Establishment of kale by direct drilling and cultivation, and their effects on soil during grazing

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Abstract

Seedbed preparation and choice of sowing method have implications for forage brassica yield. Also, soil conditions at the time of grazing may contribute to reduced utilisation efficiency and therefore the total amount of forage utilised. A split plot trial at Methven with kale (cv. 'Gruner') tested the effects of main plot sowing method (direct drilled, cultivated with seed drilled, or cultivated with seed broadcast) and subplot fertiliser (DAP) placement (no fertiliser, fertiliser (350 kg ha^{-1} DAP) drilled and fertiliser (350 kg ha^{-1} DAP) broadcast) on early growth, final growth and utilisation by dairy animals. Effects of cultivation practice and grazing were measured by soil penetrometer resistance before and after grazing by dairy animals. Responses to P placement occurred early in crop growth. However, at 70 days after emergence there were no differences in crop growth. Where plant populations were compromised the plants were larger. There were significant difference ($P<0.001$) in plant populations for differing sowing methods. At the time of final harvest, significant effects ($P<0.05$) of cultivation and seed placement on productivity only occurred if fertiliser was applied. There was no difference in yield between cultivated and direct drilled treatments. However, in the direct drilled treatments there was mean of 0.5 t ha^{-1} less residue remaining after grazing, but these differences were not apparent when calculated as percentage of crop utilised. There were measureable differences in soil penetrometer resistance in cultivated and direct drilled blocks in both the pre- and post-grazing measurements.

Additional keywords: fertiliser, forage utilsation, seed bed, soil structure, winter feed

Introduction

Inadequate seedbed preparation and poor sowing techniques are often the reason for sub-optimal brassica yield (de Ruiter *et al.*, 2009). Once a good crop has been established it is important that winter grazing management minimises the losses from trampling to achieve high utilisation (Judson and Edwards, 2008). The method of establishment, e.g. direct drilling as opposed to full cultivation, may produce benefits not only by helping to achieve optimum populations (Leach *et al.*, 1999) but by helping to prevent excessive pugging during winter grazing and possibly better utilisation of standing feed (McDowell *et al.*, 2005; Judson and Edwards, 2008).

Traditional practice involving cultivation will usually give good results for establishment (de Ruiter *et al.*, 2009) without the pressure of weed competition (Isaac *et al*., 2000; Singh *et al*., 2001) and insect damage (Furlong *et al*., 2008). However, there has been some evidence for improved early growth particularly if P fertiliser is placed close to the seed and preferably placed below the seed (Chakwizira *et al*., 2010). It has been proposed that the efficiency of P recovery may be higher for fertiliser P drilled with the seed (Wilson *et al*., 2006; Chakwizira, 2008; Chakwizira *et al*., 2010).

Brassica yield also responds strongly to N availability (Fletcher *et al*., 2007; Chakwizira *et al*., 2009) and there are possible interactions between P and N fertiliser application rates (Wiedenhoeft and Barton, 1994; Chakwizira *et al*., 2009) as well as potential effects on quality of brassicas grown with elevated fertiliser applications (Jung *et al*., 1986; Turk *et al*., 2009) and differing sowing and defoliation regimes (Brown *et al*., 2007).

The objective was to compare contrasting establishment methods (direct drilling and cultivation-conventional drilling) and fertiliser placement effects (fertiliser drilled with the seed or broadcast) on plant establishment and growth of a November sown kale (*Brassica oleracea* L.) crop on a dryland Canterbury foothills site with low soil P status. An additional objective was to determine whether direct drilled or cultivated treatments influenced the utilisation of kale by dairy animals. Dry matter yield was the primary determinant of crop response to sowing method and fertiliser.

Materials and Methods

The trial area was located on a farm (43°36'S; 171°35'E), 5km north west of Methven on a Gorge deep silt loam with available water capacity of 200mm. The site was not irrigated but was usually adequate precipitation occurs in summer and autumn for unrestricted growth of feed crops for wintering dairy stock. Old pasture was sprayed out with herbicide (4.0 l ha^{-1} Roundup™ and Pulse Penetrant) two weeks before sowing. Lorsban® (a.i. 500 g l^{-1} chlorpyrifos) insecticide was applied at 300ml per 200 l ha^{-1} water to control springtails. Excess herbage was taken for silage and the residual grazed with sheep. Plots designated for cultivated treatments were ploughed and rolled on 20 November 2007 then cultivated with a maxitill cultivator. The direct drilled treatments remained undisturbed until sowing.

