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Effects of Tillage and Stubble Residue Treatments on Termite Activity in Two Central Queensland Vertosols

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Abstract

The effects of tillage and stubble residue management practices on the activity and composition of the termite fauna of some central Queensland Vertosols has been examined, using a combination of spade sampling, baiting and deep coring techniques. Uncultivated Vertisols , previously thought to be devoid of termites, are now known to support at least five species of subterranean termites. They are *Amitermes obtusidens* Mjoberg, *A. agrilus* Gay, *Microcerotermes serratus* (Froggatt), *Heterotermes paradoxus* (Froggatt) and *Termes* sp. Clearing and cultivation for dryland cropping virtually eliminated termites from these soils. The adoption of zero till and stubble retention practices however, resulted in the re-appearance of subterranean termites. The implications of increased termite activity in cropping soils are also discussed.

Keywords: tillage, termites, vertosols, Queensland.

Introduction

Maintenance of biodiversity in the soil ecosystem is essential because of the influence of soil biota on soil physical and chemical properties. Agricultural activity affects the habitat of soil biota resulting in a reduction in diversity and activity, which in turn affects soil structure and chemical fertility, and ultimately, plant yield.

Research on the effects of tillage and stubble residue management strategies on soils has mainly concentrated on physical and chemical aspects. Studies of the non-earthworm soil biota are relatively few (Douglas 1987), and have generally shown that populations are severely depressed by tillage (Abbott *et al.* 1979; Clarke and Russell 1977; Robertson *et al.* 1993). Termites play an important role in nutrient cycling and availability, particularly in tropical ecosystems (Holt and Coventry 1990). Although termites may have a significant effect on macro-porosity, little is known of their effects on the hydraulic characteristics of soils (Lal 1987).

In this study we examined the effects of tillage and residue management practices on termite activity in two central Queensland cropping soils. The work forms part of a broader investigation of the effects of tillage on soil animals and the hydraulic properties of cropping soils in central Queensland.

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Sites and Methods

Sites

The first site, Mt Murchison, is located 10 km northeast of Biloela (24°19′ S., 150° 32′ E.) in central Queensland on an area of soils classified as Endohypersodic Crusty Grey Vertosols (Isbell 1992; CSIRO Aust. Div. Soils Tech. Rep. 1/1992, unpublished) or Haplusterts (Soil Survey Staff 1992). This site was set up by the Queensland Department of Primary Industries in 1978 for long-term tillage experiments. It supported a brigalow-dominant (*Acacia harpophylla*) forest prior to clearing in about 1935, and has been cropped annually since 1962, mainly to grain sorghum.

The second site, Biloela R.S. (24° 23′ S., 150° 31′ E.), forms part of the Queensland Department of Primary Industries Biloela Research Station on the outskirts of Biloela. The soils are classified as Haplic Self-mulching Black Vertosols (Isbell 1992; CSIRO Aust. Div. Soils Tech. Rep. 1/1992, or Haplusturts (Soil Survey Staff 1992).

Methods

Tillage and stubble treatments during the fallow

Mt Murchison site. The experimental design was a randomized block with six treatments and four replicates (Thomas *et al.* 1990). The six treatments consisted of:

DT+ conventional disc/scarifier tillage, stubble retained;
DT− conventional disc/scarifier tillage, stubble removed after harvest;
RT+ reduced tillage (blade plough/rodweeder), stubble retained;.
RT− reduced tillage (blade plough/rodweeder), stubble removed after harvest;
ZT+ zero tillage (chemical weed control), stubble retained;
ZT− zero tillage (chemical weed control), stubble removed after harvest.

The experiment commenced in 1978. Grain sorghum was grown each summer except 1988–89 when the land was fallowed and 1989–90 when cotton was grown. Winter fallow was practised each year from 1978 to 1991.

Biloela R.S. site. The experimental design consisted of a randomized block with four treatments and four replicates. The four fallow management treatments at Biloela R.S. consisted of:

DT conventional tillage (disc plough/scarifier), stubble fully incorporated early in the fallow;
SMT stubble mulch tillage (blade/chisel plough/rod weeder), stubble incorporated as little as possible while controlling weeds mechanically;
RT reduced tillage (blade/chisel plough/herbicides), stubble incorporated as little as possible by controlling weeds with herbicides or subsurface tillage;
ZT zero tillage, stubble fully retained on the soil surface by controlling weeds with herbicides.

Individual plot size was 72×22 m, and treatments at this site have been maintained since 1983 with grain sorghum grown until 1987 and wheat from 1987 to 1992.

Termite activity and species composition

Termite activity and species composition at each site were determined by a combination of spade sampling, baiting, and soil coring.

Spade sampling. A simple spade sampling technique (Robertson and Simpson 1988) was used to collect 10 or 15 soil samples (approx. 180×180 mm) to a depth of 150 mm from each of the 24 plots at Mt Murchison (six treatments×four replicates) and the 16 plots at Biloela R.S. (four treatments×four replicates) at the beginning and end of each fallow in 1990 and 1991. These samples were then handsorted and termites identified.

