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Effect of weed infestation on root functional traits of wheat (*Triticumaestivum* L.) under different treatments

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ABSTRACT

The present study was designed to understand the performance of wheat crop under weed infestation (Avena and Phalaris combination) with water and fertilizer treatments during each rabi season of 2014-2017 at Panjab University, Chandigarh.Results indicated that under different mixed combinations of weeds, root functional trait of wheat crop (root length and root biomass) were significantly reduced from monoculture. However, the highest reduction of corresponding parameters was observed when wheat was grown mixed with both the weeds and full doses of fertilizers and water supply. The over powering weed i.e. Avena had more capacity to undertake the maximum nutrients and water resources at the growth stage of the crop. The weeds have much more inclination to exploit available ground resources and have a high capacity of inter-specific root competition to the wheat crop. Yield production of the wheat crop was positively correlated with root length and root biomass under weed infestation reflecting a favourable response of the root functional traits under weed-crop competition.

Keywords: *Avena*, *Phalaris*, root functional traits, grain yield, wheat, weeds

INTRODUCTION

Competition processes between agriculture crops and weeds are a challenging field in crop science. Crop and weed species often compete for the same resources such as nutrients, water, and light. Previous reports about crop–weed interactions focused only on aboveground competition or used aboveground parameters to explain the impact of the competition for water and nutrients. However, competition should be explained at a whole plant level. Plants within one plant family are often similar in their strategy to acquire nutrients and water which can increase the competition. In several studies, root competition was more intense than shoot competition (Kiaer*et al.,* 2013, Meinen and Rauber, 2015). In general, studies of belowground competition or root competition between crop and weed species are scarce, often due to the difficulties of studying the species-specific root systems in mixtures. However, root traits i.e. root length, root weight ratio and root biomass are the key regulators of water and nutrient uptake efficiency of plants; they can be used to quantify the role of roots in relation to yield development of crops, as root length and root biomass help the plant to attain more nutrients from the soil and increases its competitive ability. The competition between spring cereals and weeds like *Avena fatua* L. for soil resources especially for nitrogen was stronger than the competition for resources like light. Therefore, this study was carried out to assess the ability of weeds (*Avena sativa* L. and *Phalaris minor* Retz.) by using selected root functional traits of wheat crop raised under various combinations of weeds and treatments.

MATERIALS AND METHODS

The experiments were conducted in consecutive three years during the Rabi season of 2014-2015, 2015-2016 and 2016-2017 at the experimental dome of Department of Botany, Panjab University, Chandigarh, India, located at 30.7601° N latitude and 76.7663° E longitude. The climate of the experimental area is humid subtropical with maximum temperature (16ºC to 25ºC), while the minimum from 9ºC to 18ºC. The average annual rainfall is about 1100 mm. To ensure maximum seedling emergence, the seed was sown at 4 to 5 cm in soil depth. According to the experimental design, total four combinations were prepared i.e. (1) monoculture (W) (100 % of *Triticum aestivum* L.) (2) mixed-culture plots as (W+A) (50:50%) seeds of wheat and *Avena* (3) *mixed* culture as (W+P) (50:50%) seeds of wheat and *Phalaris* and (4) wheat with both *Avena* and *Phalaris* (W+A+P) (33:33:33%). Five treatments namely (1) Control (2) full dose of NPK (120:60:60) kg ha^{-1} (3)half dose NPK

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(60:30:30) kg ha^{-1} (4) full dose water treatment (FW) which was maintained to the saturation point and (5) half dose water treatment (HW) were applied. Data sampling and observations on selected parameters were carried out. The plant was harvested properly, and roots were separated. Further, roots were carefully washed under the running tap water; then clean with brush and filter paper. After that, fresh weight was taken and then put the same root sample in the oven to take the dry weight. Root length (RL, cm) was measured from ground level to the tip of the root sample by using a measuring tape. Root weight ratio (RWR) was calculated by dividing root dry weight by total plant dry weight (Kadam*et al.,* 2015). Root biomass (RB, g m^{-2}) was calculated by dividing the dry weight of root per unit ground area. Specific root length (SRL, cm g^{-1}) was calculated by dividing the root length of root per unit root dry weight (Kadam*et al.,* 2015). The data were statistically analysed by adopting standard procedures. Statistical analyses were conducted through statistical software (SPSS-PC, 2005, version 14.0) for all kinds of statistical calculations. To observe the effect of combinations (monoculture and mixed culture) and treatments on the root traits, data were subjected to General Linear Model (GLM) to analyse multi-variant analysis of variance (multi-variant ANOVA). Whereas. Two tailed Spearman correlation was conducted to see the effect of root functional traits with grain yield of wheat crop under weed infestation.

