Strategic tillage impacts in long-term no-till

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Summary Continuous no-till (NT) has demonstrated tangible economic, environmental and soil health benefits aspects over conventional tillage (CT). However, adoption of NT has contributed to the build-up of herbicide-resistant weed populations, increased incidence of soil- and stubble-borne diseases, and stratification of nutrients and organic carbon near the soil surface. Some farmers resort to an occasional strategic tillage (ST) to manage constraints in NT systems. However, farmers who practice strict NT are concerned that even a single tillage operation may undo positive soil condition benefits accruing from NT farming systems. We selected five fields on long-term no-till (NT) managed soils (7–44 y) to represent typical conservation farming systems across north-eastern Australia. One-time tillage with either chisel tines or offset disc, or chain harrows in long-term NT helped control winter weeds. Grain yield overall showed no significant impact in both years; except in brown Sodosol (P = 0.06) in the first year. One-time tillage generally retained many of the soil health benefits of NT farming systems. However, tillage reduced soil moisture at most sites, but this decrease in soil moisture did not adversely affect productivity. This could be due to good rainfall received between tillage and seeding and subsequently during crop growth, which was able to replenish soil water lost from the seed zone for successful germination, seedling establishment and crop growth. These studies are allowing us to develop a conceptual framework for the potential impact of strategic tillage (ST) over time. Uptake of ST in long-term NT systems would depend on three aspects: system costs and profitability, soil health and environmental impact. For many Australian farmers, maintaining farm profitability is the priority and likely to dictate its adoption. However impacts on soil health and environment, especially the risk of erosion and the loss of soil carbon, will also influence a grower's choice to adopt ST.

Keywords No-till, strategic tillage, soil moisture, weed control, nutrient stratification.

INTRODUCTION

Conservation agriculture (CA) practices that included no-till (NT), stubble retention and crop rotations have revolutionised agricultural systems by allowing growers to manage greater areas of land with reduced energy and machinery inputs (FAO 2014). Significant benefits in yield and crop performance have accrued, especially in lower rainfall regions, while erosion control and improved soil health have also occurred. Despite these tangible benefits, a recent survey of 55 growers and advisors in north-eastern Australia indicated that diseases such as crown rot (caused by *Fusarium pseudograminearum*) and yellow leaf spot (caused by *Pyrenophora tritici-repentis*) and hard-to-kill weeds such as fleabane (*Conyza bonariensis* (L.) Cronq.), feathertop Rhodes (*Chloris virgate* Sw.) and glyphosate resistant barnyard grass (*Echinochloa crus-galli* (L.) P.Beauv.), tend to be bigger problems in NT than in systems where tillage is regularly used.

For these regions many growers are shifting towards a flexible approach to tillage performing some soil disturbance (Argent *et al.* 2013). However, growers who practice strict CA systems are concerned that even a single tillage operation may undo the positive benefits of CA systems on soil condition. Assessments of the most studies conducted in USA and Europe on soil health of adopting occasional ST in NT systems have been inconsistent (Dang *et al.* unpublished data). In some cases detrimental effects have been reported (Grandy *et al.* 2006) while others have suggested either little or no impact (Kettler *et al.* 2000, Quincke *et al.* 2007, Wortmann *et al.* 2010). To resolve the conflicting issues surrounding the use of occasional strategic tillage (ST) in CA systems, this research aims to determine impacts of ST on productivity, profitability, soil health and the environment under varying soil and climatic conditions.

MATERIALS AND METHODS

Five fields with <1% slope were selected on long-term NT soils to represent typical CA farming systems across north-eastern Australia (Table 1). On all soils except the black Vertosol, the experimental design was a randomised complete block with four replications. Plot size was a minimum of 100 m length and the width of the permanent controlled traffic tramline (typically between 12 m and 18 m). All sites received tillage treatments to depths between 0.15 and 0.20 m (tine, and/or disc or prickle (Kelly) chain harrows) at least once in March 2012. On the grey Vertosol and brown Sodosol, a second tillage was applied in the 3rd week of April 2012. On the black Vertosol, the long-term tillage experiment included a factorial combination (conventional or no-tillage × crop residue retained or burned × 0, 30 or 90 kg N ha^{-1} applied as urea) with four replications. In 2012, each plot was longitudinally split in two, with half receiving chisel tillage in March 2012 and the other half left untilled. We will present results only for NT, SR treatments at these sites.

Soil samples, sub-sampled at 0–0.1 m, 0.1–0.2 m and 0.2–0.3 m, were obtained prior to sowing of crops in both years and analysed for soil quality attributes (Rayment and Lyons 2011). Particulate organic carbon (POC), quantified by physical separation as <2 mm but >0.053 mm size (Cambardella and Elliot 1992). For soil microbial activity, five soil samples were collected to a depth of up to 0.10 m, composited and analysed using fluorescein diacetate (FDA) (Adam and Duncan 2001). During crop growth at tillering, weed populations were measured using a 0.25 m × 0.25 m frame randomly placed in four locations in each plot and the number of individual plants inside the frame recorded.