Baiting. Toilet roll baits (Haverty *et al.* 1974), buried so the tops were level with the soil surface, were used to collect termites from both sites. In May 1990, ten randomly placed baits were set out in a single replicate of each treatment at Mt Murchison, and in two replicates of each treatment at Biloela R.S. The baits were retrieved after three months and examined for termite activity. Any that had been attacked at Biloela R.S. were replaced and retrieved again after a further three months.

Baiting was discontinued in the DT and RT treatments at Mt Murchison after the first sampling (August 1990) because of the disruption caused by cultivation. The random system of bait placement in the ZT− and ZT+ treatments was replaced by a 9×9 m grid system containing 49 rolls spaced at 1·5 m intervals. These baits were examined in November 1990, and again in April 1991.

Core sampling. Eighteen soil cores (100 mm diameter and to 500 mm depth) were collected, using a Proline hydraulic push drill rig, from one ZT+ and one ZT− treatment at Mt Murchison in November 1990. Twenty cores were collected from a single replicate of a ZT and RT treatment at Biloela R.S. in November 1990. Ten cores were also collected from two replicates of SMT, RT and ZT, and from a single DT treatment at Biloela R.S. in November 1991. Each core was examined for the presence of termite galleries, termites and earthworm tunnels. Termite galleries were distinguished from earthworm tunnels by their generally more tortuous and branching path, their ellipsoidal or flattened shapes and the presence of a thin, organic matter rich lining on the gallery surface.

Termites of uncultivated sites

In addition to the studies undertaken at the Mt Murchison and Biloela R.S. sites, an examination of the termites present at two relatively undisturbed forested sites on Vertosols in the same general region was made. The sites sampled included a brigalow forest near Moura (24° 50′ S., 149° 47′ E.), and gidgee scrub in the Mazeppa National Park (22° 14′ S., 147° 15′ E.).

Table 1. Percentage of samples containing termites: Mt Murchison spade sampling results

Sampling date	Treatment[A]					
	DT+	DT−	RT+	RT−	ZT+	ZT−
May 1990	2	0	0	0	8	0
Oct. 1990	0	0	0	0	0	13
July 1991	0	0	0	0	13	7

[A] Treatments as defined in text (see *Methods* section).

Results

Spade Sampling

Mt Murchison

On each sampling occasion, termites were found in a relatively low proportion of samples collected from ZT+ or ZT−, or both (Table 1). None of the samples from RT+, RT− or DT−, and only one sample from DT+, contained termites (Table 1).

Termites usually occurred in low numbers, with only a few (<20) workers being present. Occasionally several hundred termites, made up of mature workers, third or fourth stage nymphs and soldiers, were found in a single spade sampling. Only two species, *Amitermes obtusidens* Mjoberg and *A. agrilus* Gay were identified from the spade sampling.

Biloela R.S.

Termites were recorded in a significantly higher proportion of the samples from the ZT treatments than from samples collected from the RT treatments (18%

and 5% respectively; $X^2 = 19 \cdot 3$, $P < \cdot 001$). Termites were found in only two samples from DT treatments; none were found in the SMT treatments (Table 2).

Table 2. Percentage of samples containing termites: Biloela R.S. spade sampling results

Sampling date	Treatment			
	DT	SMT	RT	ZT
May 1990	0	0	5	32
Jan. 1991	3	0	8	5
May 1991	3	0	0	20
Nov. 1991	0	0	5	15
Mean	2	0	5	18

When termites were found in the spade samples, they generally occurred in numbers similar to those occurring in the spade samples from Mt Murchison. *A. agrilus* was the only species identified from these samples.

Baiting

Mt Murchison

None of the baits in any of the treatments showed evidence of termite activity at the first sampling in August 1990 (baits were removed from all treatments except ZT+ and ZT− at this time), or in November 1990. By April 1991, however, four baits from ZT+ and one from ZT− had been attacked. Two adjacent ZT+ baits contained *Amitermes obtusidens* and another contained *Microcerotermes serratus* (Froggatt). One ZT+ and ZT− bait had been colonized and (subsequently) abandoned by termites.

Table 3. Percentage of baits attacked by termites at Biloela R.S.

Sampling date	Treatment			
	DT	SMT	RT	ZT
Aug. 1990	5	0	15	5
Nov. 1990	0	0	20	5

Biloela R.S.

The RT treatments had the highest termite activity on both sampling occasions (Table 3). *Heterotermes paradoxus* (Froggatt) and *Microcerotermes serratus* were the only termite species found in the baits.

Core Sampling

Mt Murchison

The ZT+ treatment had a significantly higher percentage of cores with termite galleries than ZT− (44% and 6% respectively; $x^2 = 7 \cdot 2$, $P < \cdot 01$). Termite galleries were not concentrated at any particular depth in the soil, but occurred throughout the 500 mm long cores and included both vertical and horizontal galleries ranging in diameter from 2 to 8 mm. When surface galleries were present, they took the form of numerous fragile tunnels (2–6 mm diam.).

Table 4. Percentage of soil cores sampled from the Biloela R.S. that contained termite galleries

$n = 20$ for all treatments except Nov. 91 DT where $n = 10$

Sampling date	Treatment DT	SMT	RT	ZT
Nov. 1990	—	—	15	65
Nov. 1991	0	0	40	79
Mean	0	0	28	72

Biloela R.S.