The trial was a split plot design comprising three main plot sowing treatments (S1 - direct drilled plots with seed sown at 1.0-1.2 cm depth; S2 - cultivated seedbed with seed sown at 1.0-1.2 cm depth and S3 - cultivated seedbed with seed broadcast on the soil surface). Main plots were 9.3 m x 30 m and replicated four times with all plots sown at 4 kg ha^{-1}. All plots were sown with SuperStrike® treated 'Gruner' kale using a 'Cross Slot' drill on 28 November 2007. Drilled treatments were sown with a standard drill configuration and broadcast treatments for seed and fertiliser achieved by removing the delivery tubes from the coulter housing.

Basal fertiliser comprising 60 kg ha^{-1} CalMag (Mg:Ca; 50:2), 15 kg ha^{-1} Boronate (10% B) and 70 kg ha^{-1} KCl (K:Cl; 1:1) K:Cl) was applied to all plots. Subplots comprised three fertiliser treatments including a no-fertiliser control (F1) and two delivery methods with DAP (N:P:K:S; 18:20:0:1) applied at the same rate in both cases (350 kg ha^{-1}, P = 70 kg ha^{-1}; N = 63 kg ha^{-1}). Fertiliser was applied either in the slot below the seed (F2) or broadcast on the soil surface (F3). Slugout (a.i. 18 g kg^{-1} metaldehyde) bait was applied at 10 kg ha^{-1} to all plots during direct drilling operation. Plots were 3.1 m wide x 30 m long. Calculations for production costs, breakeven yield and margins for respective treatments were based on actual costs incurred.

All plots were sprayed with Diazinon 800EC (a.i. 800 g l^{-1} diazinon and 100 g l^{-1} xylene) @ 1 l ha^{-1} on 1 December 2007 and the direct drilled area was sprayed for weeds using Gallant® (a.i. 100 g l^{-1} haloxyfop and 347 g l^{-1} diethylene glycol) at 1 l ha^{-1} and Versatill® (a.i. 300 g l^{-1} clopyralid) at 500 ml ha^{-1} on 27 December. The cultivated treatment was not sprayed with herbicide. Nitrogen fertiliser (100 kg N ha^{-1}) was applied on 23 January 2008 to all plots except the controls.

Plot yield was determined on two harvest dates (19 January and 26 May) by weighing 3 m^2 fresh weight from each plot and sub-sampling for %DM and drying at 90°C for 2 days. Plant populations were determined by stem counts within the quadrat samples.

The plot area was grazed over a 4-day period beginning on 16 June with an effective 7.3 m break. The face length of 151 m was grazed by 179 cows for a calculated allowance of 8.0 kg DM cow^{-1} day^{-1} assuming full utilisation of crop remaining after adjusting for crop removed for yield sampling. Average post-sampling yield across the trial was 13.0 t ha^{-1} (calculated over all plots not just the ones selected for pre- and post-grazing measurement). Pre-grazing yield was determined on 3.0 m^2 quadrats taken from the centre of each plot.

Utilisation of crop DM was determined on one day (17 June) by cutting two 3 m^2 quadrats to ground level pre- and post-grazing. Utilisation was measured for the cultivated and direct drilled plots that were not fertilised or fertilised with DAP (drilled treatment). No measurements were taken on plots with broadcast fertiliser. For post-grazing measurements, the quadrat was raked over and all remaining kale extracted and washed before %DM determination by drying at 90°C for 2 days.

Herbage quality was determined from the pre-grazing quadrat cuts. Three medium sized plants were selected, dried at 65°C for 2 days, ground and analysed for forage composition by near infrared spectroscopy (Lincoln University Analytical Laboratory).

