EFFECTS OF COMPACTION ON CROP ESTABLISHMENT, GROWTH AND YIELD ON AN ALLUVIAL SOIL IN CENTRAL QUEENSLAND

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ABSTRACT

Header wheels were used to compact moist alluvial soil in order to determine the effects of a defined compaction pressure on establishment, growth and yield of 2 wheat crops and a sorghum crop. This compaction treatment reduced establishment of all 3 crops and sometimes reduced early crop growth but had no effect on grain yield.

INTRODUCTION

Structure degradation was found in various forms and extents on all farms in all soils in south-east and central Queensland during a survey by McGarry (1990). The principal causes of degradation were wheels, tillage tools and animal hoofs.

Wheel traffic in fields has been recognised as a major source of forces causing undesired soil compaction (Schafer *et al.* 1992). For example, the compactive energy input of a tractor tyre (about 5 kJ/m^2), which is absorbed in plastic deformation of the soil, is of the same order as the energy input of a chisel plough, which is mostly used to decompact the soil (Tullberg 1990). It is difficult to envisage more than a small percentage of the energy input of a chisel plough going into soil compaction beneath the tines. It follows that most of the compaction damage from current farming practices is caused by tyres.

The first pass of a wheel causes a major portion of the total soil compaction (Burger *et al.* 1983; Koger *et al.* 1983; Pollock *et al.* 1984). Wheel damage is exacerbated by (a) increased weight on the wheel; (b) high soil water content because wet soil has reduced strength (Kirby and Kirchhoff 1990); (c) wheel slip (Soane *et al.* 1981), due to shear processes in the soil (smearing), which occur particularly at high soil water contents (Kirby and Kirchhoff 1990); and (d) high tyre inflation pressures (Soane *et al.* 1981; Rickman and Chanasyk 1988).

A large percentage of the area of a field is covered by random wheel tracks during a cropping cycle. Tullberg (1990) estimated that the trafficked area exceeds 100% in conventional tillage practice, 60% in minimum tillage and 30% in zero tillage.

It is not clear what effect random wheel compaction has on crop growth and yield. So (1990) estimated that soil compaction reduces annual productivity of Australian field crops by 300 to 850 million $. A difficulty in estimating yield losses is the uneven distribution of compacted and uncompacted areas in a field. This means that plants are using both compacted and uncompacted soil. These plants may wholly or partially compensate in terms of yield per unit area of ground. In order to assess the effects of compacted soil on crop performance, we compacted entire plots (which is not unrealistic) with a single wheel pass at certain times and avoided subsequent random wheel traffic by setting up controlled traffic beds.

MATERIALS AND METHODS

Site

The experimental site is located at Biloela Research Station (24° 22` S, 150° 31` E, altitude 173 m). Slope is 0.2%. The soil is a black cracking clay developed on an alluvium, and has been classified as a Tognolini (Shields 1989) or Vertisol (Soil Survey Staff 1975). The soil had minimal loss of structure and fabric before the experiment (P.G. Muller, pers. comm.). The long-term mean annual rainfall is 698 mm, and the long-term mean annual evaporation from a Class A pan is 1870 mm.

Treatments

The experiment commenced in April 1993 when all treatments except the control (C_0) were compacted with header tyres on wet soil. The mass on each front tyre was 4.9 t and on each rear tyre 1.0 t. Inflation pressures were high: 235 kPa (front tyres) and 205 kPa (rear tyres). Wheel slip was negligible.

Treatments C_1 - C_5 are compaction/repair treatments in which compaction is re-applied or different management regimes are used to "repair" the compaction damage. C_1 - C_3 are recompacted each fallow to simulate wheel traffic during the fallow: C_1 with header tyres on wet soil, C_2 with tractor tyres on wet soil, and C_3 with tractor tyres on dry soil. Tillage regimes are traditional tillage (C_1, C_2), reduced tillage (C_0, C_3) (tillage only at soil water contents below the plastic limit in the tilled layer), and zero tillage (C_4, C_5). C_5 was deep-ripped with a chisel plough (narrow points) after the 1993 wheat crop had dried the profile (this is a current recommendation to growers).

