Rhizosheath formation can improve wheat crop survival in a false break

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Cereals

Key findings

- Wheat varietal selection and/or management for large rhizosheaths might improve the chances of crop survival by more than 60% in prolonged false break conditions.
- Across various rainfall and false break scenarios, varieties with large rhizosheaths produced 42.5% more tillers and 52.4% fewer necrotic leaves than the alternative varieties.

Keywords wheat, rhizosheath, false break, autumn break, establishment

Introduction

Roots of young seedlings gently dug up from the soil have a small layer of adhering soil. Neither persistent shaking nor rinsing with water will remove the layer. These are the rhizosheaths (Figure 1), first described by Volkens (1887) on grasses from the Egyptian desert and later Price (1911) demonstrated their occurrence on several perennial grass species native to the sandy deserts of South Africa. Rhizosheaths are a feature of xerophytic (plants that need very little water) grasses. This experiment investigated whether rhizosheath formation in wheat can help buffer the effects of false breaks and reduce plant seedling death.

Figure 1 Rhizosheaths occur throughout the angiosperms (Brown et al. 2017) including wheat.

Experiment details

Location	Glasshouse environment
Soil type	• Kandosol (collected from Wagga Wagga Agricultural Institute: latitude 35° 5′ S, longitude 147° 35′ E). • Vertosol (collected from the Leeton Field Station: latitude 34° 36′ S, longitude 146° 21′ E).

Soil preparation/pot size	• Each soil type was dried in the dehydrator at 105 °C for 48 hours, and then ground to produce grains capable of passing through a 2 mm sieve mesh. • The soil was reconstituted to achieve 40% of the field capacity of each respective soil type. • The soil was then packed into PVC tube pots (10 × 30 cm) to a bulk density of 1.3 grams per cubic centimetre ($g\ cm^{-3}$).
Experiment design	Split-split plot design with 6 replicates.
Rhizosheath measurement	Rhizosheaths were measured at the end of the simulated false break for each treatment unit. The seedling was lifted out and gently shaken by hand until all bulk soil was removed and weighed to obtain the plant fresh weight. After weighing, the root system was excised at the root/shoot interface. The shoot was weighed to obtain data on biomass (fresh weight) of the above-ground parts. The below-ground parts (root and adhering soil) were transferred to a 250 mL plastic container containing 200 mL of water and kept overnight to loosen soil from the roots. Roots were then washed clean and the rhizosheath size was measured on a dry weight basis to remove differences in soil water content that might have persisted due to the applied rainwater treatment. The soil washed from the roots was captured in a container and placed in a dehydrator at 50 °C for a week to dehydrate. The soil was then weighed to obtain the rhizosheath size in grams of dry soil.

Treatments

Variety

- Halberd (high) and Westonia (low) rhizosheath-forming lines.
- Untested commercial varieties (Mace$^{\phi}$, Scepter$^{\phi}$, Beckom$^{\phi}$, LongReach Flanker$^{\phi}$).

Autumn break rain

Defined as the first significant rain of the winter growing season and signals the start of the growth period (Delloitte 2017). Rainwater was applied to represent various amounts of autumn break rain. Treatment units (pots) were watered with 5 mm, 10 mm, 15 mm, and 25 mm.

False break

Defined as a period of drought which follows an autumn break and leads to the widespread death of establishing seedlings (Chapman and Asseng 2001). The following false break durations were applied: 14 days, 28 days, 42 days and 56 days after sowing.

Results

Rhizosheath formation

Figure 2 shows the 2 soil types used in the experiment and Figure 3 shows rhizosheaths measured in the kandosol for the 6 wheat varieties after 56 days growth with 5 mm of autumn break rainfall and no follow-up rain.

Rhizosheath formation in the vertosol was largely driven by the amount of autumn break rain, while in the kandosol it was the length of the false break that was most influential (Table 1). In both soil types, the variety effect was small but highly significant ($P \leq 0.001$) indicating options for varietal selection. Importantly, while the variety × soil moisture interactions were only marginally significant, the variety × false break interactions were highly significant ($P<0.001$). This relationship indicates that wheat varieties might respond similarly to the amount of autumn break rain, but differ significantly in how long they can survive before follow-up rain occurs.

Figure 2 Soil types used for the experiment.

Figure 3 Rhizosheath size in wheat seedlings after 56 days growth with 5 mm autumn break rainfall in kandosol.

Table 1 Mean squares and F-probability values for rhizosheath size measured in the vertosol and kandosol soil types.

Source of variation	Degrees of freedom	Vertosol			Kandosol		
		MSq	*P*-value	Etasq (%)	MSq	*P*-value	Etasq (%)
Replication	5	2.01	0.806	0.05	78.32	0.063	0.63
Variety	5	25.98	0.001	0.66	402.90	<0.001	3.26
Whole plot error	25	4.40	0.820	0.56	32.29	0.399	1.30
Rainwater	3	3700.94	<0.001	56.80	408.63	<0.001	1.98
Variety × rainwater	15	11.98	0.012	0.92	61.24	0.063	1.48
Sub-plot error	90	5.43	0.705	2.50	35.81	0.167	5.21
False break	3	415.37	<0.001	6.38	11939.70	<0.001	57.89
Variety × false break	15	15.70	<0.001	1.21	186.32	<0.001	4.52
Rainwater × false break	9	344.60	<0.001	15.87	202.30	<0.001	2.94
Variety × rainwater × false break	45	17.51	<0.001	4.03	40.05	0.100	2.91
Residual	360	5.98	–	11.02	30.73	–	17.88

The split-split plot model was analysed in r (https://cran.r-project.org/).