Soil penetrometer measurements were taken before and after grazing from three locations within all plots except the broadcast seed and broadcast fertiliser treatments. Post-grazing measurements were taken from breaks exposed to 1 and 4 days of treading. Penetration resistance measurements were made at successive 2.5 cm depths down to 40 cm using a Field Scout™ SC 900 Soil Compaction meter (Spectrum Technologies Inc.).

Data for establishment, biomass and utilisation was analysed using balanced analysis of variance in Genstat v12 (VSN International Ltd).

Results and Discussion

Crop establishment

Soil (0-15 cm) taken in early November gave the following MAF Quick Test result: pH 6.0, Olsen P 10, Ca 9, Mg 8, K 4, Na 5, S (SO_4) 7 and anaerobic mineral N 190 kg ha^{-1}. Emergence counts on 23 January and 12 February (Figure 1) showed better establishment in the drilled treatments than by broadcasting the seed. Lower populations were established in broadcast treatments compared to direct drilled or cultivated-drilled. Up to 40 plant per m^2

were established in direct drilled and cultivated seed beds but were lowered to 30 per m^2 in the cultivated-broadcast seed treatment. This was further reduced by 10 plants per m^2 if no fertiliser was applied or fertiliser was broadcast. Differences in plant numbers that resulted from the differing sowing methods were less apparent at crop maturity.

There appeared to be little difference in plant establishment when direct drilled or sown in a cultivated seedbed. Early visual observations indicated better emergence in the direct drilled plots primarily because of better soil moisture conditions. There was no rainfall in the 3-week period after sowing and top soil in the cultivated plots was drier than in the direct drilled plots. When seed was broadcast there were higher plant numbers if fertiliser was placed below the seed than if fertiliser was broadcast (including soil incorporation with the drilling process). The reason for this was unknown although fertiliser placed at depth could assist with root development and therefore aid survival of the germinating seedlings in the dry conditions (Chakwizira *et al*., 2010). Also, banding the fertiliser increases the possibility of seedling injury from ammonium (urea or DAP fertiliser) or fluoride (super phosphate fertiliser) burning (Carter, 1967). Improved populations from the fertiliser placement below the seed in the broadcast treatment were apparent at final harvest (Figure 1) although they were lower than achieved with direct drilling or cultivated and drilled seed.

Biomass

The biomass harvest on 12 February (Figure 2) showed fertilised plots in cultivated and direct drilled treatments with similar yields of around 4.5 t ha^{-1}. However, unfertilised plots yielded significantly less (Figure 2). Yield of the broadcast (S3) treatment was lower than the drilled treatments (S1 and S2). Average productivity from emergence to 13 February was 76 kg DM^{-1} ha^{-1} day^{-1} for a maximum plot yield of 4.5 t ha^{-1}.

At final harvest on 26 May, there were no yield responses that could be attributed to seed placement by direct drilling or down the spout treatments. Broadcasting the seed also gave a similar result. Yield was, however, reduced significantly in the control (no fertiliser treatment). The dry soil conditions during germination and establishment had some effect on the plant numbers, but the effect on yield was minimised as there was significant yield compensation whereby larger plants were produced in treatments with lower plant populations.

Soil compaction

Soil compaction measurements just prior to grazing and after 4 days of treading showed marked differences in the 5-20 cm layers (Figure 3). Differences between direct drilled and cultivated treatments were apparent before grazing (Figures 3a and 3b). A plough layer was detected down to 20 cm in the cultivated treatments. Penetrometer resistance measurements were near linear through depth in the direct drilled treatment meaning that there was little stratification in the soil layers with little or no soil disturbance from the sowing operation. The effect of grazing (Figures 3c and 3d) reduced the penetration resistance down to approximately 15 cm depth. This was more apparent in the direct drilled treatment than in the cultivated treatment. It appeared there was little influence of treading on the soil structure below 20 cm. The effects of grazing were limited to measurements on the soil surface layers only. Prior cultivation did change the soil structural properties but the long term effects of cultivation or direct drilling were minimised given the dry conditions during grazing. The soil surface was visibly more structurally intact with residual grass herbage still present on the surface in the direct drilled treatment.