The ZT treatments had a significantly higher proportion of cores with termite galleries than the RT plots (72% and 28% respectively; $X^2 = 15\cdot5$, $P < 0\cdot001$) (Table 4). No galleries were found in cores taken from the SMT and DT treatments.

The galleries ranged in size from 2 to 8 mm, with larger flattened galleries up to 75×75 mm cross section and 8 mm high occurring at depths greater than 250 mm. These galleries often contained termites. Mature workers, soldiers, neotenics, and large numbers of 1st, 2nd and 3rd stage instars of *A. obtusidens* were recovered from one extensive gallery system that was located between 300 and 450 mm below the soil surface. This collection of galleries most probably represented the central nest area of a subterranean termite colony.

Termites of Uncultivated Sites

Three subterranean termites, *Amitermes* sp., *Termes* sp. and *M. serratus*, were found in the soil and fallen timber of the brigalow forest near Moura. Another species, *H. paradoxus*, was collected from soil in the Mazeppa National Park.

Discussion

It has previously been reported that termite mounds do not occur on the cracking clay soils (Vertosols) of central Queensland (Ratcliffe *et al.* 1952; Gay and Calaby 1970), presumably because of the disruptive effect on mounds of the shrink/swell behaviour of these soils. Nevertheless, two species of subterranean termites, *A. obtusidens* and *M. serratus*, are known to occur in Vertisols of northeastern Australia (Holt and Coventry 1982). Thus it would appear that the shrink/swell behaviour of these soils has less effect on subterranean than on mound-building termites. In this study another three subterranean termite species have been found in the soils of two relatively undisturbed forests in central Queensland, two of which are common to the Biloela R.S. site. Therefore, although mound-building termites do not normally occur on Vertosols , at least five subterranean nesting species are now known to be widespread in the Vertosols of central and northeastern Queensland. The feeding preferences of these species are poorly known, but *A.agrilus* (Gay 1968), and *A. obtusidens* and *M. serratus* (Holt and Coventry 1982) have been found in cow dung. *H. paradoxus* usually feeds on wood in various stages of decay (Hill 1942). The presence of galleries on the soil surface indicates that these termites are feeding on the stubble of the various crops in order to survive in the experimental plots.

Regular sampling of the tillage experiments at Mt Murchison and Biloela R.S. showed that four subterranean termites are relatively common in zero till, but rarely found in conventionally cultivated treatments. These termites have also been collected from relatively undisturbed forested areas in the same general region or from pastoral areas further north.

The baiting trials indicated that there may have been more termite activity in the RT than the ZT treatments at Biloela R.S. This was not supported by evidence from the soil cores which showed that termite galleries extended to at least 500 mm below the soil surface (maximum depth of sampling) and that there were significantly more gallery structures in the zero till treatments at Biloela R.S. (approximately 70% of samples), than the reduced till and conventional till treatments (approximately 25% and 0% of samples respectively). The results of the baiting trials in the RT treaments may have been influenced by the presence of a single colony that had a slightly larger than normal foraging area.

At least one species, *A. obtusidens*, constructs its nest approximately 400 mm below the soil surface and vertical and horizontal galleries radiate from there towards the soil surface. Thus, it would appear that the shrink/swell behaviour of Vertosols does not adversely affect the stability of subterranean termite galleries or nests. The virtual absence of termites from the DT treatments suggests that tillage operations have a negative effect on termite activity, most probably because of the frequent physical disruption of their surface and near-surface feeding galleries.

No differences in termite activity between the ZT+ and ZT− treatments were detected by spade sampling or baiting in 1990. The April 1991 baiting results, however, showed higher activity in the ZT+ than the ZT− treatment and coring also indicated that there was greater termite activity in the ZT+ treatment. This site had been sown to cotton in December 1989 following a long fallow after the sorghum harvest of 1988. The 18 month fallow coupled with a low-yielding dryland cotton crop in 1990 resulted in relatively low stubble levels, and therefore a small mass of forage material for termites, perhaps explaining the lack of difference in observed activity between ZT+ and ZT− in 1990. During the period of sorghum cropping prior to the long fallow and cotton crop, a considerable mass of sorghum residue was present on ZT+. The significantly higher incidence of galleries in the ZT+ may therefore be a reflection of increased termite activity during the period when more substrate was available.

The implications of increased termite activity in cropping soils include increased stubble decomposition rates and therefore a more rapid recycling of plant nutrients (Holt and Coventry 1990). The associated increase in soil macropore volume (in the form of termite galleries) should also improve the rate of water entry into the soil, albeit at low tensions, thus increasing supply of crop available water and reducing surface runoff and soil erosion. Concurrent studies of the hydraulic properties of these soils show that the ZT treatments do have higher infiltration rates than the DT treatments (B.J. Bridge, personal communication). The contribution of termites to these improved infiltration rates may be difficult to assess since the activity of other soil animals, particularly earthworms, is also higher in ZT treatments (Robertson *et al.* in press).

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