Variety-specific effects

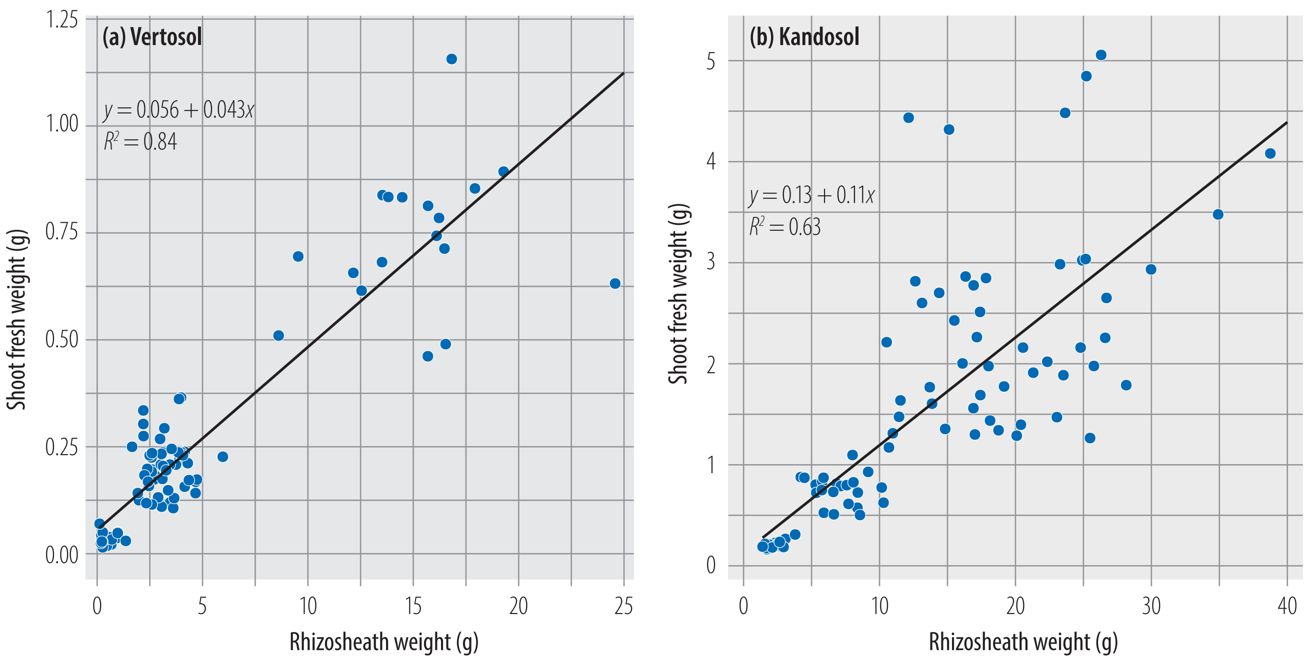
Significant variety-specific effects were found for rhizosheaths on the 2 different soil types. Across environments (false break × rainfall) Halberd had a significantly larger rhizosheath than Westonia in the vertosol. In the kandosol, LongReach Flanker(d) had a significantly larger rhizosheath than Westonia.

These differences were associated with faster growth (leaf area) and seedling survival (tiller survival) across the range of simulated false breaks that lasted up to 56 days.

This led to the question of whether varietal selection can help buffer the effects of false break conditions and reduce plant seedling death. The ability to survive a prolonged false break (more than 28 days) was measured by calculating the percentage of wilted and necrotic (dead) leaf sections per plant. In the vertosol, Halberd (large rhizosheath) produced 42.5% more tillers than Westonia (small rhizosheath) and the difference in necrotic leaves was also statistically significant (P-value = 0.013) with Halberd showing 52.4% fewer necrotic leaves than Westonia. Leaf necrosis was not observed in the kandosol experiment and wilting was only observed in the 56 day false break treatment; varietal differences were not significant (P = 0.20).

Regression analysis determined the predictive ability of rhizosheath size on seedling establishment across the 2 soil types. Shoot fresh weight was used as a measure of seedling establishment and in the analysis was fitted as the dependent variable. In both soil types the relationship between rhizosheath size and seedling establishment was positive and highly significant (P-value: <0.001).

Simple linear regression showed that shoot fresh weight in the vertosol increased by 43 g/plant for every unit increase in rhizosheath size (Figure 4). The coefficient of determination (R^2), which measures how differences in one variable can be explained by the difference in a second variable, was 84%. This implies that in this soil type wheat seedlings that produced larger rhizosheaths are ~84% more likely to survive a false break than those producing smaller rhizosheaths. Similarly, in the kandosol, for every unit increase in rhizosheath size, shoot fresh weight increased by 110 g/plant. The standardised regression coefficients for both soil types were 0.82 and 0.92 respectively, indicating that variety and/or management practices that increase rhizosheath size by one standard deviation unit will increase seedling survival in a false break by a ratio of almost 1:1.



Note: Data were from 6 varieties grown with 4 levels of simulated autumn break rainfall and 4 lengths of false break duration.

Figure 4 Regression of rhizosheath weight with shoot fresh weight of wheat seedlings on 2 different soil types.

Summary

- Rhizosheaths were found to explain between 63% and 84% of seedlings ability to survive false break conditions depending on the soil type. This does not suggest a cause–effect relationship, but implies similarity of response to declining water availability.

- Root size might be a significant factor, but varietal differences in root length were not significant in the vertosol ($P = 0.42$) or the kandosol ($P = 0.12$).
- Root hairs have been reported as potentially important contributors to rhizosheath formation (Marin et al. 2021), but their role remains controversial (Cai et al. 2021).
- Overall, the conclusion is that varietal selection and/or cultural management for large rhizosheaths might improve the chances of crop survival by more than 60% in a false break.

Cereals

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