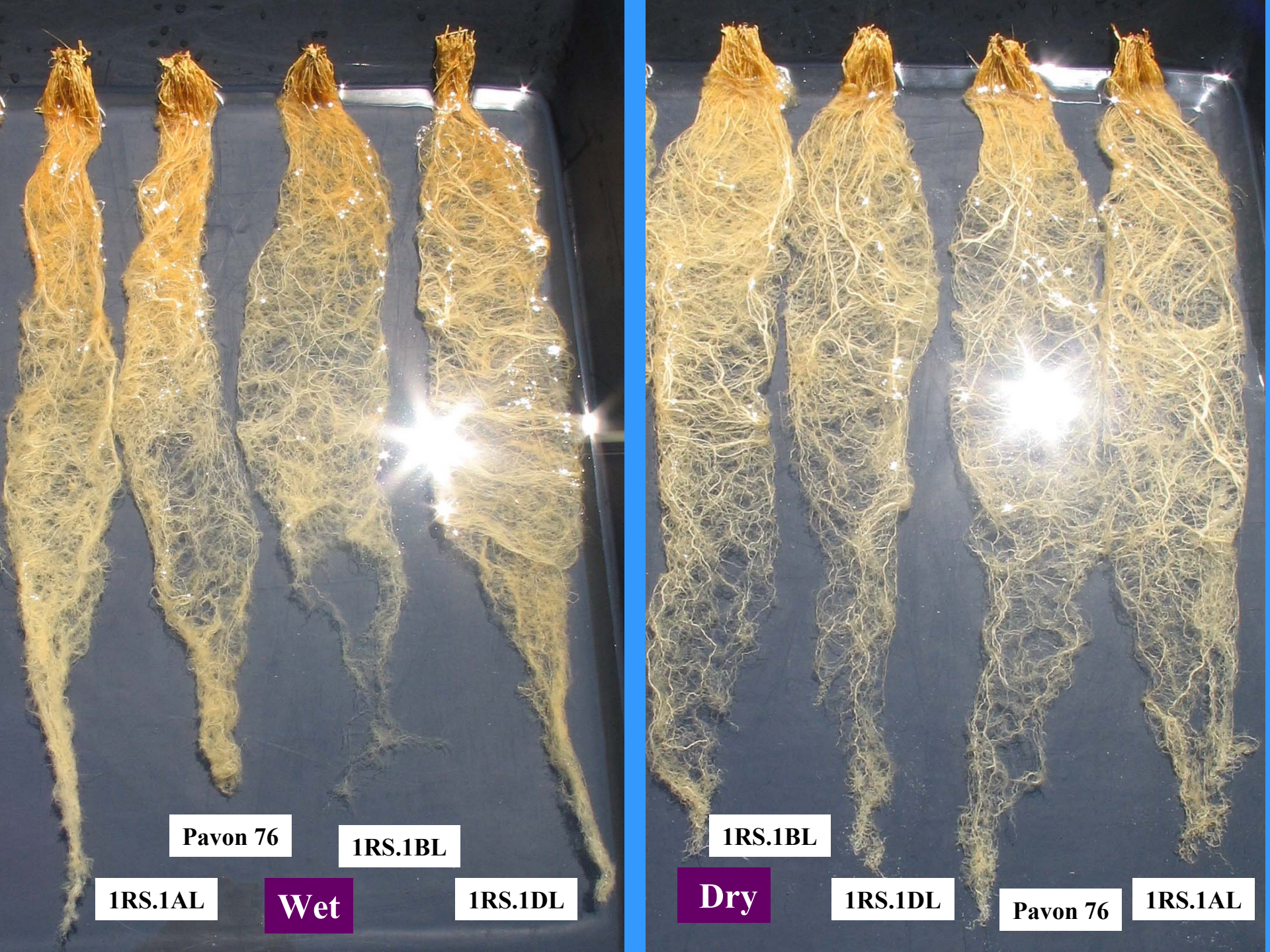
- The evolutionary significance of phenotypic plasticity in plants was explored by A.D. Bradshaw 1965, and C.D. Schlicting 1986.

- Genotypes that did or did not exhibit phenotypic plasticity were found in maize, wheat, soybean, cotton and other species.

