What influence does summer rainfall and stubble retention have on wheat production in Southern farming systems?

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Abstract

Southern Australian broad-acre farming systems are characterised by low frequency, high intensity summer rainfall, and high frequency, low intensity winter rainfall. The contribution of out-of-season rainfall to wheat yield is largely unknown for southern farming systems. An experiment was conducted in which different quantities of summer rainfall (control (0mm), 50mm and 100mm; applied through trickle irrigation) was combined with four stubble treatments (bare, standing (2t/ha), and mulched (2t/ha and 5t/ha)) in a factorial field experiment to determine their influence on capture and efficiency in the use of resources and yield components. Stubble did not influence the ability of the soil to retain moisture in the profile. Summer rainfall significantly contributed to increased soil moisture at sowing deep in the soil profile (50-100cm). Relative to the control, biomass water use efficiency was the same for all summer rainfall treatments, the additional subsoil moisture contributed to increased early crop growth and radiation-use-efficiency and increased yield by 0.5t/ha.

Key Words

Summer rainfall, subsoil moisture, resource use efficiency

Introduction

In southern Australia, broad-acre farming systems are dependent on two sources of water; rainfall which occurs in-season, and water stored from the summer fallow. The benefits of summer rainfall are underestimated because of the reliance on growing season rainfall to produce viable yields. In central NSW, moisture stored 120-180cm in the soil profile can contribute to growth during grain filling adding 34-67kg/ha per mm stored (Kirkegaard et al., 2007). Stored soil moisture at sowing is more effective for growth and yield than in-crop rainfall because of reduced exposure to evaporative losses (French and Schultz, 1984).

Southern Australia is characterised by high soil evaporation and winter dominant, low intensity rainfall events (Sadras and Rodriguez, 2007). Summer rainfall is characterised by its low frequency and high intensity with potential for effective soil storage. Because these events are infrequent, their contribution to soil moisture at sowing is highly variable.

In unrestricted soils, wheat has the ability to extract water at depths below 200cm (Incerti and O'Leary, 1990). However subsoil constraints such as compaction, salinity and alkalinity that restrict root growth are common in SE Australia (Incerti and O'Leary, 1990). This restriction in soils needs to be accounted for when considering water use within the soil profile. The ability of stubble to increase ground cover, reduce evaporation and improve infiltration could potentially benefit the upcoming crop by increasing soil moisture stored before sowing. Stubble benefits in terms of soil water storage during fallow are more likely in the Wimmera than in Mallee conditions, partially due to rainfall regimes (Incerti et al., 1993).

The aim of this study was to measure the influence of summer rainfall and stubble on the storage of water, and on the growth and yield of wheat in a typical south-eastern farming system.

Methods

The experimental site was located at Hart, South Australia, a Mediterranean-type climate with an annual rainfall of 400mm (growing season 305mm). The soil is a sandy loam over medium clay with a texture transition 20-30cm in the soil profile. To account for soil variability the experimental site was selected using a map generated from electromagnetic induction (EM-38) equipment.

The trial was established on the 10th of February 2009 with the aim of examining the effects of three rainfall treatments and their interaction with stubble on the following wheat crop. Control (no irrigation applied; equivalent to Decile 1 summer rainfall), 50 mm rainfall (equivalent to Decile 5) and 100 mm rainfall (Decile 9) were applied using a single trickle irrigation event. Four stubble treatments were super imposed across the summer rainfall treatments - stubble removed, standing stubble at 2t/ha, mulched stubble at 2t/ha and 5t/ha.

The rainfall/irrigation levels were selected from a historical analysis of Snowtown rainfall (Figure 1), the closest weather station to Hart with historical figures.

Wheat (cv Gladius) was sown the 8th of May using a commercial seed drill with 65kg/ha DAP. Soil moisture was monitored bi-weekly using a locally calibrated capacitance probe (Diviner 2000). Measurements taken throughout the season included; PAR interception measured with a ceptometer, chlorophyll content (SPAD), stomatal conductance (leaf porometer), and canopy temperature measured with an infra red thermometer. Biomass samples were taken at Zadoks growth stages (GS) 31, 65 and 95. All data was analysed using a standard analysis of variance. A 5% probability level was applied for determining significant differences between treatments.