RESULTS AND DISCUSSION

Effect of Combinations of weeds

Root length: RL, one of the important root functional traits, is considered primary drivers of uptake of the soil moisture and nutrients. Maximum root length of wheat (8.87 cm) was recorded in monoculture while minimum (7.10 cm) in the W+P combination ` (Table 1). It was observed that the development of root was getting suppression due to the presence of neighbouring sown plants in mixed culture. This may due to large root system with a high uptake of phosphorus and nitrogen by weeds under crop-weed competition. It has been reported a widespread root system in *Avena* which has a higher level of competition for soil resources particularly with water and nutrients with neighbouring plants. This may be due to species with low specific leaf area, have more of dry matter content with maximum concentrations of cell walls and secondary compounds; resulted in more leaf growth and root longevity.

Table 1: Average root parameters of wheat crop under various combinations (Pooled data of three years)

Combinations	DAS (days)				Average	CD (p=0.05)
	30-	60-	90-	120-		
			Root length (cm)			
W	5.12	9.03	10.15	11.20	8.87	0.06
W+A	3.83	7.88	9.42	9.81	7.74	0.06
W+P	4.40	5.64	8.65	9.72	7.10	0.16
W+A+P	4.18	6.98	8.85	8.54	7.14	0.04
			Root weight ratio			
W	0.056	0.084	0.056	0.013	0.052	0.062
W+A	0.050	0.085	0.078	0.026	0.060	0.064
W+P	0.062	0.163	0.093	0.028	0.087	0.164
W+A+P	0.055	0.056	0.040	0.030	0.045	0.048
			Root biomass (g m^{-2})			
W	0.67	8.02	22.75	27.97	14.85	27.35
W+A	0.53	6.19	13.17	20.88	10.19	13.11
W+P	0.55	5.39	17.64	23.52	11.78	20.22
W+A+P	0.53	2.41	8.04	12.10	5.77	8.49
			Specific root length (cm g^{-1})			
W	767.57	338.41	96.70	41.11	784.75	767.57
W+A	976.16	245.42	89.66	50.07	870.63	976.16
W+P	550.05	114.43	105.74	62.19	458.21	550.05
W+A+P	957.28	322.58	192.64	92.32	660.83	957.28

Root weight ratio: The results showed that root weight ratio of wheat crop increased in wheat-weed mixture plots than monoculture which is in agreement with findings of Singh *et al.* (2013) who observed in *P. minor*-wheat mixture, the root weight ratio of the wheat crop was slightly increased from wheat monoculture.

Root biomass: The root biomass of wheat crop was substantially declined by 52.0 % when both weeds were grown together (Table 1). This finding is in accordance with Siddiqui *et al.* (2010). This reduction may be attributed to its rapid and luxurious growth in the wheat field. Furthermore, being a member of the same family (Poaceae) to which wheat belongs, this weed may have the same nutrient requirements as that of wheat.

Specific root length: The results indicated that specific root length of wheat was higher in various mixed combination with *Avena* than with *Phalaris* and with both weeds from monoculture (Table 2). This might be due to a negative relationship with root dry weight i.e. more the root dry weight, less the SRL. The competition for water and nutrients occurs in below ground which mainly depends on the rooting pattern and their volume and for producing of an equal amount of dry matter the weeds absorbs more moisture from the soil than the crop (Korav *et al.,* 2018).

