Age of cultivation is not a good indicator of profitable crop production

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ABSTRACT

In 1997, local growers and agronomists established an on-farm research trial on a grey vertosol near Croppa Creek, northern NSW. Their main interest was the relative productivity of adjacent paddocks that had been continuously cropped for 40 (old), 14 (medium), and 4 years (new) post-clearing, and whether N fertiliser could overcome the impact of four decades of cropping. Two wheat crops (1997, 1998), one mungbean (1998/9) and one sorghum (1999/2000) crop were grown at the site. Three rates of fertiliser N were applied to the cereals (30, 60, 120 kg N/ha in 1997; 0, 70, 140 kg N/ha in 1998 and 1999/00). At nil and low rates of fertiliser N, cereal yields, proteins and gross margins were higher in the "new" and "medium" aged paddocks than the "old" paddock. At the high rate, most paddock differences disappeared and some were reversed due to differences in available water and available P, the latter due to a history of superphosphate use. Mungbean yields were unaffected by paddock age. Paddock age on its own was not a reliable indicator of potential productivity on this soil. Rather, yields were strongly related to N supply.

KEYWORDS

Organic carbon, cultivation age, nitrogen fertiliser, wheat, sorghum, mungbean.

INTRODUCTION

By the end of the 1980's, many farmers had become aware of the large decline in natural soil fertility in land that had been continuously-cropped for several decades. This fertility decline was highlighted by studies e.g. Dalal and Mayer (1986), that focussed on the loss of soil organic matter following clearing of native vegetation for cultivation. Subsequently, researchers in northern NSW and southern Qld devised field trials to examine ways of halting and restoring this lost fertility through the introduction of pasture phases, rotations of cereals with pulse crops, conservation tillage and stubble retention.

Should soils with different "ages" of cultivation and therefore different levels of organic fertility be managed differently because of this fertility decline? The dominant soil types under production in this region are vertosols containing significant amounts of swelling and cracking clays. In these soils the clay type and clay % are primarily responsible for many of the properties often attributed to soil organic matter, such as structural integrity, cation-holding capacity, water-holding capacity, pH buffering etc. However, the soil organic matter still plays a prominent role in these soils in its capacity as a source and sink of N, P and S, and its influence on the availability of micronutrients. Therefore, if shortfalls in soil nutrient supply can be met through fertiliser application, there may be no need for measures such as pasture leys to restore organic matter levels in these soils in order to attain the yields previously experienced when cropping newly-cleared land.

In northern NSW, many farmers practise continuous cropping and are hesitant to invest in new infrastructure to accommodate grazing in paddocks normally used for cropping. Therefore, a group of farmers and local agronomists established an on-farm experiment in 1997 to see if the application of conservation farming and optimum fertiliser techniques could dispense with the need for pasture-based restoration of lost soil fertility. Much emphasis was placed on the trial being farm-scale as opposed to typical small-plot research, so all operations were conducted with the participating farmer's normal equipment. In 1998, to add rigour in measurement and interpretation of data, NSW Agriculture researchers incorporated the trial as an on-farm participatory research activity into the newly-formed 'Eastern Farming Systems' project (GRDC DAN 363). As the investigation was truly participatory, regular meetings were conducted to facilitate discussion of results, modifications to trial treatments as deemed necessary, and swift adoption of findings by local farmers.

A four-year research experiment began in 1997 at Croppa Creek to investigate the hypothesis “can differences in productive capacity and economic viability between ‘old’ and ‘newly’ cropped land of the same soil type be eliminated through N fertiliser use?”

METHODS

In 1997, local farmers and agronomists established an ‘age of cultivation’ experiment at “Merwood” (K.N. Nixon & Co.), near Croppa Creek in northern NSW. Adjacent paddocks of similar soil type were selected that had been continuously cropped for 40 (old), 14 (medium) and 4 years (new), mostly to wheat. Comprehensive nutrient analyses and morphological descriptions were conducted on soils to 120 cm depth from each of these blocks plus an area of uncleared brigalow/belah woodland located between two of the selected paddocks. In 1999, an additional ‘newly-cleared’ paddock (new-new) of similar ‘cultivation age’ to the “new” paddock was also included in the study.

Two wheat crops (1997, 1998), one mungbean crop (1998/9) and one sorghum (1999/2000) crop were grown at the site. Chickpeas were sown in 2000. In each paddock there were 6 plots (15 m x 90 m). Three rates of fertiliser N (30, 60, 120 kg N/ha in 1997 and 0, 70, 140 kg N/ha in 1998 and 1999/2000) were applied as urea 3 months before the cereal crops were sown. Each treatment was duplicated.