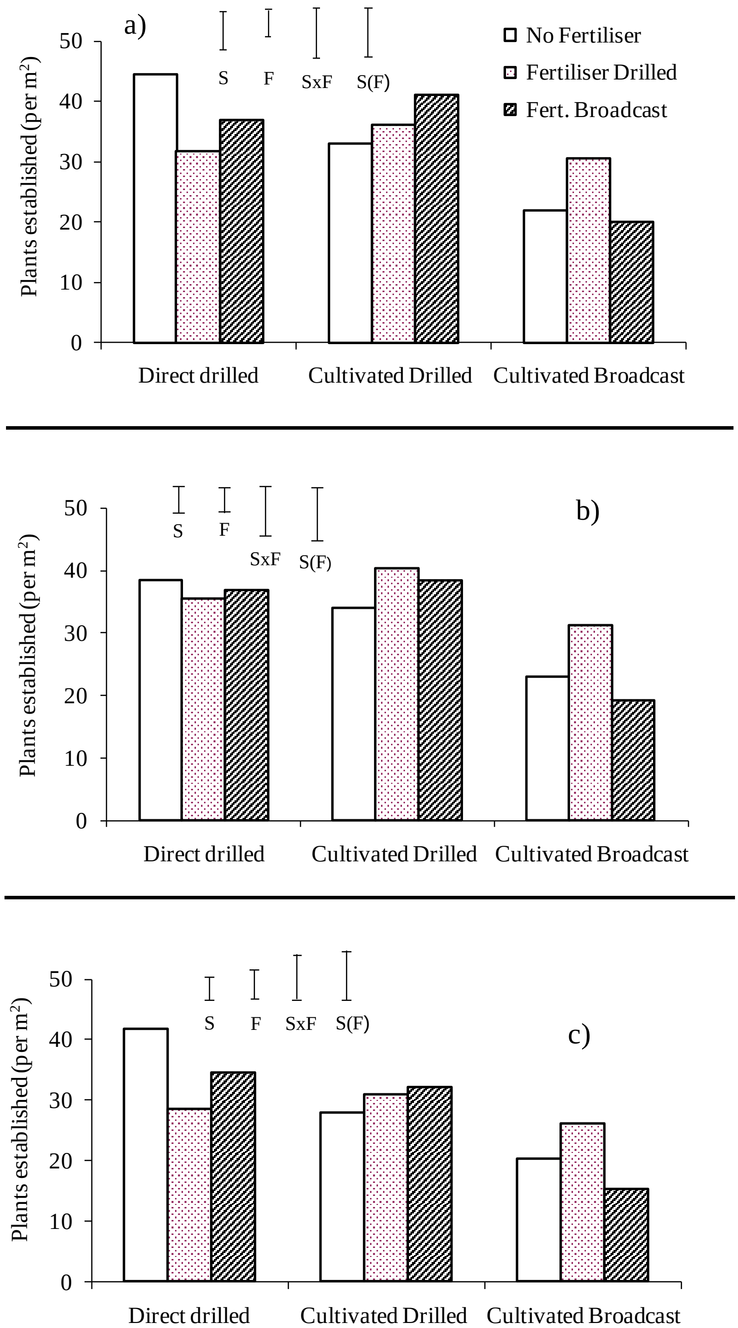

Figure 1: Plant populations measured on 23 January (a), 12 February (b) and final harvest on 26 May 2008 (c). Vertical bars are LSD (at the 5% significance level) for sowing treatment (S), fertiliser (F), sowing x fertiliser interaction (SxF) and fertiliser treatments within sowing treatments (S(F)).