Table 2: Average root parameters of wheat crop under different treatments. (Pooled data of three years)

Treatments	DAS (days)				Average	CD (*p=0.05*)
	30-	60-	90-	120-		
			Root length(cm)			
C	3.79	7.71	9.32	9.80	7.65	0.17
FNPK	4.66	10.44	12.44	13.01	10.13	0.19
HNPK	3.86	9.09	10.37	11.11	8.61	0.22
FW	3.63	5.43	7.67	8.47	6.30	0.33
HW	3.72	4.63	6.77	7.26	5.60	0.25
			Root weight ratio			
C	0.083	0.101	0.062	0.017	0.065	0.170
FNPK	0.095	0.081	0.051	0.013	0.060	0.193
HNPK	0.062	0.108	0.054	0.012	0.059	0.227
FW	0.100	0.140	0.093	0.031	0.091	0.336
HW	0.061	0.121	0.081	0.035	0.074	0.257
			Root biomass (g m^{-2})			
C	0.76	6.10	15.11	19.23	10.30	10.77
FNPK	0.88	9.16	27.45	34.49	18.00	24.26
HNPK	0.44	8.15	22.71	24.86	14.04	17.81
FW	0.43	2.42	6.94	15.19	6.24	7.71
HW	0.34	1.68	4.79	11.83	4.66	6.23
			Specific root length (cm g^{-1})			
C	562.31	160.01	68.56	58.61	212.37	224.38
FNPK	694.29	138.37	68.88	43.65	236.30	380.77
HNPK	748.96	134.99	65.44	47.78	249.29	246.38
FW	1058.91	261.62	153.01	61.69	383.81	543.25
HW	999.35	581.05	250.02	95.38	481.45	678.82

Effect of fertilizers and water

Root length: The root length increased by 32.4 % with FNPK and 12.5 % under HNPK and decreased by 17.6 % in FW and 26.7 % in HW (Table 3). However, fertilizer addition has increased the root length and decreased the root weight ratio of the wheat crop (Sheikh and Dwivedi, 2018). This may be due to the direct stimulation of cellular activities and effective translocation of compounds to the roots, along with this extensive root system which are mainly associated with resourceful absorption and utilization of mineral nutrients resulting in

vigorous growth of the plant under high and low fertility levels.Shahi *et al.* (2015) have found that root length was sensitive to water deficit conditions and decreased at more water deficit stress resulted in 11.8 – 43.9% reduction from control ones in root length of the wheat.

Root weight ratio: The root weight ratio showed a significant reduction in FNPK by 7.6 % and HNPK by 9.2 % whereas increased in FW by 40 % and in HW by 13.8 % from the control (Table 2).Fertilizer addition has decreased the root weight ratio of the wheat crop and their associated weeds which is supported by previous studies (Sheikh and Dwivedi, 2018). On the other hand, water treatment has increased root weight ratio which agrees with the findings of previous studies Shahi *et al.* (2015) and Faisal *et al.* (2017). This may be due to the fact that the root system at different depths depends upon water potential, movement of water within the root and the availability of water for plants to use (Najed *et al.,* 2010).

Root biomass: The maximum root biomass of wheat crop was observed under FNPK and minimum under FW treatment. Thus, in terms of fertilizers application, moderate quantities have been shown to favour root growth in winter wheat.It seems that above-ground growth and development depend on the acquisition of soil nutrients and water, which is closely associated with root morphology and physiology (Ju *et al.,* 2015).

Specific root length: The maximum specific root length was observed in HW followed by FW, FNPK and HNPK while minimum in control (Table 2). Tshikunde *et al.* (2019) reported a similar trend. This may be due to root development (based on root dry weight) under water deficient condition. The extensive root development enhances water stress tolerance by the accumulation of carbohydrates (Liu *et al.,* 2018).

Correlations between root traits and grain yield under various combinations

Better development of root architecture in the wheat crops may augment a good grain yield. Therefore, all studied root functional traits (RL, RWR, RB and SWR) were subjected to develop correlations. Root biomass is a direct function of the grain yield, while other remaining traits i.e. root length, root weight ratio and specific root length significantly represent the extent of the root biomass production in any condition even under weed infestation. However, under weed infestation, it has been observed that growth and reproductive traits (grain yield) were significantly varied under different treatments and combinations.