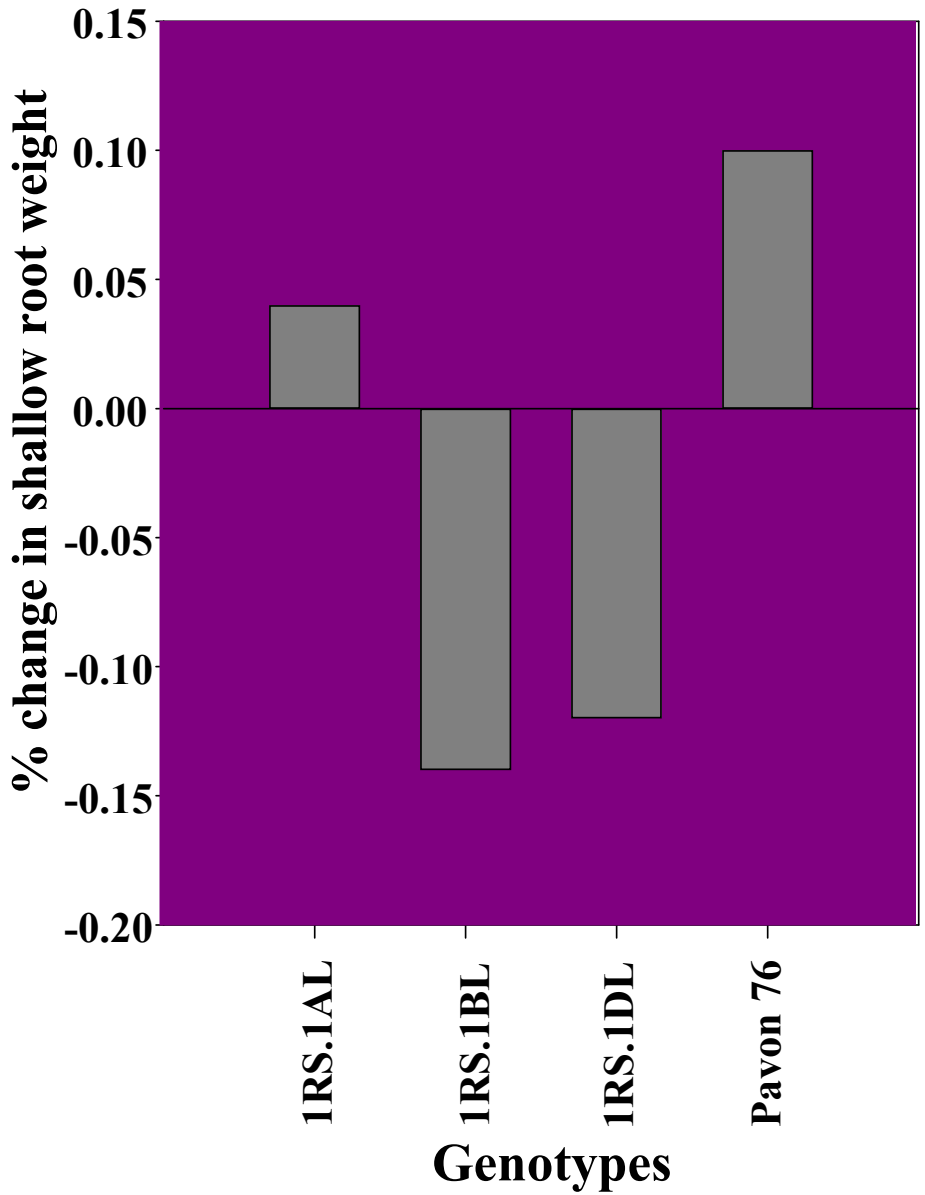
Materials & Methods

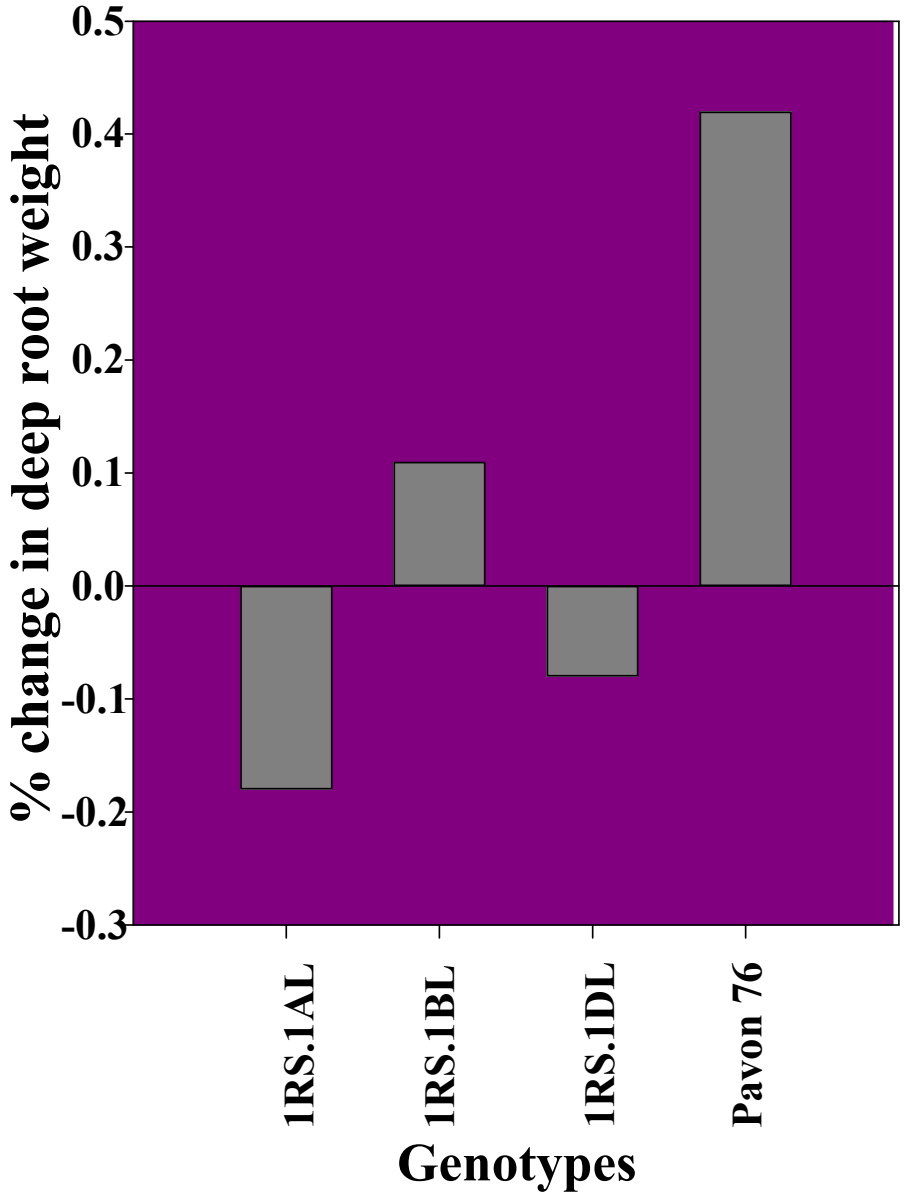
- 4 genotypes: Pavon 76, Pavon 1RS.1AL, Pavon 1RS.1BL & Pavon 1RS.1DL
- 2 treatments: Well-watered and drought stressed at boot stage; 50% (2008) or 60% (2009) of water given to well-watered applied resulting in reduction of 36% and 19% in grain yield, respectively
- 80 cm sand tubes, plants grown to maturity
- Factorial experiment with 4 replicates



