Agronomic Interactions between Drought and Crop Sequence

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ABSTRACT

A severe drought across south-eastern Australia in 1994 coincided with the second year of a crop sequence experiment involving 3-year crop sequences (6 first crops x 6 second crops x wheat). Impacts of crop sequence were observed both during and after the drought which could generally be explained in relation to soil water, soil nitrogen and root diseases. For example, nitrogen remaining after legume crops in 1993 was preserved in the subsoil during the 1994 drought and caused “haying-off” in 1995 wheat crops. Similarly, root disease inoculum which built up in the 1993 wheat crop was preserved during the 1994 drought, even under break crops, and caused significant yield reduction in the 1995 wheat crop. These and other interactions of crop sequence that may influence management decisions following a drought are discussed.

Key word

Canola, wheat, water use efficiency, nitrogen, root disease.

INTRODUCTION

Severe droughts are common within the Australian wheatbelt (6) and farmers face important management decisions both during and following drought. Retention of crop residues and a stable soil structure under conservation cropping systems may conserve soil moisture and increase crop yield during drought, although this depends upon the distribution of the rainfall (2). The fate of N applied to crops that fail due to drought, and the impact of the drought on subsequent mineralisation can influence N application decisions in the following year (1). Similarly, inoculum of soil-borne diseases such as take-all are unlikely to build up during a drought, but existing levels may be preserved and influence following crops (3). In this paper we report results from a crop sequence experiment conducted from 1993-1995 which experienced a severe drought in its 2nd year. We focus on those interactions between crop sequence treatments and the drought that influenced the growth of a subsequent wheat crop, and consider the implications for management following drought.

METHODS

The experiment was established following a 3 year winter-cleaned lucerne/clover pasture on a gradational red earth soil at Bethungra on the southern slopes of NSW. A range of Crop 1 species were grown in large (18 x 32 m) adjacent plots in the first year (1993) and Crop 2 species were sown in strips (18m x 2m) across these in the second year. All plots were sown to wheat in the 3rd year. The experiment was arranged in a plaid design with four blocks. In the second year, the effect of Crop 1 species on the growth and yield of the Crop 2 species was evaluated in relation to soil water, soil nitrogen and disease. In the third year the main effects of Crop 1 and Crop 2 species and their interaction on the growth and yield of wheat was evaluated.

Previous history	Year 1	Year 2	Year 3
(1989-1992)	(1993)	(1994)	(1995)

Lucerne/clover	Crop 1	Crop 2	Wheat
Rainfall April-Oct.(mm)	363	166	379

Crop 1 – wheat (Dollarbird), oats (Dalyup-grain), oats (Cooba-grazing), clover pasture, lupin (Albus), canola (Hyola 42)

Crop 2 – wheat (Janz), triticale (Abacus), barley (Skiff), oats (Dalyup), canola (Oscar), field pea (Alma)

The previous lucerne/clover pasture was cut for hay, grazed and then cultivated on 5/3/1993. Grazing oats (Cooba) were sown on 10/3/93 and was cut and removed on 21/7 and 4/8 to simulate heavy grazing. All other Crop 1 species were sown on 14/6/93, while the clover was left to regenerate in the pasture treatment. The Crop 2 species were all sown on 10/6/94, and the wheat in 1995 on 10/5/95. All cereal and oilseed crops in the experiment received 22 kg/ha N and 20 kg/ha P as starter fertiliser at sowing and legume species received 20 kg/ha P as superphosphate. Weeds were controlled using recommended herbicides. Detailed descriptions of methodologies for soil and plant measurements can be found in a previous paper (4). Briefly, soil water and N were measured gravimetrically to 2 m at sowing and harvest in each year, and wheat biomass cuts were taken at DC30, anthesis and final harvest and tissue analysed for N content. Grain yield and protein and yield components were estimated from both the biomass cuts at harvest and a machine harvest (1.5m) from the plots. Take-all were assessed on wheat seedlings at the 5-leaf stage and by counting whiteheads during grainfilling.

Stubble treatments were imposed as subplots in the 1994 wheat-wheat treatment as follows: (1) stubble burnt immediately following harvest of 1993 crops, (2) stubble burnt immediately prior to sowing in 1994, and (3) stubble (5t /ha) retained after sowing in 1994.