Brief descriptions of the 6 compaction/repair treatments are:

- C_0: Control (uncompacted)
- C_1: Extreme compaction
- C_2: Traditional tillage
- C_3: Reduced tillage
- C_4: Zero tillage
- C_5: Current best advice

The compaction treatments were investigated with and without fertiliser (50 kg N/ha at sowing and one spray of 1% zinc sulphate heptahydrate 59 days after sowing in 1994).

All treatments were investigated with and without supplementary irrigation (75 mm of spray irrigation at or just before anthesis).

Design

The experimental design comprises 2 replications of 2 main plot treatments (irrigation) split into 12 subplot treatments (2 fertiliser x 6 compaction treatments).

Experimental details

Crops grown after the April 1993 compaction treatment were wheat (June-March 1993), wheat (June - November 1994) and sorghum (January - June 1995). The cultivars used were Hartog (1993, 1994) and MR 31 (1995). The number of seeds sown/m^2 was 192 (1993), 74 (1994) and 12 (1995). The wheat was sown in 275 mm rows with a zero till planter equipped with smooth coulters, spearpoint openers, rigid tines and press wheels. The sorghum was sown in 750 mm rows through precision seeding units with narrow (35 mm wide) sowing points, rigid tines and press wheels providing individual depth control. Plots measured 30 x 9 m, and each plot contained 3 beds each 3 m wide.

Measurements

Crop establishment: Percentage establishment of seed sown was determined by calibrating the seeder and taking counts of emerged seedlings at 14 days for wheat and 8 days for sorghum. Counts were taken in 10 m (1993), 15 m (1994) and 50 m (1995) of row per plot.

Aboveground dry matter: Plant tops were sampled at anthesis from bed areas of 1m^2 in the wheat plots and 3 m^2 in the sorghum plots. Sorghum plant tops were also sampled from 3 m^2 bed areas at 35 days after sowing. The plant material was oven-dried at 80°C to constant weight. The sorghum plants were counted for determination of dry weight per plant.

Grain yield: Wheat grain was harvested mechanically (with a small-plot header) and sorghum grain by hand. Datum areas were 30 x 1.9 m (wheat) and 10 x 3 m (sorghum). Grain moisture content was determined by moisture meter (wheat) and gravimetrically (sorghum), and yield data were standardised to 12% moisture content.

RESULTS

Crop establishment

In 1993, the compaction treatment with the header reduced wheat establishment from 93 to 73%. A rotary hoeing operation 4 weeks after compaction shattered the compacted soil but failed to improve establishment.

In 1994, the C_1 treatment had lower establishment than the other treatments (Table 1) after compaction with the header on wet soil 5 months before sowing.

In 1995, C_1 again had the lowest establishment (Table 2) after compaction with tractor tyres immediately before sowing and with header tyres on wet soil 2 months before. The compacted soil in C_1 reduced penetration of the sowing points, resulting in too shallow placement of the seed.

Table 1. Effect of controlled compaction on wheat establishment, growth and yield in 1994

Treatment	Wheel traffic (surface soil moisture at trafficking)	Tillage operations during fallow (chisel plough, scarifier)	Establishment (%)	Plant dry matter at anthesis (88 days) (t/ha)	Plant dry matter at anthesis (88 days) (g/plant)	Grain yield (t/ha)
C_0	Nil	2	76	5.21	9.6	2.55
C_1	Header (wet)	4	59	4.67	11.4	2.40
C_2	Tractor (wet)	4	73	4.77	9.2	2.41
C_3	Tractor (dry)	2	82	5.48	9.2	2.61
C_4	Nil	0	67	4.60	9.5	2.35
C_5	Nil	2	76	5.49	9.9	2.52
	lsd, $P = 0.05$:		11	0.66	ns	ns

Table 2. Effect of controlled compaction on sorghum establishment, growth and yield in 1995