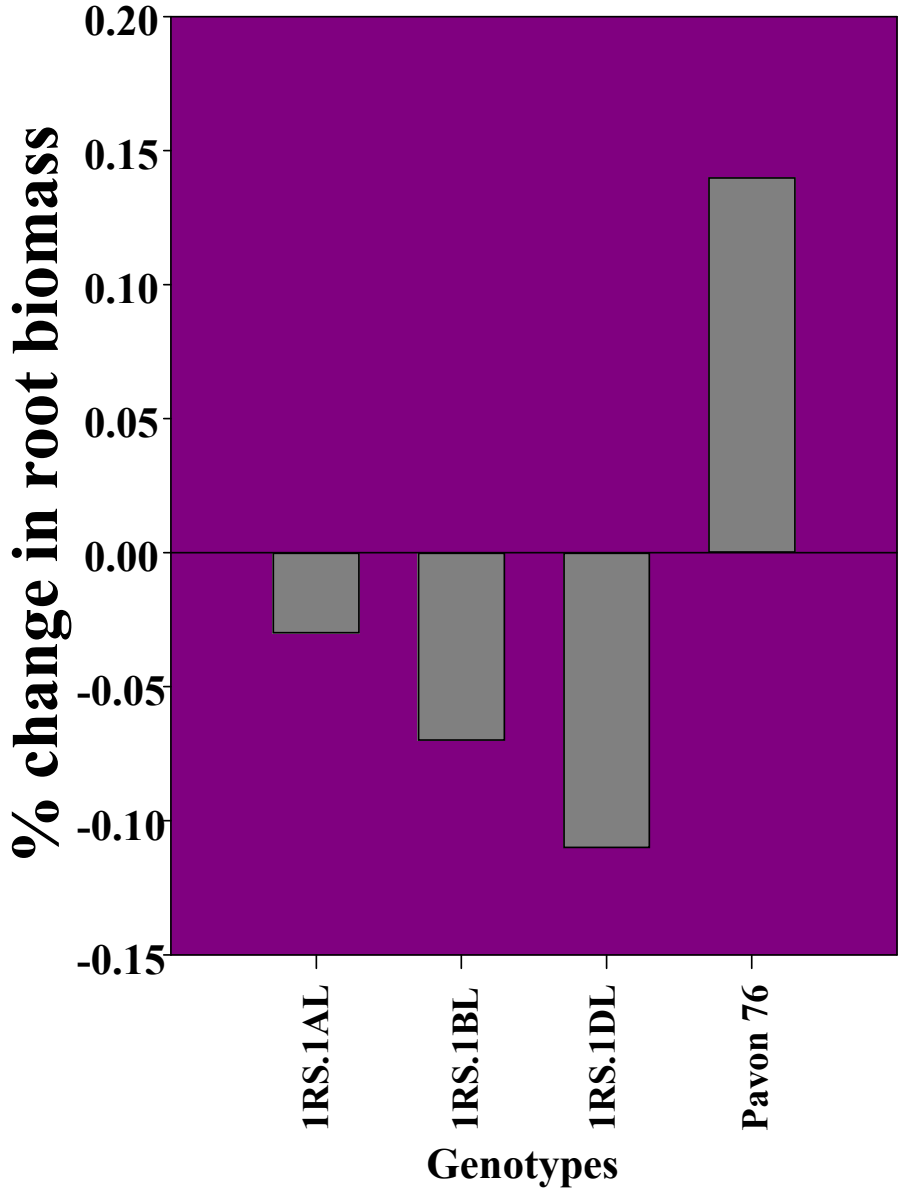

Pavon 76
1RS.1BL
1RS.1AL
Wet
1RS.1DL
1RS.1BL
Dry
1RS.1DL
Pavon 76
1RS.1AL

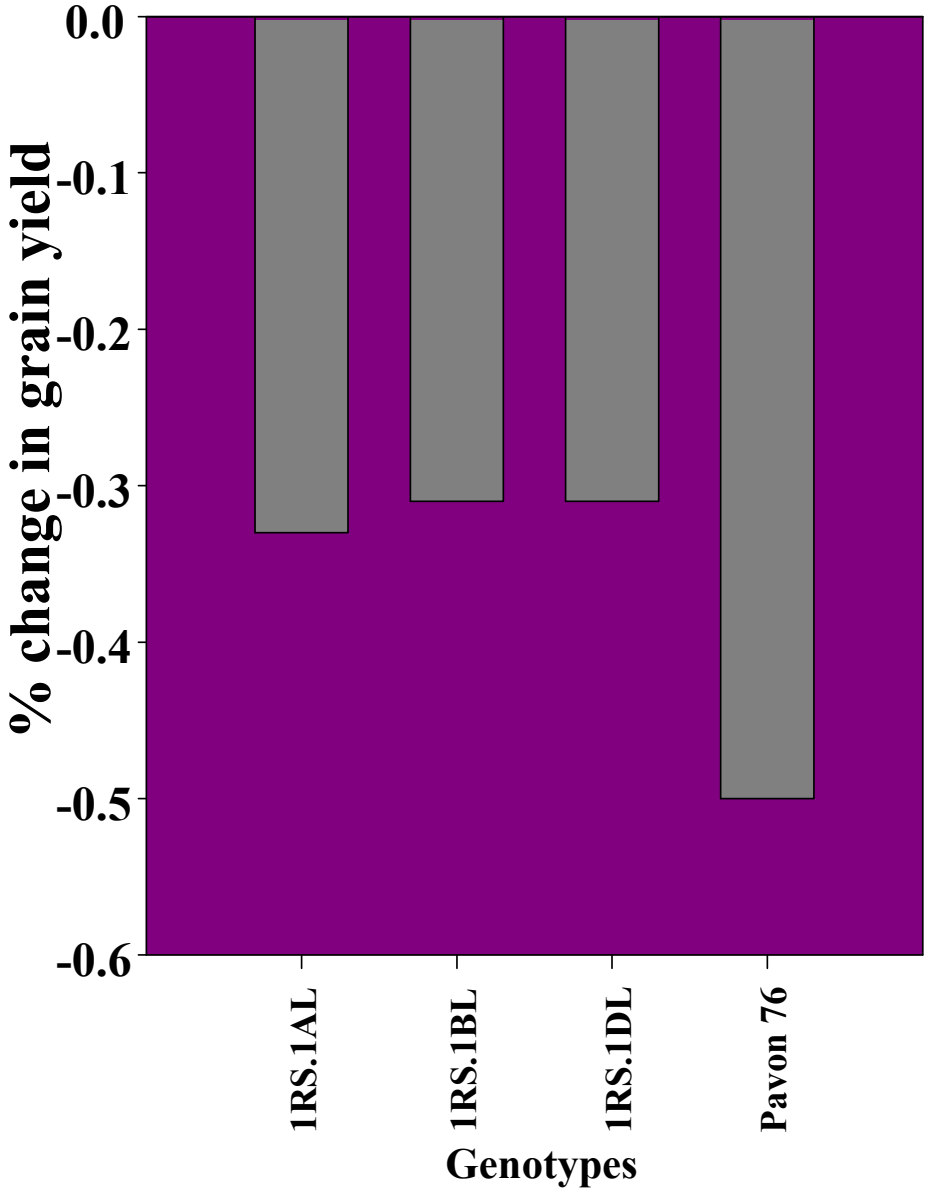
2008 : Drought intensity 36%



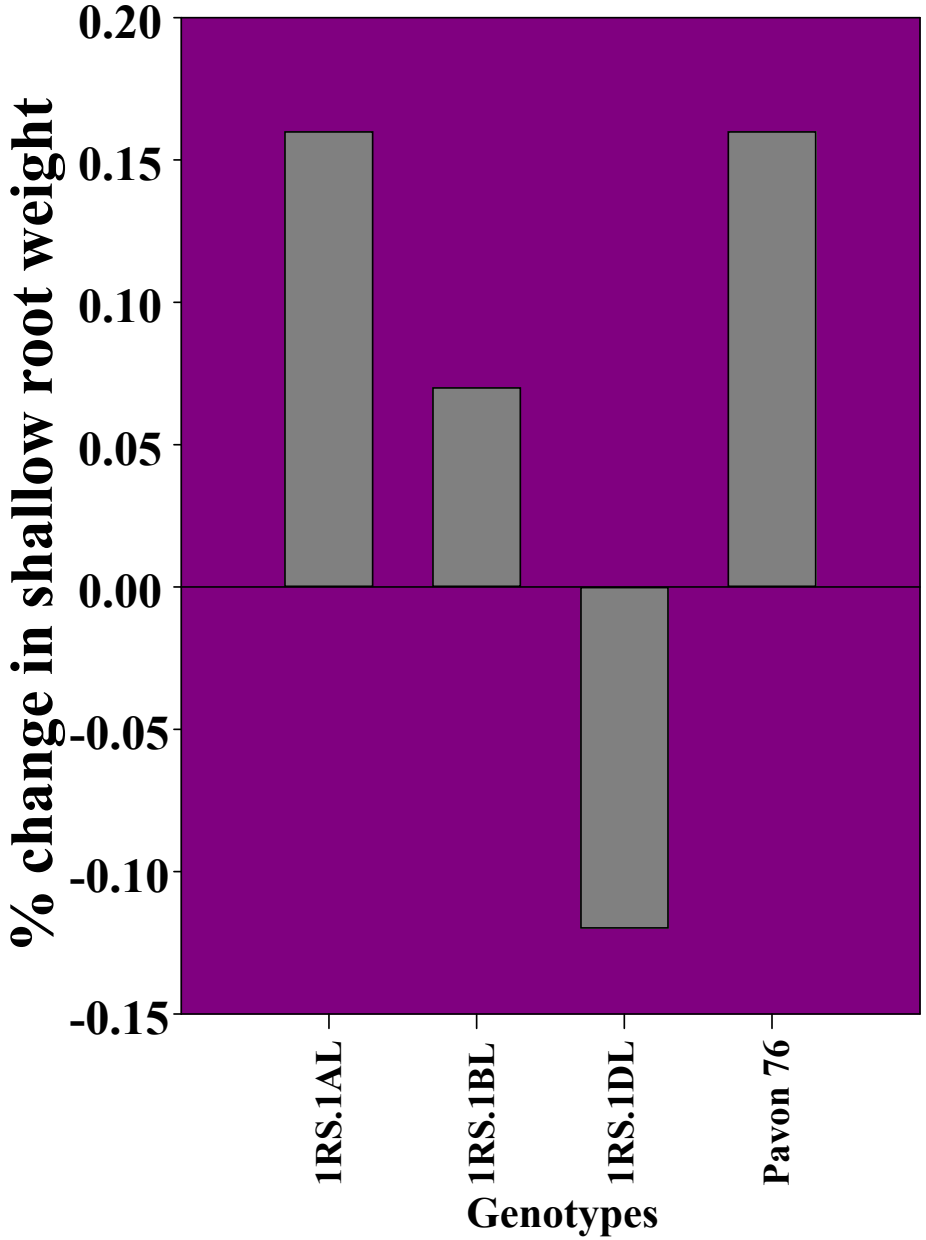


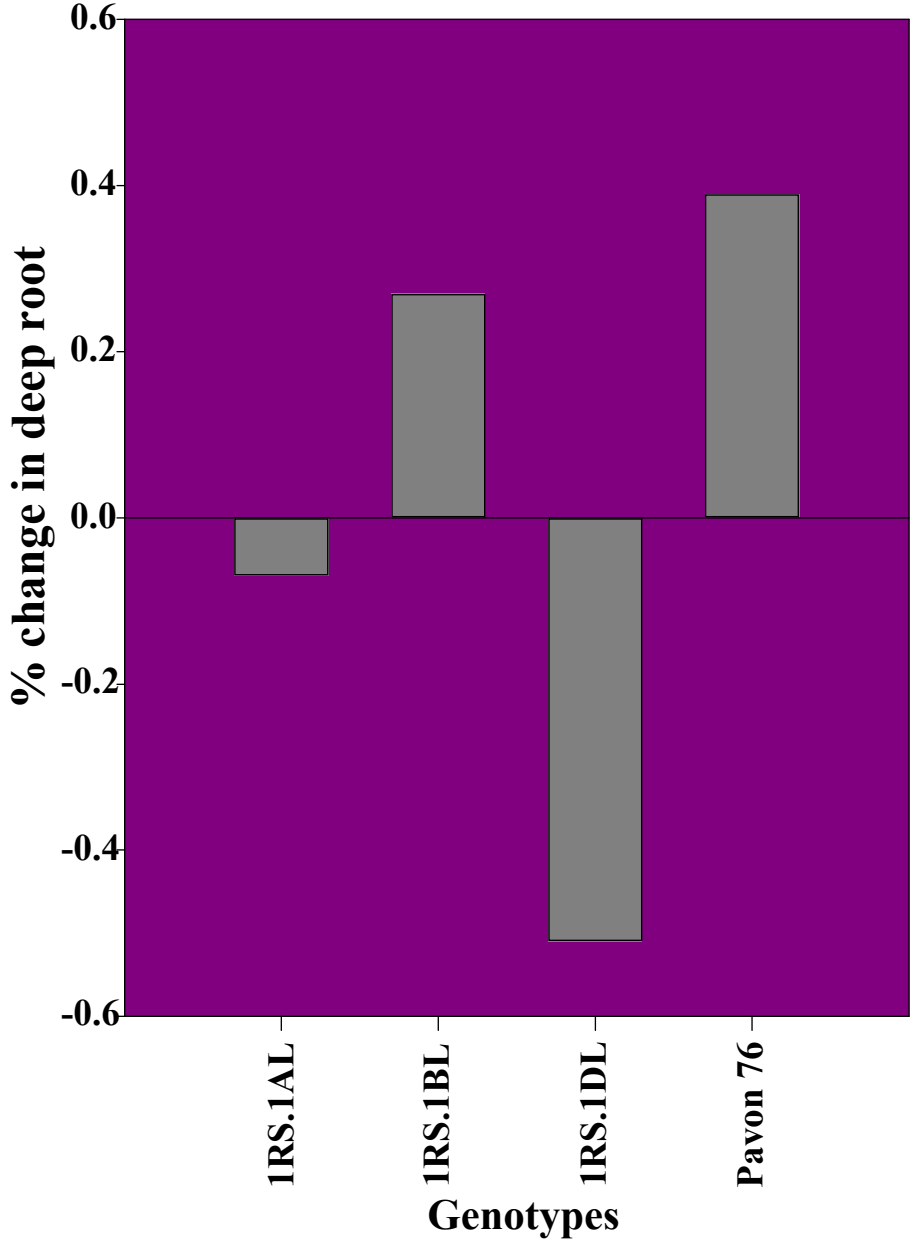
2008 : Drought intensity 36%



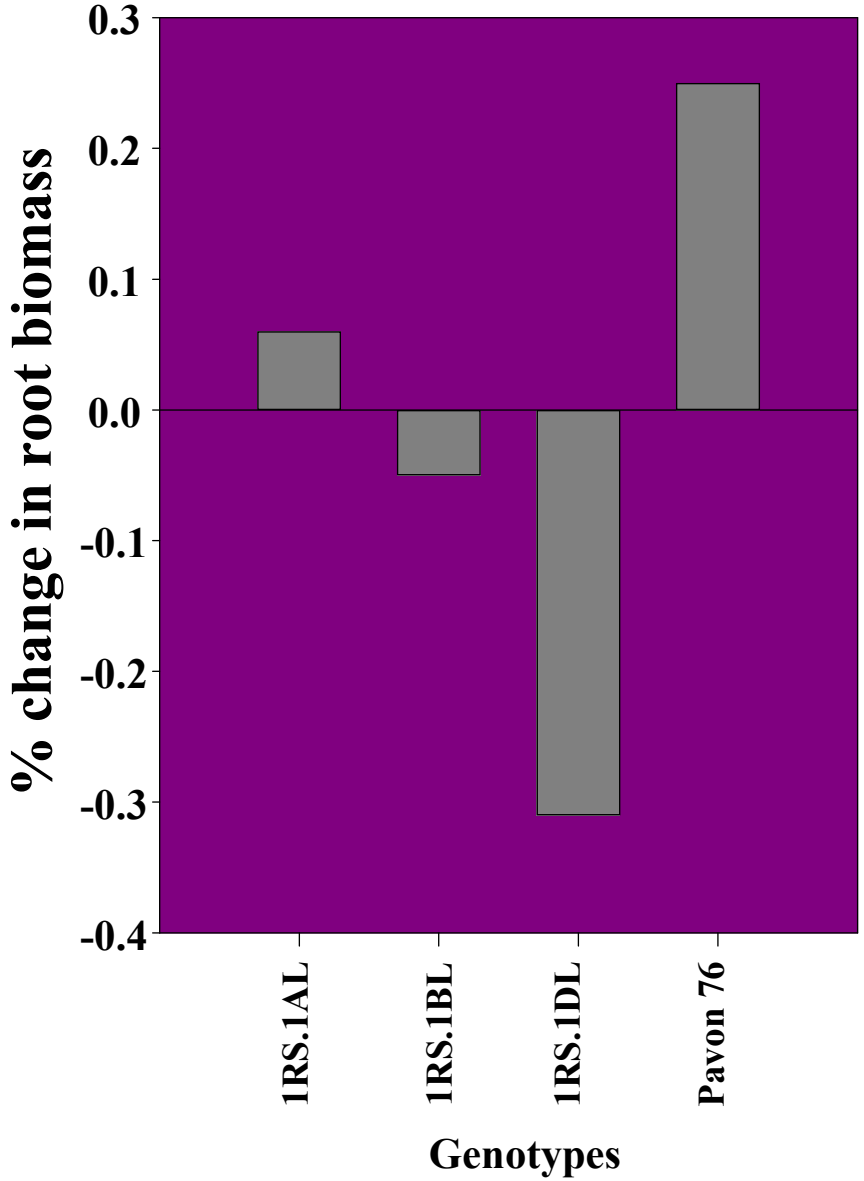


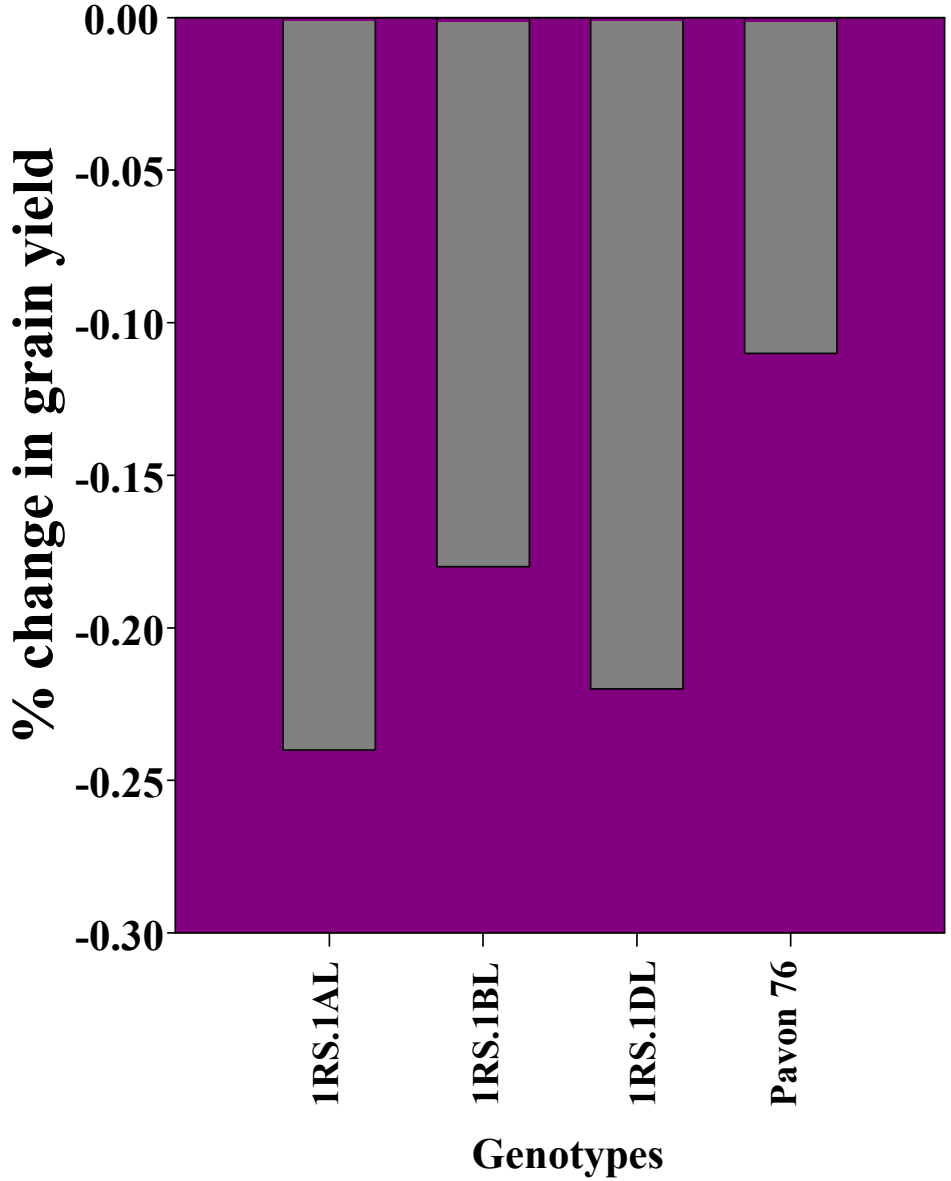
2009 : Drought intensity 19%





