FACTORS LIMITING WHEAT YIELDS UNDER ZERO TILLAGE IN SOUTHERN QUEENSLAND

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Summary. Wheat yields under zero tillage do not always exceed those under mechanical tillage, despite improved soil water storage under zero tillage. A field experiment was carried out on a red-brown earth near Goondiwindi in southern Queensland to determine the reasons for lack of yield response under zero tillage, and to develop strategies for eliminating or minimising these yield-limiting factors. Treatments included zero and mechanical tillage, each with and without nitrogen fertiliser, nematicide application and soil fumigation. In zero tillage, 1-year chickpea and 2-year lucerne rotations with wheat were also compared. Although higher soil water storage under zero tillage resulted in higher dry matter production and water use, wheat grain yields were similar to those under mechanical tillage. Fumigation and chickpea or lucerne rotations reduced the occurrence of disease, particularly crown rot, and resulted in higher wheat yields. Available nitrogen did not appear to be a major factor limiting yields at this location.

INTRODUCTION

Because of the summer-dominant rainfall pattern in Queensland, successful winter crop production depends to a considerable extent on storage of rainfall in the soil profile during a fallow period between successive crops (1, 8). However, land under fallow during the summer period is prone to soil erosion from high intensity rainfall, particularly under bare fallow tillage practices. Reduced tillage practices, combined with retention of crop residues as cover on the soil surface, have been shown to give increased protection from soil erosion and improve soil water storage during fallow periods (4). Zero tillage (ZT), in particular, has been shown to reduce soil erosion to a minimum (4) and to reduce the decline in soil organic matter resulting from long-term cropping (3). Although ZT has benefits with regard to long-term stability and productivity of soils, its potential for producing higher grain yield has not always been realised in the short-term, both in experimental work and in commercial practice (2, 6). Factors identified as being associated with lower yield under reduced tillage include reduced availability of soil nutrients, increased incidence of plant diseases and insect pests, poor crop establishment, poor fallow weed control, and inadequate management expertise (2). This study was designed to gain further information on nutritional and biological factors which may be limiting wheat yields under ZT under certain conditions.

MATERIALS AND METHODS

A field experiment was conducted from 1990 to 1993 on the property of S. and D. Ford, *Moruya*, in the Billa Billa district (28°10'S, 150°15'E), approximately 40 km north of Goondiwindi in southern Queensland. Soil type is a red-brown earth (7), with Principal Profile Forms Db2.33, Db2.13 and Dr2.33 (5). The site has a slope of 1% and has been cropped continuously, mainly to wheat, since clearing in 1971.

Treatments included ZT and mechanical tillage (MT), each with and without nitrogen (N) fertiliser, nematicide application and soil fumigation. In ZT, 1-year chickpea and 2-year lucerne rotations with wheat were also compared. Treatments were evaluated under raingrown conditions and also with supplementary irrigation. Treatments were arranged in a randomised, complete block design with 3 replications. Plot size was 25x4.5 m in the raingrown experiment, and 12.5x2.25 m in the irrigated experiment.

During fallow periods, glyphosate (360-720 g a.i./ha) was applied to control weeds in plots under ZT. MT treatments were cultivated with a chisel plough or scarifier for fallow weed control. Fumigation was carried out just prior to sowing each year with a mixture of 98% methyl bromide and 2% chloropicrin, applied at a rate of 988 kg/ha using a 2 m-wide, tractor-mounted applicator. The fumigant was injected into the soil at a depth of 5-10 cm through delivery tubes behind tines at 25 cm spacing. In the same operation, the plots were covered with plastic sheets, which were left in place for 3-4 days before being removed. Wheat (cv. Cunningham) and chickpea (cv. Amethyst) were sown with a 9-row planter at a row spacing of 25 cm. Sowing rate was 35-40 kg/ha for wheat and 50-60 kg/ha for chickpea. In the appropriate treatments, lucerne (cv. Trifecta) was sown at a rate of 5 kg/ha with wheat in 1990. Basal fertiliser applied with the seed at sowing in all treatments was a mixture of trifos (21% P, 1.3% S), potassium sulphate (41% K, 16.5% S) and zinc sulphate mono-hydrate (35% Zn, 16.8% S). At a rate of 165 kg/ha, this mixture supplied 20 kg/ha P and K, 12 kg/ha S and 5 kg/ha Zn. Nitrogen (75 kg N/ha) was applied at sowing as ammonium nitrate (35% N) drilled into the soil between every second seed row, at a spacing of 50 cm. The nematicide aldicarb was applied at a rate of 4 kg a.i./ha with the seed at sowing in appropriate plots.

Soil water content was measured just after sowing to a depth of 1.2 m using a neutron moisture meter and aluminium access tubes. There were 2 access tubes/plot in the raingrown experiment and 1 tube/plot in the irrigated experiment. Soil nitrate-N was determined just before sowing to 1.2 m depth on composite samples from 4 soil cores/plot in the raingrown experiment and 2 cores/plot in the irrigated experiment. Dry matter yields at anthesis were determined from whole-plant samples cut at ground level from 2 m^2 and 0.5 m^2 areas in each plot, in the raingrown and irrigated experiments, respectively. Samples were dried to constant weight at 80^{o}C in a forced-draught oven and then weighed. Grain yields were determined from 70 m^2 and 18 m^2 harvest areas in each plot in the raingrown and irrigated experiments, respectively, using a small-plot auto-header with 1.75 m width of cut. Crop water use was calculated as the difference between soil water content to a depth of 1.2 m at sowing and maturity, plus rainfall received between these two times. Runoff and drainage were assumed to be zero. Efficiency of water use for grain production was calculated by dividing grain yield by crop water use.