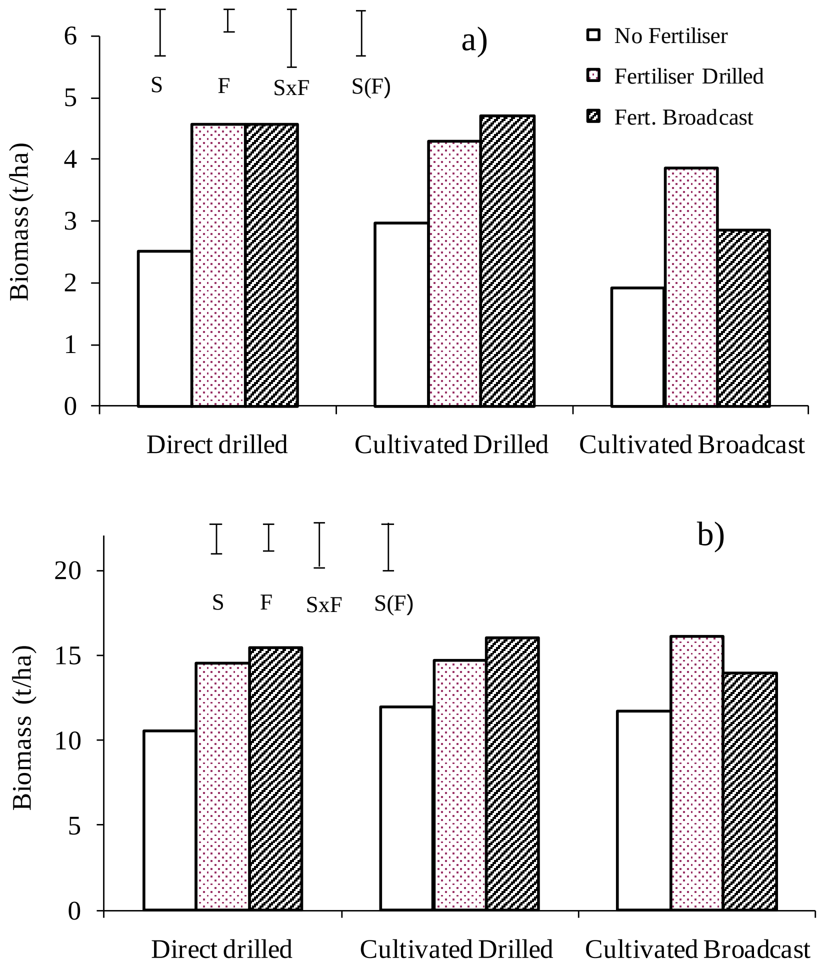

Figure 2: Crop yield measured on 12 February 2008 (a) and at final harvest on 26 May 2008 (b). Vertical bars are LSD (at the 5% significance level) for sowing treatment (S), fertiliser (F), sowing x fertiliser interaction (SxF) and fertiliser treatments within sowing treatments (S(F)).