Treatment	Wheel traffic (surface soil moisture at trafficking)	Tillage operations during fallow (chisel plough)	Establish-ment	Plant dry matter				Grain yield
				35 days		55 days (anthesis)		
			(%)	(t/ha)	(g/plant)	(t/ha)	(g/plant)	(t/ha)
C_0	Nil	1	35	1.19	19.9	3.54	67.6	2.56
C_1	Header, tractor (wet)	1	22	0.54	17.0	2.49	82.5	2.53
C_2	Tractor (wet)	1	39	0.84	15.4	2.88	52.6	1.99
C_3	Tractor (dry)	1	39	1.27	21.1	4.11	79.9	2.97
C_4	Nil	0	41	1.30	20.8	4.33	78.3	3.43
C_5	Nil	0	46	1.23	19.3	4.52	68.9	3.09
	lsd, $P = 0.05$:		8	0.26	2.5	0.65	13.6	0.67

Aboveground dry matter

The initial compaction treatment with the header on wet soil had no effect on plant dry matter per ha at anthesis in 1993 (data not shown), but in 1994 and 1995 the treatments which had been recompacted while wet (C_1, C_2) reduced anthesis dry matter per ha in comparison with the control (C_0) treatment (Tables 1 and 2). In C_1, this was due, at least in part, to significantly lower plant populations because of reduced establishment. In C_2, plant populations were similar to the control in both 1994 and 1995, and reductions in anthesis dry matter in C_2 indicate growth retardation, the effects of which lasted to anthesis.

Despite a reduced plant population (which increases dry weight per plant) in the C_1 treatment in 1995, C_1 had a lower dry weight per plant than C_0 at 35 days in 1995 (Table 2). This indicates that compaction also retarded early plant growth in C_1.

The compaction treatment with the tractor tyres on dry soil (C_3) had no effect on aboveground dry matter in comparison with the uncompacted control (C_0).

Grain yield

Applied compaction had no statistically significant (P>0.05) effects on grain yield, despite reduced early growth in 1994 and 1995 (Tables 2 and 3). In 1995, zero tillage (C_4) outyielded the control treatment (C_0).

DISCUSSION

Our results indicate that compaction affects crops adversely in their early growth stages but these effects do not persist long enough to reduce grain yield.

The compaction treatment with the header each year (C_1) reduced establishment in all three crops at this site. Reduced establishment can be attributed in part to reduced seedbed tilth caused by the compaction treatment. This results in poor soil-seed contact and poor coverage of the seed with soil, both of which limit the amount of water available to the seed. The tight, compacted seedbed would have caused even greater problems if traditional sowing machinery had been used, for example a combine with duckfeet openers and spring-loaded tines. However, with the state-of-the-art sowing machinery in use, no dramatic reductions in establishment occurred.

The annual compaction treatments on wet soil (C_1, C_2) also reduced aboveground dry matter in comparison with the control (C_0) treatment in 1994 and 1995. This was due in part to suboptimal plant population densities as a result of the reduced establishment. The lowest wheat population in 1994 was 44 plants/m^2 (in C_1), which is below the recommended range of 50-150/m^2 (Colwell 1963). The lowest sorghum population in 1995 was 2.6 plants/m^2 (also in C_1), which is below the recommended range of 5-10/m^2 (Thomas *et al.* 1981). Reductions in dry matter production can also be attributed to impeded root growth in the compacted soil surface.

The absence of grain yield reductions in response to our applied compaction indicates that the crops compensated for low plant populations and early retardation of growth. We hypothesise that such compaction could conceivably result in positive effects of compaction on grain yield. Firstly, the slow early root growth in compacted soil could delay soil water use and leave more stored soil water available at critical growth stages such as anthesis or grain filling. Secondly, the reduced establishment in compacted soil could lead to lower but more optimal plant populations under harsh environmental conditions.

It may be that the two crop species investigated (wheat and sorghum) are not particularly susceptible to the effects of compaction by heavy wheel traffic. It can also be speculated that both species were effective in repairing compaction damage to the soil or the soil quickly repaired itself through shrinking and swelling processes.. Investigation of other crop species and assessment of soil properties are being carried out to determine whether the mechanism is one of tolerance to, or repair of, compaction damage.

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