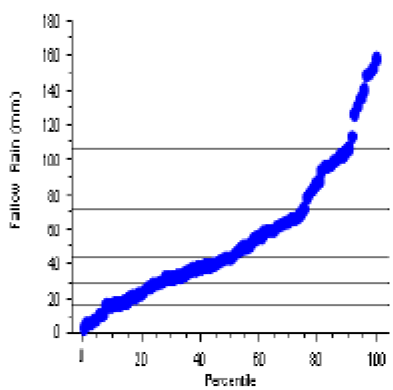
106mm

17mm

30mm

44mm

72mm



Percentiles

Percentile	Total rain (mm)
10	17.18000
25	29.50000
50	44.40000
75	71.90000
90	106.31000

Figure 1. Historical (1910-2007) analysis of Snowtown rainfall during fallow period (1st January to 31st March)

Results

Soil Moisture

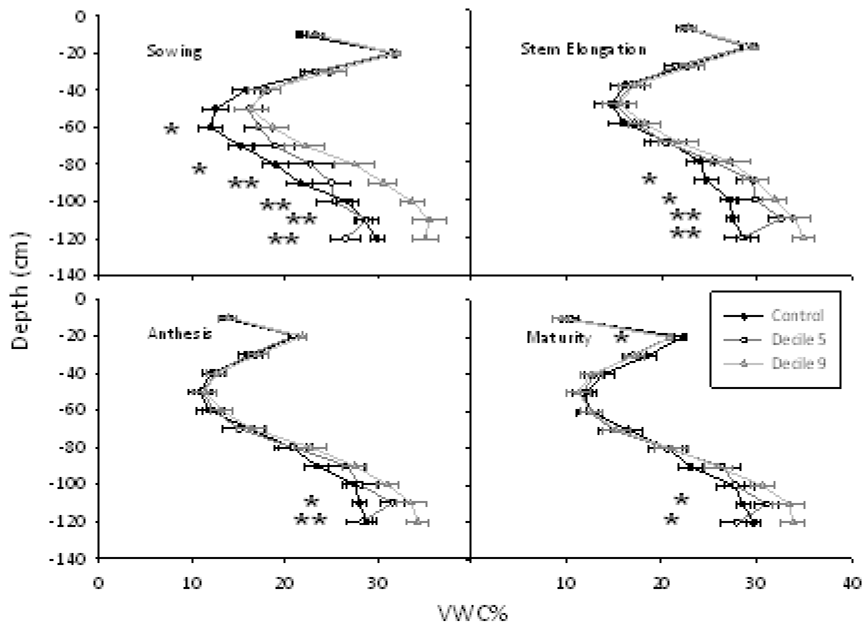


Figure 2: Profile of soil volumetric water content (VWC%) at sowing, stem elongation, anthesis and maturity. Values are averaged across stubble treatments, which had no significant effects on VWC. Stars indicate significant difference between treatment (*P <0.05, ** P<0.005).

Approximately half the water applied through summer rainfall was retained at sowing, the remainder lost to evaporation. This high fallow efficiency can be attributed to the large size of the single “rainfall” (irrigation) event.

At sowing there was a large difference between the decile 9 and control treatment (47.5mm), most of which (38.1mm) occurred below 50cm (Fig 2). The difference between the treatments reduced as the growing season progressed. At stem elongation the difference between the control and decile 9 treatment was 16.2mm. Below 100cm, there was little change throughout the season, suggesting the roots did not take up this water. Soil analysis (not presented) showed high levels of boron and high EC readings below 90cm.

Stubble Effects

Stubble had no significant influence on maintaining the additional water added to the soil through the fallow period or the moisture profile throughout the growing season. Stubble did significantly influence topsoil temperature during early crop stages (data not presented). The heavy stubble treatment (5t/ha mulched) had lower maximum temperatures and higher minimum temperatures compared to the bare stubble treatment. This insulation effect influenced the speed of crop emergence; crops in the 5t/ha treatment reached 160plants.m^{-2} five days before their counterparts in bare soil. Owing to the lack of significant effects of stubble on soil water content, growth and yield, results for the remainder of this report are pooled across stubble treatments.

Yield Components and Resource Use Efficiencies

Summer “rainfall” had its greatest influence on crop growth early in the season, particularly from sowing to GS32 (Table 1). Rainfall increased radiation use efficiency between GS0 and GS32 and did not affect water use efficiency. SPAD readings (not presented) suggest the differences in RUE were unlikely to be related to differences in foliar nitrogen. Greater water use in the summer rainfall treatments early in the season and higher stomatal conductance around anthesis suggest a link between crop water status and RUE.