Grain yields and protein (for wheat) were measured in quadrat samples taken from each plot at harvest. Paddocks were monitored for soil water content and nitrate-N concentration to 90 cm (1997), 120 cm (1998/99) or 150 cm (1999/00) depth at sowing and harvest of each crop.

RESULTS AND DISCUSSION

Crop production

Yields and proteins (for wheat) for all crops grown in the trial to date are given in Table 1. In 1997, nitrogen (N) uptake by wheat on plots where 30 kg N/ha was applied reflected differences in current N fertility status (Table 2), i.e. 52 kg N/ha (new paddock) versus 41 kg N/ha (old). At the high N fertiliser rate (120 kg N/ha), these differences were reversed, i.e. 59 kg N/ha (new) versus 69 kg N/ha (old). Trends in gross margins were similar owing to premiums paid for higher protein contents (Table 1). For example, gross margins for the “new” paddock were $220/ha where 30 kg N/ha was applied and $170/ha with 120 kg N/ha, whereas gross margins for the “old” paddock were $110/ha where 30 kg N/ha was applied and $220/ha with 120 kg N/ha.

Table 1. Crop yields (t/ha) and proteins (%, figures in parentheses) were affected by paddock age and N fertiliser rate. All results are means of two replicates (n.d. indicates no data).

Year	Crop	Paddock age[A]	Nitrogen fertiliser[B]		
			low / nil	medium	high
1997	wheat	new	2.6 (11.3)	2.7 (11.9)	2.8 (12.0)
		medium	n.d.	n.d.	n.d.
		old	2.5 (9.3)	3.0 (10.9)	3.3 (12.0)
1998	wheat	new	1.1 (12.7)	1.6 (12.8)	2.0 (13.3)
		medium	1.0 (11.3)	1.5 (11.7)	1.8 (13.0)
		old	1.0 (11.8)	1.7 (12.3)	2.1 (13.7)
1998/1999	mungbean	new	1.4 -	1.4 -	1.5 -
		medium	1.5 -	1.2 -	0.8 -
		old	1.5 -	1.7 -	1.1 -
1999/2000	sorghum	new-new	6.1 -	6.1 -	6.1 -
		new	6.0 -	6.0 -	6.1 -
		medium	5.6 -	n.d. -	6.5 -
		old	5.3 -	6.3 -	6.7 -

[A]age of cultivation in 1997: new and new-new = 4 yrs, medium = 14 yrs, old = 40 yrs

[B]30, 60, 120 kgN/ha in 1997; 0, 70, 140 kgN/ha in 1998 and 1999/2000

Despite high nitrate-N levels in the soil at sowing in 1998 (Table 2) from unused 1997 N fertiliser, organic matter mineralisation over the summer fallow and applied 1998 N fertiliser, yields of nil-N wheat in 1998 (Table 1) were still N-limited because of denitrification and leaching of N and poor root exploration in the waterlogged soil after record in-crop rainfall (568 mm). All remaining nitrate-N at harvest (Table 2) was found below 60 cm, with 60% below 90 cm.

Table 2. Soil nitrate-N (kg N/ha) in plots varying in paddock age and N fertiliser rate. All results are means of two replicates (n.d. indicates no data).

Paddock age[A]	N fertiliser[B]	Year (month)						
		1997		1998		1999		2000
		(Apr)	(Nov)	(May)	(Dec)	(Apr)	(Jun)	(Jun)
		Pre-trial[C]	Harv[D]	Pre-sow[D]	Harv/sow[D]	Harv[D]	Pre-sow[E]	Sow[E]
new	low/nil	61	48	164	56	73	182	91
	medium	61	98	216	80	105	239	142
	high	61	75	321	79	155	304	186
new-new	low/nil	-	-	-	-	-	155	13
	medium	-	-	-	-	-	220	61
	high	-	-	-	-	-	294	98
medium	low/nil	37	7	126	71	59	72	0
	medium	37	31	187	98	76	135	n.d.
	high	37	25	282	92	130	256	109
old	low/nil	35	8	90	37	42	49	0
	medium	35	8	162	49	48	86	0
	high	35	28	279	57	78	143	30

[A]age of cultivation in 1997: new and new-new = 4 yrs, medium = 14 yrs, old = 40 yrs

[B]30, 60, 120 kgN/ha in 1997; 0, 70, 140 kg N/ha in 1998 and 1999/2000

[C]0-90 cm [D]0-120 cm [E]0-150 cm

The lack of any clear treatment effects in 1998/1999 mungbean yields (apparent N fertiliser differences actually resulted from poor establishment in the wet paddocks) indicated that water was not limiting despite large differences in plant available water at sowing (Table 3). In crop rainfall was 318 mm.