Table 3: Correlation matrix of selected root traits with grain yield of wheat crop under the influence of various combinations

		RL	RWR	RB	SRL	GY
RL	Pearson Correlation	1				
	Sig. (2-tailed)					
	N	180	180			
RWR	Pearson Correlation	-.393**	1			
	Sig. (2-tailed)	.000				
	N	180	180	180		
RB	Pearson Correlation	.755**	-.218**	1		
	Sig. (2-tailed)	.000	.003			
	N	180	180	180	180	
SRL	Pearson Correlation	-.180*	-.026	-.352**	1	
	Sig. (2-tailed)	.016	.730	.000		
	N	180	180	180	180	180
GY	Pearson Correlation	.784**	-.382**	.757**	-.248**	1
	Sig. (2-tailed)	.000	.000	.000	.001	
	N	180	180	180	180	180

***Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed)*

Through, this correlation, it would be clear that root functional traits of the wheat crop are significantly affected under weed infestation and their development of below-ground component directly depict a positive relationship with most important traits of above-ground component (grain yield). The maximum grain yield was observed under monoculture (247.86 kg ha^{-1}) and minimum (61.08 kg ha^{-1}) when wheat grow with both the weeds followed by W+A (136.11 kg ha^{-1}) and W+P (108.66 kg ha^{-1}) (Kaur *et al.,* 2020). Present study indicated a positive relationship between root biomass and root length (r= 0.755) and grain yield (r= 0.784). Since root length is the parameter that reflects more accumulation in biomass of root, therefore, root biomass reflected a very positive significant relationship with grain yield (r= 0.757) (Table 3). This is in acceptance with Mahajan *et al.* (2014) which reported that root biomass had a significant positive correlation grain yield in rice-weed competition. These results indicate that this parameter could have played a vital role in improving grain yield under crop-weed competition.

Correlations matrix of selected root traits with grain yield under various treatments

Root growth is very sensitive to the soil nutrients i.e. it tends to proliferate in high nutrient concentration resulting in enhanced root growth of the plant. Moreover, roots are a major sink for assimilates, requiring twice as much photosynthesis to produce dry matter compared to shoots which further increase grain yield. Increase in root growth is considered to cause efficient consumption of energy and is useful to improve shoot biomass accumulation and grain yield (Ma *et al.,* 2010). The highest grain yield (116.67 kg ha^{-1}) was reported in FNPK and lowest (52.04 kg ha^{-1}) in HW followed by FW (69.23 kg ha^{-1}), control (116.67 kg ha^{-1}) and HNPK (177.69 kg ha^{-1}) treatments (Kaur *et al.,* 2020). The root biomass has significant positive correlation with root length (r = 0.755) and grain yield (r= 0.757) (Table 4). A similar trend was reported in nutrients uptake rate of roots and relative aboveground growth rate (Yang *et al.,* 2012). Also, grain yield had positive relation with root length (r= 0.784) and root biomass (r= 0.757) as supported by Ehdaie *et al.* (2016).

Table 4: Correlation between various root traits with grain yield under the influence of water and fertilizers treatments

		RL	RWR	RB	SRL	GY
RL	Pearson Correlation	1				
	Sig. (2-tailed)					
	N	180				
RWR	Pearson Correlation	-.258**	1			
	Sig. (2-tailed)	.000				
	N	180	180			
RB	Pearson Correlation	.755**	-.229**	1		
	Sig. (2-tailed)	.000	.002			
	N	180	180	180		
SRL	Pearson Correlation	-.180*	-.020	-.352**	1	
	Sig. (2-tailed)	.016	.787	.000		
	N	180	180	180	180	
GY	Pearson Correlation	.784**	-.289**	.757**	-.248**	1
	Sig. (2-tailed)	.000	.000	.000	.001	
	N	180	180	180	180	180

**Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed)*

This study concludes that the root trait, root length and root biomass of wheat crop suppressed due to interference of both weeds (*A. sativa* and *P. minor*) and difference observed due to various doses of nutrient and water conditions and vice versa for root weight ratio. Also, the yield trait i.e. grain yield has a positive correlation with root length and root biomass.

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REFERENCES

Ehdaie, B., Mohammadi, S. A. and Nouraein, M. (2016) QTLs for root traits at mid-tillering and for root and shoot traits at maturity in a RIL population of spring bread wheat grown under well-watered conditions. *Euphytica* **211**:17–38.