RESULTS AND DISCUSSION

Crop growth during the drought

Wheat yield during the 1994 drought was strongly related to the level of stored soil water at sowing (Fig.1). The amount of stored water following the previous crop treatments was principally influenced by the amount of surface residue left by the treatments, which was lowest for the pasture and lupin (0 – 0.5 t/ha) and higher for canola and the cereals (4-6 t/ha). The higher residue levels preserved the heavy rainfall (two events totalling 100 mm) which fell in early autumn. Further evidence for the importance of retained residue was obvious from the stubble treatments imposed on the wheat-wheat sequence. Burning the stubble immediately after harvest in 1993 resulted in wheat yields of 1.3 t/ha, which were comparable to the lupin and pasture treatments, and 0.4 t/ha less than the treatments in which stubble was retained until sowing. There was no yield benefit provided by maintaining the stubble after sowing (yield was 1.7t/ha), presumably due to the light and infrequent rain that rarely exceed 10 mm. The results indicate that prior to sowing, the retained residues acted like a mulch to preserve early autumn rainfall, which fell in heavy storms. After sowing, it may have intercepted the low and infrequent rainfall and limited water infiltration into the soil. Thus, the benefits of stubble retention in terms of water conservation for crops are highly dependent on the pattern of rainfall in relation to crop development as discussed in detail by Fischer (2).

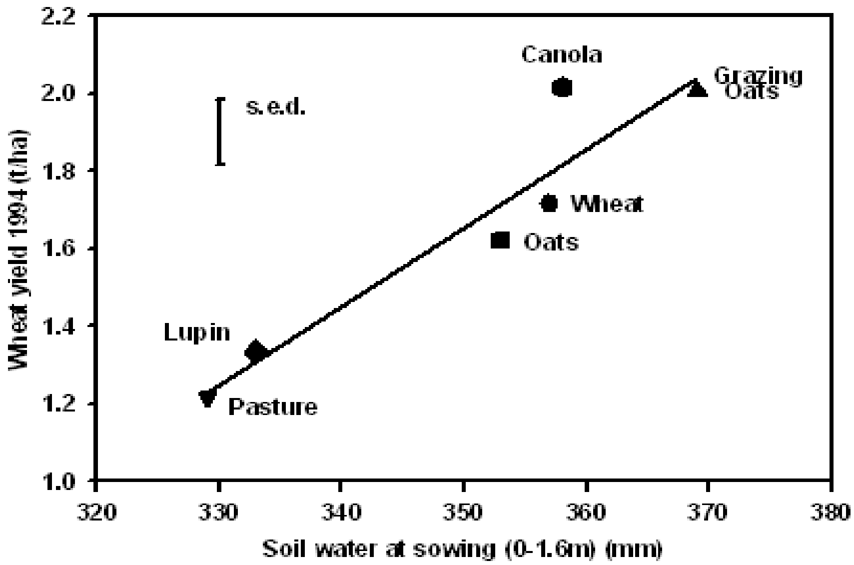

Figure 1. Yield of wheat during the 1994 drought in relation to soil water at sowing following a range of previous crops

The yield of wheat following canola was higher than that indicated by the soil water at sowing (Fig 1). In particular, wheat after canola yielded more than wheat after oats and wheat after wheat despite similar initial water content. Yields were not generally related to initial available soil N or to differences in growth up to anthesis (Table 1) and root disease levels were low in all treatments. However the higher yield following canola was associated with greater post-anthesis growth (Table 1).

Table 1. Effect of 1993 Crop 1 species on soil conditions and wheat growth in 1994. Post anthesis growth was higher after canola.

Crop 1 (1993)	Soil Water at sowing (mm) (0-1.6 m)	Soil N at sowing (kg/ha)	Anthesis biomass (g/m^2)	Final biomass (g/m^2)	Post-anthesis growth (g/m^2)
Wheat	357	128	473	498	25
Oats	353	133	465	473	8
Graz.Oats	369	177	498	527	29
Pasture	329	240	399	413	14
Lupin	333	226	386	390	4

Canola	358	247	472	565	93
lsd p=0.05	10	19	70	71	-

Apparently, wheat after canola had access to more water during the post-anthesis period than wheat after oats or wheat, despite similar amounts at sowing (Table 1) and at harvest (data not shown) and similar rooting depths (110cm). This may have resulted from more and/or deeper infiltration of 20 mm of storm rain that fell one day after anthesis. More rapid water infiltration in soil following canola compared to that following wheat has been reported previously on similar soils in the area (5), and was associated with more rapid flow into channels made by taproots and to greater sorptivity of the soil matrix. This may partly explain the superior growth of wheat after canola in the absence of root disease or soil N differences. The greater “in-crop” water use efficiency would have arisen from the deeper penetration and storage of water after each rainfall event, which reduced evaporation and increased transpiration. In this experiment, direct-drilling the 1994 crops would have facilitated the preservation of these soil structural benefits.