Table 1. Growth rates and efficiencies of radiation (RUE, g biomass/MJ PAR) and water (WUE, kg biomass/hectare/mm evapotranspiration) throughout key periods of growing season.

Growth Rate (g.m^{-2}.day^{-1})

Summer Rainfall	Zadocks Growth Stage		
	0-32	32-65	65-95
Control	1.71a	9.97a	1.94
Decile 5	2.04b	12.34b	1.89
Decile 9	2.36c	12.02b	2.13
P-Value	<.0001?	<0.05?	n.s?

RUE (g.MJ^{-1})

Summer Rainfall	Zadocks Growth Stage		
	0-32	32-65	65-95
Control	0.78a	1.81?	0.48
Decile 5	0.82b	2.09?	0.44
Decile 9	0.98c	1.99?	0.46
P-Value	<0.005?	n.s ?	n.s?

Biomass WUE (kg.ha.mm^{-1})

Summer Rainfall	Zadocks Growth Stage		
	0-32	32-65	65-95

Control	15	43.4?	10.5
Decile 5	15.5	50.6?	9.3
Decile 9	15.2	50.1?	10.7
P-Value	n.s?	n.s?	n.s?

Summer rainfall significantly influenced grain and shoot biomass at harvest (Table 2). The higher yield is attributed to greater number of heads.m^{-2}. The additional moisture available in the summer rainfall treatments did not influence the grain weight, harvest index or grain protein.

Discussion

In our experiment in the mid-north of SA, subsoil moisture from simulated rainfall was a valuable contributor to final grain yield due to its influence on early crop growth. This contrasts with the benefits of subsoil moisture associated with late growth in NSW (Kirkegaard et al., 2007). Lack of growth and yield difference between decile 5 (50mm) and 9 (100mm) was probably due to subsoil constraints that restricted the crop's ability to utilise subsoil moisture below 100cm. While nitrogen was not limiting, higher rates of application may have expressed greater difference between these treatments.

Table 2. Yield components calculated from final dry matter cut split by summer rainfall treatments. WUE calculated using the 100cm profile.

	Yield components and resource use efficiencies					
Summer Rainfall	Grain Yield	Biomass Yield	Harvest Index	No. Ears	No Grains	Protein
	t/ha	t/ha	%	no.m-2	no.m-2	%
Control	2.64a	6.11a	43?	220a	6185a	12.5
Decile 5	3.17b	7.21b	44?	254b	7420b	12.6
Decile 9	3.18b	7.51b	42?	263b	7432b	12.1
P Value	<0.005	<0.0001	n.s	<0.005	<0.001	n.s
?	1000 Grain Wt	RUE	Grain WUE	Biomass WUE	ET	
?	g	g.MJ^{-1}	kg.ha.mm^{-1}	kg.ha.mm^{-1}	mm	
Control	42.5?	0.99a	9.18	21.2?	289a	

Decile 5	42.8?	1.07ab	9.99	22.8?	313b
Decile 9	42.8?	1.09b	9.46?	22.4?	336c
P Value	n.s	<0.05	n.s	n.s	<0.0001

Summer rainfall increased yield by increasing biomass rather than harvest index. Biomass increased, in turn, in response to increased capture of resources including radiation (not shown) and water (Table 2), with a marginal contribution of improved radiation use efficiency early in the season and no change in water use efficiency (Tables 1 and 2). Water use early in the season was an important yield determinant. The greater water use between GS0 and GS32 lead to an increased growth rate and therefore greater radiation interception. The early growth difference resulted in more heads and increased grain set, thus higher yield.

Under our experimental conditions, plants can use subsoil moisture earlier in the growing season than expected (Figure 2), exemplified by the reduction in the decile 9 soil water profiles between sowing and stem elongation. This meant the additional water available at sowing was largely depleted by anthesis and therefore its influence during the grain filling period was minimal, for example there was no difference in grain size (Table 2).

While it is not possible to quantify the value of summer rainfall from one year's data, this work showed that summer rainfall may significantly increase yield by encouraging early vigour. This data increases the understanding we have of the impact of summer rainfall events in southern faming systems and the potential it holds to significantly increase yields.

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