Optimum Root Biomass for Maximum Grain Yield in Bread Wheat under Well-watered and Drought Field Conditions

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INTRODUCTION

An optimum root system in wheat might enhance water and nutrient uptake under a drought environment without depleting soil moisture, thus improving grain yield. Information on the relationship between root biomass and grain yield is scarce in wheat. Our main objective was to determine optimum root biomass to maximize grain yield under well-watered and drought field conditions.

MATERIALS and METHODS

A set of 5 genotypes with different root biomass per plant, but with similar days to anthesis (NDA), to maturity (NDM) and plant height (PH) was selected from a RIL population derived from a cross Iran #49 × Yecora Rojo (Fig. 1 and Table 1). These genotypes plus Yecora Rojo (YR) were planted in two experiments under well-watered (wet, a total of 412 mm of water) and drought (dry, a total of 268 mm of water) field conditions at the University of California, Riverside in 2014. Traits including grain yield (GY) were measured and a stress tolerance index (STI, Table 3) based on GY was calculated. The relationships between root biomass measured in a glasshouse and GY and STI measured in the field were determined.

RESULTS and CONCLUSIONS

The covariate analysis of GY with NDA, NDM, and PH was not significant. Significant differences were found among the genotypes. The genotype × irrigation interaction was relatively low. Drought significantly reduced some traits including GY (Table 2). A quadratic pattern of relationship was observed between root biomass measured in the glasshouse with GY measured in the wet and dry field conditions and with STI (see Figures). GY in wet and dry field conditions was maximized at 5.806 and 4.575 t /ha when root biomass was 1.630 and 3.975 g/plant, respectively. STI was highest when root biomass was 3.5 g/plant. Over-sized root biomass reduced GY.

Fig. 1.

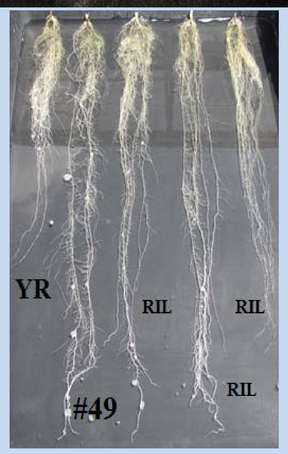


Table 1. Mean values for root biomass (RB), shallow root weight (SRW), deep root weight (DRW), ratio of DRW to SRW, days to anthesis (DTA) and maturity (DTM), grain-filling period (GFP), and plant height (PH) of the bread wheat RILs and the check variety (Yecora Rojo, YR) measured under well-watered conditions in a sand-tube glasshouse experiment in Riverside in 2013 used in the study (Ehdaie et al., 2014).

RILs/ Genotype	RB	SRW (g/plant)	DRW	DRW/ SRW	DTA	DTM (days)	GFP	PH
YR	1.820	1.280	0.590	0.42	71	113	42	60
#8	1.535	1.165	0.370	0.32	67	119	52	81
#57	7.850	4.890	2.960	0.61	86	119	33	77
#115	1.525	0.985	0.540	0.55	66	117	51	83
#122	3.975	2.035	1.940	0.95	74	120	46	72
#136	1.175	0.695	0.480	0.69	64	117	53	78

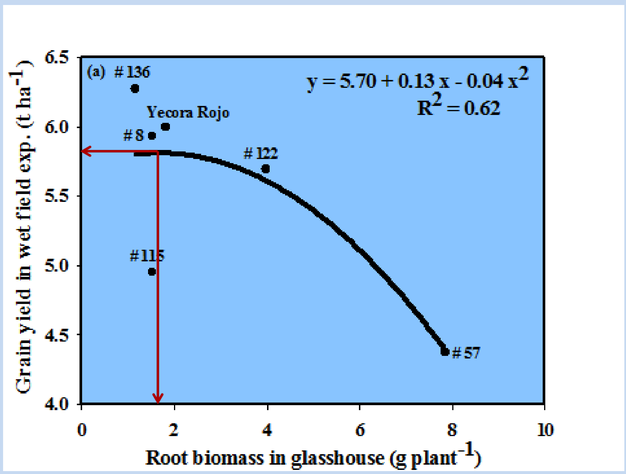
Table 2. Mean values for number of days to anthesis (NDA) and to maturity (NDM), plant height (PH), number of spikes per plant (NS), thousand grain weight (TGW), grain yield (GY), and harvest index (HI) for the genotypes evaluated under well-watered and droughted field conditions in Riverside, CA, in 2014.