Crop growth following the drought

In 1995, the 1993 (Crop 1) species had the major influence on wheat yield while the impact of the 1994 crops (Crop 2) was small and there was no interaction. Despite average rainfall, a dominant feature of the 1995 season was a hot dry period for 2 weeks at the end of October (about 14 days after anthesis) which caused rolling of upper wheat leaves and death of lower leaves. The major impact of Crop 1 species appears to have resulted from “haying off” caused by the combination of large amounts of residual soil N following some Crop 1 species and the effect of the hot period following anthesis. Crop 1 species that left high levels of soil N had greater anthesis biomass and lower yield associated with pinched grain, high protein and higher screenings (Table 2).

Table 2. Effect of Crop 1 species in 1993 on growth and yield of wheat in 1995.

Crop 1 (1993)	Residual N (kg/ha) 18/1/94	Residual N 20/1/95	White-heads (m^{-2})	Grain yield (t/ha)	Anthesis biomass (gm^{-2})	Grain protein (%)	Seed Wt (g/100seed)	screenings (%)
Wheat	116	184	3.4	5.2	1178	11.4	2.9	4.7
Oats	119	163	0.5	5.5	1224	11.2	3.0	4.4
Graz.Oats	113	210	0.9	5.6	1240	11.3	3.0	4.0
Pasture	191	305	1.0	5.0	1294	13.6	2.6	6.6
Lupin	229	246	1.4	4.6	1290	13.8	2.5	7.0
Canola	198	197	0.9	5.1	1227	12.6	2.8	5.2
lsd p=0.05	15	20	1.0	0.3	62	0.3	0.1	0.7

These symptoms are characteristic of “haying off” which was associated with crops of higher N status and greater pre-anthesis growth (7). The added yield loss of wheat following the 1993 wheat crop was associated with a greater number of whiteheads (Table 2) indicating that disease inoculum established in 1993 had carried over to infect 1995 crops. The 1994 crop type had no effect on whitehead numbers in the 1995 wheat crop (data not shown).

Impacts of drought on the economics of the crop sequence

The highest gross margin in 1993 ($700/ha) was achieved by the wheat crop due to the high yield (5.6t/ha) and protein content (12.2%) in the first year after the winter-cleaned lucerne/clover pasture. This was much higher than for the 2.3 t/ha canola crop ($415/ha) or for other crops and pasture (<$200/ha). The economic losses in the 1994 drought were highest for canola (-$83/ha averaged over all Crop 1 treatments) and peas (-$66/ha) due to high input costs and low yields (< 0.4t/ha), while all of the cereal crops provided some profit ($50 - $450/ha) due to higher yields and low input costs. In 1995, there were limited benefits from the 1994 break crops due to the 1994 drought, and treatments with lower N status suffered less from haying-off. As a result of these effects, largely driven by the 1994 drought, the wheat-cereal-wheat sequences gave the highest 3 year gross margins ($1,632 - $1927/ha) compared to either breakcrop-cereal-wheat ($872-$1706) or wheat-breakcrop-wheat ($1425 - $1623/ha) (Table 3).

Table 3. Three-year gross margins for various Crop 1/Crop 2/Wheat sequences. Calculations based on actual costs and prices in each year.

	Crop 2					
Crop 1 (1993)	Wheat	Triticale	Barley	Oats	Canola	Peas
Wheat	1632	1745	1854	1927	1425	1623
Oats	1187	1349	1399	1280	926	1088
Graz.Oats	1197	1342	1443	1375	965	1078
Pasture	897	1038	1106	899	758	815
Lupin	872	1017	1047	898	702	843
Canola	1455	1608	1706	1492	na	1305

CONCLUSIONS

The results presented here demonstrate the significant biological and economic consequences of drought on the performance of a range of crop sequences. Crop performance during the drought was most influenced by water conserved by previous crop residues, although canola appeared to provide additional benefits in terms of the efficiency of post-anthesis water use. Soil mineral N and disease inoculum remaining after the 1993 season were preserved during the 1994 drought and significantly influenced wheat yield in 1995. Break crops grown during the drought were ineffective, and the high residual soil N led to “haying off” in the 1995 season. As a result of these interactions of crop sequence and drought, the wheat-cereal-wheat sequence provided the highest gross margin in the experiment, a sequence that would not generally be recommended for the area. The results indicate that adjustments to general recommendations on crop sequence may be necessary following drought to account for the specific impacts on soil water, mineral-N and disease levels which can arise.

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