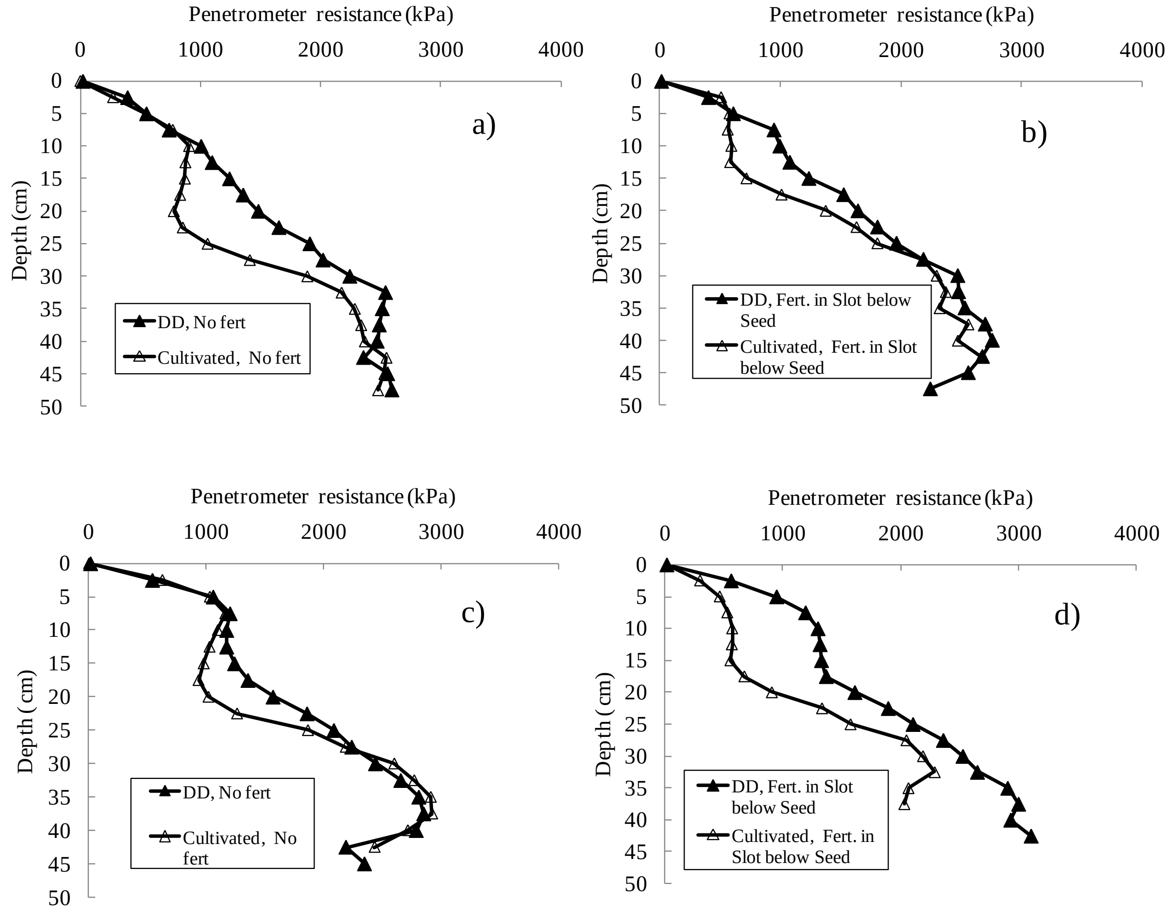

Figure 3: Soil penetration resistance profiles measured before grazing (a and b) and after 4 days exposure to treading (c and d).

Utilisation and quality

DM remaining after grazing ranged from 1.6 to 2.2 t DM ha^{-1} and was greater (P<0.05) in cultivated than in direct drilled plots (Table 1). The difference in residual herbage was possibly a result of less trampling losses on the more compact soil surface in the direct drilled treatment. Differences in pre-grazing crop biomass resulting from fertiliser treatment (unfertilised versus DAP fertiliser) had no effect on the residual DM after grazing (Table 1). A mean of 1.85 t ha^{-1} biomass was not utilised. DM utilisation ((pre DM - post DM)/pre DM x 100) ranged from 82 to 89% but was not affected by cultivation or fertiliser treatment (Table 1).

Metabolisable energy content of the kale was unaffected by fertiliser or sowing treatments (average = 12.8 MJ ME kg DM^{-1}). However, there were treatment differences (P<0.01) in the N% of kale plants. Cultivated crop (1.9%) had greater N% than in direct drilled plots (1.7 % N) and DAP fertilised (2.0%) plots had significantly higher N% (P<0.01) than unfertilised (1.5%) plots. It is probable that the higher N% in cultivated plots and indeed the higher productivity in the absence of fertiliser was due to higher N mineralisation rates resulting from soil disturbance.

Table 1: Pre- and post-grazing crop yield and DM utilisation measured on 17 June 2008 in cultivated and direct drilled plots sown with and without DAP.

Sowing treatment		Fertiliser treatment	Pre-grazing yield (t DM ha^{-1})	Post-grazing yield (t DM ha^{-1})	% DM utilisation
S1	Direct drilled	F1 (Control)	10.6	1.6	84.4
		F2 (Fert. drilled)	14.9	1.7	89.0
S2	Cultivated	F1 (Control)	12.4	2.1	82.4
		F2 (Fert. drilled)	14.4	2.2	84.7
LSD $_{(0.05)}$					
Fertiliser			3.12	0.16	2.17
Cultivation			4.45	0.15	1.94
Fert. x Cult.			3.80	0.18	2.91

Costs

Production costs, using prices at the time of the experiment for the direct drilled and cultivated-drilled treatments, are given in Table 2. The treatments were managed intensively to minimise any fertiliser or crop health constraints on yield. The cost of growing kale crops can exceed $1,300 per ha although the actual costs per kg DM do not account for the cost of land or time required to return the land to pasture. The costs for grazing were also not included.