2009 : Drought intensity 19%





Results

- Small variation from seed germination to booting, heading, anthesis, and physiological maturity.
- Small variation for ph, # til, and # sp/pl.
- Root biomass & components not correlated with phenological periods.
- Shallow and deep root weight and root biomass negatively correlated with plant height, but positively correlated with shoot biomass under both irrigation regimes.
- They were negatively correlated with no. of tillers under drought.

- **1RS translocation lines had greater root biomass per plant, from 7.37 – 8.6 g compared to 5.81 for Pavon 76.**
- **Only Pavon 76 showed a positive response to drought by producing more shallow roots and deep roots in both years**
- **At DI 19% (2009) grain yield of Pavon 76 reduced only by 11% compared to other lines with yield reduction of 18-24%.**

- **At DI of 36% (2008) grain yield of Pavon 76 showed maximum reduction.**
- **Indicates greater root production under drought is advantageous only when plant available water is enough to support grain production.**
- **Grain yield was positively correlated with shallow and deep root weight and root biomass under drought.**

Conclusions

- **Genes influencing adaptive phenotypic plasticity of the root system to drought in Pavon 76 are located on short arm of chromosome 1 (1BS).**

- **The 1BS-1RS homoeologous recombinant inbred lines (Lukaszewski 2000) could be used to identify segments of 1BS associated with this plasticity.**

Reference

1- Waines, J. G., B. Ehdaie, and A.P. Layne. 2011. Root system plasticity to drought influences grain yield in bread wheat. Euphytica. DOI 10.1007/s10681-011-0585-9.

2- PAG 2012: Poster P0310