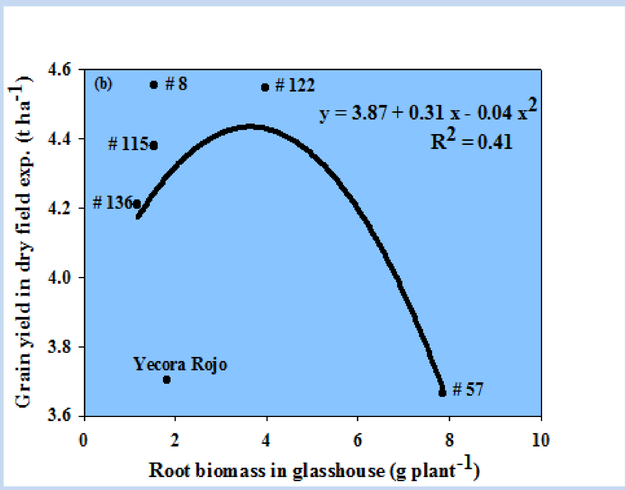
Treatment/ Genotype	NDA (d)	NDM (d)	PH (cm)	NS (no.)	TGW (g)	GY (t/ha)	HI (%)
Well-watered							
Yecora Rojo	72 c	128 d	69 e	3.5 ab	33.2 c	5.994 a	43.9 a
# 8	73 c	134 b	85 c	3.7 ab	37.7 b	5.928 a	43.7 a
# 57	82 a	137 a	101 a	4.1 a	34.1 c	4.375 c	25.7 d
# 115	72 c	132 c	95 b	3.3 b	42.1 a	4.953 bc	37.7 b
# 122	77 b	137 a	77 d	4.1 a	37.8 b	5.694 ab	32.1 c
# 136	69 d	125 c	90 c	3.8 ab	38.4 b	6.271 a	40.0 ab
Mean	74 A	132 A	86 A	3.8 A	37.2 A	5.536 A	37.2 A
Droughted							
Yecora Rojo	70 d	118 d	61 d	2.6 c	27.7 c	3.703 b	43.2 a
# 8	73 c	126 c	80 b	2.9 abc	32.1 b	4.554 a	37.6 ab
# 57	80 a	134 a	88 a	2.7 bc	30.8 bc	3.665 b	30.9 c
# 115	73 c	126 c	88 a	3.2 bc	37.7 a	4.379 ab	36.3 bc
# 122	76 b	130 b	69 c	3.0 ab	36.6 a	4.546 a	35.8 bc
# 136	68 e	117 d	82 b	3.3 a	32.8 b	4.209 ab	37.0 bc
Mean	73 A	125 B	78 A	2.9 B	33.0 B	4.176 B	36.8 A
Reduction (%)		5		25	11	25	

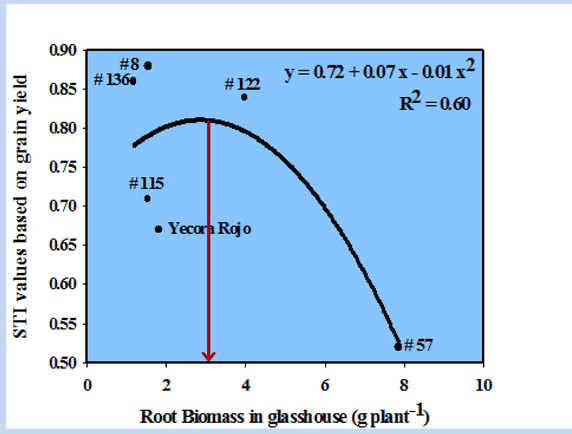
Table 3. Stress tolerance indices based on number of spikes per plant (NS), number of grains per spike (NGS), thousand grain weight (TGW), and grain yield (GY) for bread wheat genotypes evaluated under well-watered and droughted field conditions in Riverside, CA, in 2014.

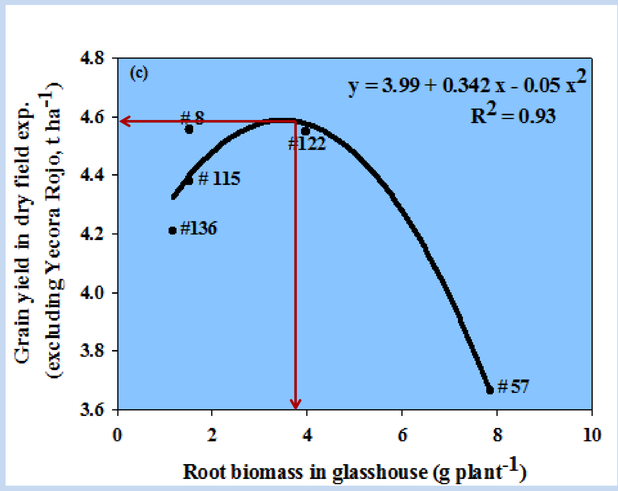
Genotype	Stress tolerance index (STI)			
	NS	NGS	TGW	GY
Yecora Rojo	0.65	1.37	0.66	0.67
# 8	0.74	0.90	0.87	0.88
# 57	0.76	0.98	0.76	0.52
# 115	0.76	0.53	1.15	0.71
# 122	0.89	1.14	1.00	0.84
# 136	0.78	1.07	0.91	0.86

STI = $(Y_P/\bar{Y}_P)(Y_S/\bar{Y}_S)(\bar{Y}_S/\bar{Y}_P) = (Y_P)(Y_S) / (\bar{Y}_P)^2$, where Y_P and Y_S are means of a genotype for a trait, and $\bar{Y}_P$ and $\bar{Y}_S$ are overall mean in non-stressed and stressed environments, respectively. Greater values of STI mean greater stress tolerance.









Reference

Ehdaie, B., Maheepala, D.C., Bektas, H., Waines, J.G. , 2014. Phenotyping and genetic analysis of root and shoot traits of recombinant inbred lines of bread wheat under well-watered conditions. J. Crop Improv. 28, 834-851.