A demonstration of the value of stimulating early growth by increasing the amount of N fertiliser is given in Table 3. Control plots with no additional N applied over the amount recommended at sowing gave a kale yield of 5 t ha^{-1} by 13 February at a cost of 13.7 c kg^{-1} DM. With the accumulation of additional yield and few additional costs occurring after February the cost of the feed declined sharply.

A break even yield (given cost at the time) for a Canterbury crop sown with varying establishment methods was between 3.9 and 6.1 t ha^{-1} with less than $1,300 per ha costs (Table 3). The cost of producing the crops was less than 9.0 c kg^{-1}. Surprisingly, the low yielding treatments (no fertiliser) had the lowest break even yield and the lowest production cost. However, the yields were considerably lower and therefore the margins were lower (Table 3). Generally, the treatments that increased yield resulted in lower production cost (c kg^{-1}) and increased margins ($ per ha).

Table 2: Comparative costs[1] of production for direct drilled and cultivation treatments assuming a high rate of DAP fertiliser application.

Activity	Rate per ha	Direct drilled	Cultivated
Tractor and implement hours	4 hr		$320.00
Contract sowing (per ha)	$150	$150.00	$50.00
Seed	4 kg	$108.00	$108.00
Fertiliser			
Muriate of potash	70 kg	$34.65	$34.65
Urea	100 kg	$61.50	$61.50
CalMag	60 kg	$36.90	$36.90
DAP	350 kg	$291.55	$291.55
Boron	15 kg	$19.80	$19.80
Spreading	2x	$50.00	$50.00
Weed and Pest			
Roundup	4 l	$71.20	$71.20
Gallant	1 l	$108.00	
Diazinon	1 l	$21.00	$21.00
Slugout	10 kg	$79.00	
Versatill	0.5 l	$35.90	
Pulse	0.2 l	$6.72	$6.72
Application	$40 per application	$120.00	$80.00
	Total	$1,194	$1,151

[1]Does not include harvesting or feed out costs.

Table 3: Costs, break even yield and margin.

Sowing treatment		Fertiliser Treatment	Total Production Costs ($ ha^{-1})	Production Cost (c kg^{-1})	Breakeven yield[1] (t ha^{-1})	Margin[1] ($ ha^{-1})
S1	Direct drilled	F1 (Control)	816	7.7	4.1	1299
		F2 (Fert. drilled)	1194	8.7	6.0	1634
		F3 (Fert. broadcast)	1194	8.3	6.0	1806
S2	Cultivated (drilled seed)	F1 (Control)	773	6.5	3.7	1621
		F2 (Fert. drilled)	1151	8.3	5.8	1715
		F3 (Fert. broadcast)	1121	7.4	5.6	2011
S3	Broadcast	F1 (Control)	743	6.4	3.7	1591
		F2 (Fert. drilled)	1223	7.6	6.1	2001
		F3 (Fert. broadcast)	1193	8.6	5.9	1591

[1]Assuming $0.20 per kg.

Conclusions

Significant responses to N and P fertiliser placement only occurred early in crop growth. After about 70 days after emergence the crops with poorer establishment had caught up. Differences in plant numbers resulting from the differing sowing methods were also less apparent at crop maturity as natural crop thinning occurred. Higher populations were achieved in the cultivated and broadcast treatments if fertiliser was supplied down the spout.

At the time of final harvest, significant effects on yield resulting from seed bed preparation or seed placement treatments depended on whether fertiliser was or was not applied at sowing.

DM utilisation from pre- and post-grazing measurements was high (mean 85%). Despite differences in biomass among treatments there was no detectable difference in utilisation of the crop between fertiliser and cultivation treatments. However, direct drilling did reduce the amount of post-grazing residual.

Direct drilling gave a more stable soil structure (higher penetrometer observations) at the time of grazing. The differences in soil structure induced by grazing pressure were, however, not considered significant because of the comparatively dry soil condition during grazing.

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