Sorghum yields in 1999/00 showed a similar response to N fertiliser rate and paddock age as the wheat in 1997. Once again, yields in the “new” paddock were below that expected of a relatively recently cleared paddock and showed no response to added N fertiliser (Table 1). Another paddock of similar age to the “new” paddock (the “new-new” paddock) was included in the trial but also failed to meet yield expectations being out-yielded by the “old” paddock at the high N rate. N uptake data is not yet available.

Soils

Continuous cropping reduced organic carbon in the surface soil (0-10 cm) from 1.6% (nearby woodland) to 1.5% (“new” and “new-new” paddocks), 1.2% (“medium” paddock), and 1.1% (“old” paddock). That the “old” paddock out-yielded the “new” suggested paddock differences other than N fertility were important, particularly since soil testing at harvest indicated much nitrate-N remained unused in the “new” profile (Table 2), 70% of which was below 90 cm. Surface soil (0-10 cm) test results in pre-trial samples were higher in the “old” than “new” paddock for phosphorus (Colwell P) [17 versus 8 mg/kg] and zinc (DTPA) [1.1 versus 0.3], indicating a history of previous fertiliser use on the “old” paddock. Subsequently, fertiliser P and Zn were applied to all trial plots at the sowing of each crop and later soil tests indicated comparable levels of P and Zn in all paddocks.

Differences in cation exchange capacity (sum of basic cations extracted in ammonium acetate) between “old” and “new” paddocks [41 versus 25 in the surface soil (0-10 cm)] indicated differences in soil texture, a supposition strongly supported by plant available water results taken throughout the trial (Table 3). A detailed morphological investigation of whole soil profiles at all paddocks confirmed that the “new” paddock was significantly different from the “medium” and “old” paddocks in clay content, depth of cracking, and subsoil pH; all differences attributed to the composition of the soil’s parent material.

Table 3. Plant available water (mm) in plots varying in paddock age and N fertiliser rate. All results are means of two replicates (n.d. indicates no data).

Paddock age[A]	N fertiliser[B]	Year (month)						
		1997		1998		1999		2000
		(Apr)	(Nov)	(May)	(Dec)	(Apr)	(Jun)	(Jun)
		Pre-trial[C]	Harv[D]	Pre-sow[D]	Harv/sow[D]	Harv[D]	Pre-sow[E]	Sow[E]
new	low/nil	68	24	79	89	54	46	79
	medium	68	21	69	73	20	79	63
	high	68	12	92	89	33	51	86
new-new	low/nil	-	-	-	-	-	146	202
	medium	-	-	-	-	-	159	109
	high	-	-	-	-	-	159	129
medium	low/nil	156	39	163	169	88	141	118
	medium	156	47	154	160	81	134	n.d.
	high	156	37	148	127	92	148	106
old	low/nil	132	27	150	180	93	145	135
	medium	132	24	147	175	76	131	152
	high	132	33	160	144	101	150	123

[A]age of cultivation in 1997: new and new-new = 4 yrs, medium = 14 yrs, old = 40 yrs

[B]30, 60, 120 kgN/ha in 1997; 0, 70, 140 kgN/ha in 1998 and 1999/2000

[C]0-90 cm [D]0-120 cm [E]0-150 cm

These results mean that one of the initial assumptions of the trial – that paddocks differed only in age of cultivation – was invalid. Consequently, a “new-new” paddock, more closely matching the soil type of the “old” and “medium” paddocks and having a similar age to the “new” paddock, was added to the trial in 1999. Pre-sowing soil tests to 120 cm depth showed no nutrient deficiencies or toxicities. However, in 1999/00, sorghum in the “new-new” paddock was out-yielded by the “old” paddock when the latter was fertilised with 140 kg N/ha (Table 1). Despite the 0N “new-new” and the 140N “old” paddocks having similar nitrate-N (Table 2) and plant available water (Table 3) at sowing, their distribution through the profile differed between treatments, with both nitrate-N and water concentrated nearer to the surface in the “old” paddock. Also, as sorghum roots can explore depths greater than 150 cm, unmeasured soil differences below 120 cm (soil tests) or 150 cm (nitrate-N, available water) may have influenced yields.

CONCLUSIONS

On the main soil type(s) under investigation, the principal impact of several decades of continuous low-input cultivation proved to be a decrease in N-supplying capacity. Therefore, the detrimental effects of ‘cultivation age’ could be ameliorated through N fertiliser application. Paddock age on its own was not a reliable indicator of potential productivity.

The participatory aspect of this trial benefited the farmers involved in interpreting the results and helping to decide consequent courses of action. The issue of the “new” and “old” paddocks having different soil types has especially highlighted the value of going beyond the surface in assessing the productive potential of a paddock. The farmers involved in this project now realise the significance that subsoil characteristics, such as clay content and soil depth, can have on soil water holding capacity.

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REFERENCE

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