Faisal, S., Mujtaba, S., Khan, M. and Mahboob, W. (2017). Morpho-physiological assessment of wheat (*Triticum aestivum*) Genotypes for drought stress tolerance at seedling stage. *Pakistan Journal of Botany* **49**(2): 445-452.

Ju, C., Buresh, R. J., Wang, Z., Zhang, H., Liu, L. and Yang, J. (2015) Root and shoot traits for rice varieties with higher grain yield and higher nitrogen use efficiency at lower nitrogen rates application. *Field Crops Research* **175**: 47–55.

Kadam, N. N., Yin, X., Bindraban, P. S., Struik, P. C. and Jagadish, K. S. (2015) Does morphological and anatomical plasticity during the vegetative stage make wheat more tolerant of water deficit stress than rice? *Plant physiology* **167**(4): 1389-1401.

Kaur, A., Chand, R. and Singh, A.N. (2020) Suppressibilty of nutrients and water use efficiencies of wheat (*Triticum aestivum*) under weed infestation. *Annals of Plant and Soil Research* **22**(2): 166-171.

Kiaer, L. P., Weisbach, A.N., Weiner, J. and Gibson, D. (2013) Root and shoot competition: a meta-analysis. *Journal of Ecology***101**: 1298–1312.

Korav, S., Dhaka, A.K., Singh, R., Premaradhya, N. and Reddy, G. C. (2018) A study on crop weed competition in field crops. *Journal of Pharmacognosy and Phytochemistry* **7**(4): 3235-3240.

Liu, K., He, A., Ye, C., Liu, S., Lu, J., Gao, M., Fan, Y., Lu, B., Tian, X. and Zhang, Y. (2018) Root morphological traits and spatial distribution under different nitrogen treatments and their relationship with grain yield in super hybrid rice. *Scientific reports* **8**(1):1-9.

Ma, S., Li, F., Xu, B. and Huang, Z. (2010) Effect of lowering the root/shoot ratio by pruning roots on water use efficiency and grain yield of winter wheat. *Field Crops Research* **115**: 158–164.

Mahajan, G., Ramesha, M. S. and Chauhan, B. S. (2014) Response of rice genotypes to weed competition in dry direct-seeded rice in India. *The Scientific World Journal.* 64 1589.

Meinen.C. and Rauber, R. (2015) Root discrimination of closely related crop and weed species using FT MIR-ATR spectroscopy.*Frontiers in Plant Science***6**:765.

Najed, T. S., Bakhshande, A., Nasab, S. B. and Payande, K. (2010) "Effect of Drought Stress on Corn Root Growth."*Report and Opinion* **2***(*2): 47-52.

Shahi, C., Bargali, K. and Bargali, S. S. (2015) How Seed Size and Water Stress Effect the Seed Germination and Seedling Growth in Wheat Varieties? *Current Agriculture Research Journal* **3**(1): 60-68.

Sheikh, M.A. and Dwivedi, P. (2018) Response of Wheat (*Triticum aestivum* L.) to Organic manure and Chemical fertilizer.*International Journal of advance Research in Science and Engineering* **7**(4): 2515-2528.

Siddiqui, I., Bajwa, R., Zil-e-Huma, and Javaid, A. (2010) Effect of six problematic weeds on growth and yield of wheat.*Pakistan Journal of Botany* **42**(4): 2461-2471.

Singh, V., Singh, H. and Raghubanshi, A. S. (2013) Competitive interactions of wheat with *Phalaris minor* or *Rumex dentatus*: A replacement series study. *International journal of pest management* **59**(4): 245-258.

SPSS Inc., (2005. SPSS/PC version 14.0 For the IBM PC/XT/AT Chicago, IL.

Tshikunde, N.M., Mashilo, J., Shimelis, H. and Odindo, A. (2019) Agronomic and Physiological Traits, and Associated Quantitative Trait Loci (QTL) Affecting Yield Response in Wheat (*Triticum aestivum* L.): A Review. *Frontiers in Plant Science* **10**:1428.

Yang, J.C., Zhang, H. and Zhang, J.H. (2012) Root morphology and physiology in relation to the yield formation of rice.*Journal of Integrative Agriculture* **11**(6): 920-926.