Results are presented for 1993, which was the first year in which comparisons were possible between continuous wheat and wheat following chickpea and lucerne. Rainfall received during crop growth was 91 mm, with an additional 80 mm of water being applied to the irrigated experiment.

RESULTS AND DISCUSSION

In both the raingrown and irrigated experiments, soil water at sowing was significantly higher in ZT than in MT, but it was not affected by the nematicide, fumigant and N fertiliser treatments (Table 1). Soil water at sowing was significantly lower following the 2-year lucerne phase than following wheat, as a result of greater drying of the soil by lucerne and insufficient rainfall during the fallow period to re-fill the soil profile. Soil nitrate-N at sowing was significantly higher where 75 kg N/ha was applied in previous years, but was not affected by tillage, disease control and rotation treatments (Table 1).

In both the raingrown and irrigated experiments, ZT resulted in significantly higher dry matter yields at anthesis than MT, but grain yield and water use efficiency of ZT and MT did not differ significantly (Table 1). In the raingrown experiment, crop water use in ZT (212 mm), was significantly higher than in MT (201 mm). Apparently, the higher water use under ZT was associated with an increase in dry matter production, but the extra soil water storage under ZT was not sufficient to enable this response to be carried through to grain yield. This result is in contrast with those in both 1991 and 1992, when ZT and MT had similar dry matter yields at anthesis, but ZT had significantly higher grain yields.

Table 1. Available soil water (ASW) and soil nitrate-nitrogen (ASN) from 0 to 1.2 m at sowing, dry matter yield at anthesis (DMY), grain yield (GY) and water use efficiency for grain production (WUE) for 1993 wheat crop in raingrown (R) and irrigated (I) experiments.

Treatments	ASW (mm)		ASN (kg/ha)		DMY (t/ha)		GY (t/ha)		WUE (kg/ha/mm)	
	R	I	R	I	R	I	R	I	R	I

Tillage										
Zero	159	155	207	142	5.09	7.23	1.87	3.32	8.5	11.3
Mechanical	145	133	207	159	4.45	6.43	1.89	3.19	9.1	11.1
l.s.d.(P=0.05)	12	22	n.s.	n.s.	0.28	0.70	n.s.	n.s.	n.s.	n.s.
Disease control										
Nil	137	131	204	147	4.59	6.31	1.57	3.30	8.0	12.1
Nematicide	149	-	198	-	4.67	-	1.88	-	9.1	-
Fumigation	152	155	220	154	6.14	7.36	2.25	3.21	10.4	10.3
l.s.d.(P=0.05)	n.s.	n.s.	n.s.	n.s.	0.39	0.70	0.18	n.s.	1.3	n.s.
Nitrogen fertiliser										
Nil	137	131	150	111	4.73	6.39	1.88	3.30	9.0	12.1
75 kg N/ha	157	146	264	190	4.80	7.28	1.87	3.21	7.6	11.3
l.s.d.(P=0.05)	n.s.	n.s.	21	28	n.s.	0.70	n.s.	n.s.	1.3	n.s.
Rotations										
Wheat-wheat	138	157	133	102	4.87	6.29	1.61	3.15	7.8	11.5
Wheat-wheat + 75 kg N/ha	162	155	269	169	5.06	7.45	1.53	3.40	7.3	11.2
Chickpea-wheat	150	141	146	-	5.13	5.87	2.33	3.68	10.9	13.1
Lucerne-wheat	98	136	131	136	4.40	7.20	1.83	2.63	7.8	9.7
l.s.d.(P=0.05)	26	n.s.	59	57	n.s.	1.41	0.35	n.s.	1.9	2.3

Under raingrown conditions, wheat following fumigation had significantly higher dry matter yield at anthesis and higher grain yield and efficiency of water use than wheat in the control and nematicide treatments (Table 1). The responses to fumigation were similar under both ZT and MT, and were mainly associated with a reduction in the effect of plant diseases, in particular crown rot (*Fusarium graminearum*) and, to a lesser extent, root-lesion nematodes (*Pratylenchus neglectus*). The chickpea and lucerne phases had similar effects to fumigation in reducing the effects of crown rot. This benefit was reflected in significantly higher grain yield in wheat following chickpea, similar to that in wheat following fumigation. However, this benefit was not realised in wheat following lucerne, because of lower stored soil water following lucerne (Table 1). With additional water supply to wheat in the irrigated experiment, crown rot was not as severe as in the raingrown experiment. Although there was a significant dry matter response to fumigation in the irrigated experiment, grain yield of untreated, continuous wheat was not significantly different from that of wheat following fumigation, chickpea or lucerne (Table 1).

Dry matter yield at anthesis was significantly higher with N fertiliser application in the irrigated experiment, but there were no significant grain yield responses to N fertiliser application under raingrown or irrigated conditions (Table 1). Therefore, N supply to wheat did not appear to be a major limiting factor at this site, even at the higher yields obtained in the irrigated experiment.

CONCLUSIONS

Results indicate that the balance between water supply and dry matter production, which may vary from season to season, is an important factor in determining whether improved soil water storage under ZT will result in higher grain yields. Plant disease, in particular crown rot, was a major factor limiting wheat yields under both ZT and MT at this location. The experiment has demonstrated that short crop rotations with chickpea or lucerne can reduce the build-up of crown rot and result in higher wheat yields in this area.

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