RESULTS

Imposition of one-time tine-tillage in otherwise NT system significantly lowered in-crop weed populations including fleabane, turnip (*Rapistrum rugosum*), wild radish (*Raphanus raphanistrum*) and wild oats (*Avena fatua*) in all the soils after 3 months (Table 2). Twelve months post tillage; weed population was significantly lower in grey Vertosol and grey Dermosol but increased significantly on brown Sodosol. Soil bulk density in top 0.1 m soil depth was quite variable and not significantly affected by tillage except in brown Sodosol, although it tended to decrease in all soils except grey Dermosol. There were no significant differences in soil moisture resulting from tillage prior to seeding except in black Vertosol in 0–0.1 m soil depth, however all soils tended to decreased soil moisture due to higher evaporation rates in tilled soil. One-time tine-tillage had no significant effect on soil organic carbon mass; however, it tended to slightly decrease in 0–0.1 m soil depth. The impacts on particulate organic carbon were significant ($P < 0.05$) only in grey Vertosol after three months. One-time tillage tended to lower available P in 0–0.1 m soil depth at all sites, however, significant differences were obtained only in grey Vertosol. Total microbial enzymatic activity between tine-tillage treatment and NT did not differ significantly in any soil.

Grain yield overall showed no significant impact in both years; except in brown Sodosol ($P = 0.06$) in

Table 1. Detailed site and experiment description.

Soil type and location	Grey Vertosol Biloela	Brown Sodosol Condamine	Grey Dermosol Moonie	Black Vertosol Warwick	Brown Vertosol Wee Waa
No-till history (yrs)	18	19	7	44	16
Previous crop	Wheat	Wheat	Wheat	Wheat	Chickpea
Date of tillage I	29.03.12	06.03.12	03.03.13	07.03.12	26.03.12
Date of tillage II	20.04.12	18.04.12	-	-	-
Tillage implements	Chisel tine	Chisel tine	Chisel tine, Offset disc	Chisel tine	Chisel tine, Chain harrows
Clay content (%) 0–10 cm	50	25	38	65	52
Rain between Tillage I and sowing (mm)	25	99	80	118	91
Rain between Tillage II and sowing (mm)	25	70	–	–	–
In-crop rain (mm)	145	205	111	122	95

Table 2. Impacts of occasional strategic tine-tillage in otherwise long-term no-till farming systems.

	Grey Vertosol		Brown Sodosol		Grey Dermosol		Black Vertosol		Brown Vertosol
Soil type	3 m	12 m	3 m	12 m	3 m	12 m	3 m	12 m	3 m
Weeds (no. m^{-2})	↓	↓	↓	↑	↓	–	–	–	↓
$BD_{0–10\ cm}$ (g cm^{-3})	–	–	–	↓	–	–	–	–	–
$SW_{0–10\ cm}$ (mm)	–	+	–	–	–	–	↓	–	–
$SOC_{0–10\ cm}$ (t ha^{-1})	–	–	–	–	–	–	–	–	–
$POC_{0–5\ cm}$ (t ha^{-1})		↓		–		–		–	
$P_{0–10\ cm}$ (mg kg^{-1})	↓	–	–	–	–	–	–	–	–
$TMA_{0–10\ cm}$ (µg h^{-1} g^{-1})	–	–	–	–	–	–	–	–	
$MB_{0–10\ cm}$ (µg g^{-1})				–		–			
Yield (t ha^{-1})	–	–	↑	–	–	–	–	–	–
Net return ($)	–	–	–	–	–	–	–	–	–

↑, significant ($P < 0.05$) increase; ↓, significant ($P < 0.05$) decrease; –, no significant effect; 3 m, 3 months after tillage; 12 m, 12 months after tillage; TMA, total microbial activity; MB, microbial biomass; BD, bulk density; SW, soil water; SOC, soil organic carbon; POC, particulate organic carbon; P, available (Colwell-P).

the first year. Brown Sodosol recorded a decrease in yield in 2013, a likely result from a significant increase in weed population. Based on farmer costs of tillage, the net returns per hectare from one-time tillage, using either chisel or offset disc in long-term NT systems, were estimated to range from $−24.9 to $103.6. Introduction of a single tillage operation in continuous NT showed a slight increase in simulated sediment loss. There were no significant differences between different tillage implements on agronomic or soil quality attributes (results not shown).

IMPLICATIONS

Tillage treatments generally had no significant impacts on soil health attributes expect on texture contrast (brown Sodosol) and soils with weakly structured A-horizons (grey Dermosol). A potential negative effect from tillage was the reduced soil moisture in most soils, although under the seasonal conditions with good rainfall between tillage and the sowing of the crops did not adversely affect productivity. Reduced weed pressure resulting from ST has significant implications for managing resistant and hard-to-kill weeds; however increase in weed population at one site suggest that understanding weed seed bank at a given site or farm would be key factor to implement successful ST. Most studies conducted in USA and Europe suggests that one-time tillage in NT systems could improve productivity and profitability in the short term; however in the long-term, the impact is negligible or may be negative (Dang *et al.* unpublished data). For many Australian farmers, maintaining farm profitability is a priority, and this is likely to dictate its adoption. However impacts on soil health and environment, especially the risk of erosion and the loss of soil carbon, will also influence a grower's choice to adopt ST. We anticipate that inclusion of ST in NT systems would offer management flexibility and is likely to improve farm profitability with less reliance on pesticides and herbicides.

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