Can nitrogen fertiliser applied before sowing increase brassica yields in a dry environment?

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Abstract

Two experiments compared the effects of five rates (0, 100, 200, 300, and 400 kg urea/ha) of urea (46% N) applied to existing pasture on subsequent establishment and final yields of two direct drilled brassica crops (turnips and kale, and swedes) on different soils in East Otago. Dry conditions in both early spring and again in late summer (estimated soil moisture deficit of 110 to 135 mm throughout) were reflected in low average yields (4300 and 1400 kg DM/ha in March and 6700 and 5400 kg DM/ha in July at Palmerston and Stoneburn respectively). Adding urea to pasture in early spring before a double spraying regime for swedes sown in November boosted yield by 17 kg DM/kg N applied. The turnip and kale crop showed a small response to added N in March but no response by July. This research suggests that knowledge of the available soil nitrogen levels will assist in decision making concerning rates of fertiliser use.

Keywords: brassica, fertiliser, kale, nitrogen, swede, turnip

Introduction

While side dressings of up to 100 kg N/ha are often recommended for brassica crops in mid summer, it is often too dry in the East and North Otago environment for the soil to take up the applied N. This reduces the farmers' opportunities to maximise crop yields. However, urine patch effects have been observed for up to 12 months in crops grown after dairy cow wintering in this environment suggesting that winter applied N may still remain in the system and be available for crop growth.

Applying nitrogen fertiliser 1-2 months before drilling the crop may ensure a better establishment without damaging the seed. Broadcasting urea onto the soil before the pasture is sprayed off is the cheapest way to add nitrogen. Potential losses of added N may occur mainly through volatilisation (gaseous loss: Black *et al.* 1985) or leaching (drainage: Chalmers & Darby 1992). Factors that influence volatilisation include the soil moisture status, rainfall (pre and post N application), temperature, N application rate and localised soil pH changes near the urea pellet (Genermont & Cellier 1997). Leaching losses occur when soil moisture exceeds field capacity. These conditions seldom occur in the dryland East and North Otago environment (D. Houlbrooke pers. comm.). Applying N as urea in the early spring in East and North Otago should minimise volatilisation losses whilst remaining a relatively low leaching risk. This would allow some of the N to be captured in the plant material and then become available as the plant decays.

These experiments compared the effects of different rates of N as urea on the establishment and final yields of brassica crops (turnips, kale and swedes) when applied in early spring, before spraying out pasture and direct drilling in late spring. Increasing rates of N were used to determine a response curve to identify how much fertiliser N could be used before the crops stopped responding.

Materials and Methods

Two experiments compared the effects of N on establishment and final yields of two brassica crops (turnips and kale, and swedes) on different soils. A randomised split plot design used five rates of urea as main plots (0, 100, 200, 300, and 400 kg urea/ha; 46% N) and three rates of DAP (0, 80 or 160 kg DAP /ha; 18% N, 20% P) as sub plots in three replicates of plots of 9 m x 100 m. The DAP results are not reported here.

The trials in the Shag valley in East Otago were done at Palmerston on the valley floor (Waitohi deep silt loam: Fragic Perch-gley Pallic) soil (Hewitt 1998); 12 m a.s.l.; 45.4° S, 170.7° E; mean annual rainfall 600-650 mm) and at Stoneburn on a north facing slope (Wehenga: Acidic Firm Brown) soil (Hewitt 1998); 350 m a.s.l.; 45.4° S, 170.5° E; mean annual rainfall 650-700 mm). Data for rainfall and potential soil water deficit were derived from the National Institute for Water and Atmosphere meteorological sites at Palmerston and Stoneburn.

In trial 1 at the Palmerston site the paddock was used as part of the normal winter grass feeding rotation, and had ewes and lambs set stocked for lambing for the first 2 weeks of September. Urea was surface applied on 21 September 2006, 1 week before the first spraying. In early October, 250 kg/ha borated (12 kg B/ha) serpentine superphosphate (6.8% P; 8.6% S, 5.5% Mg, 15.0% Ca) was surface applied. A crop of turnips (0.5 kg/ha) and kale (2 kg/ha) was direct drilled with 180 kg/ha CropMaster brassica fertiliser (14.4% N, 16.0% P, 10% K, 0.8% S) in mid November after a double spraying regime using Roundup Transorb (540 g a.i./L glyphosate) in both late September (3 L/ha) and early November (1.5 L/ha) plus Versatill (0.4 L/ha, ametryn 225 g a.i./L; 2,4 D 130 g a.i./L).

In trial 2 at the Stoneburn site, the paddock was used as a feed pad during the winter with no grazing from late August. Urea was spread directly onto the soil surface on 21 August 2006. Borated (12 kg B/ha) superphosphate was surface applied at 350 kg/ha in late November. A crop of Dominion swedes was direct drilled in early December with 80 kg/ha CropMaster 20 (19.4% N, 10% P, 12.5% S) after a double spraying regime of Roundup Renew (6 L/ha, glyphosate 360 g a.i./L) and Kamba (0.5 L/ha, MCPA 340 g a.i./L; dicamba 80 g a.i./L) on 30 September and Roundup Renew (3 L/ha) on 4 December. The insecticide Lorsban (0.35 L/ha, chlorpyrifos 500 g a.i./L) was also applied in December.

Soil fertility, including Olsen P, sulphate S, quick test K, pH and total and potentially available N (N incubation test) was measured before applying the treatments and again before sowing by taking 10 cores per plot to 15 cm depth at the Palmerston site and to an average of 10 cm at the Stoneburn site due to the shallow depth of the soil over the rock base. At both sites, forage yield was measured from two 5 m row lengths in each DAP sub plot. Only above ground (not including turnip or swede bulbs) forage was recorded on 1 and 5 March 2007. Plant counts were made and herbage samples taken for dry matter (DM) and total N analysis (by NIRS). Final forage yields measured on 3 and 4 July 2007 were separated into the leaf and bulb or stem components for the sown species at each site with samples of each taken for DM content and total nitrogen analysis.

Data were analysed by ANOVA using polynomial contrasts in GenStat 10.2 (GenStat 2007) and compared using least significant difference for the mean response of the DAP applications.

Results

Total rainfall was 390 and 484 mm at the Palmerston and Stoneburn sites respectively, while soil water deficits of between 100 and 135 mm were estimated throughout most of the experimental period at both sites (Fig. 1). The rainfall at both sites was 100 to 150 mm lower than the long term average, while the soil water deficit was greater than the potential soil water holding capacity, indicating long periods of drought with soil moisture below the plant wilting point.

Soil fertility results are presented in Table 1. While potentially available soil N increased on average by 46-48 kg/ha between August and November, this was not related to the amount of urea applied as the increase also occurred in the control plots at both sites.

The turnip/kale crop at Palmerston was significantly affected by early spring urea application when harvested in March (Table 2). Dry matter percent decreased as the amount of urea increased, while DM yield increased. The concentration of N in the harvested forage increased

Figure 1 Cumulative rainfall and actual soil water deficit for the experimental period at the Palmerston and Stoneburn sites.

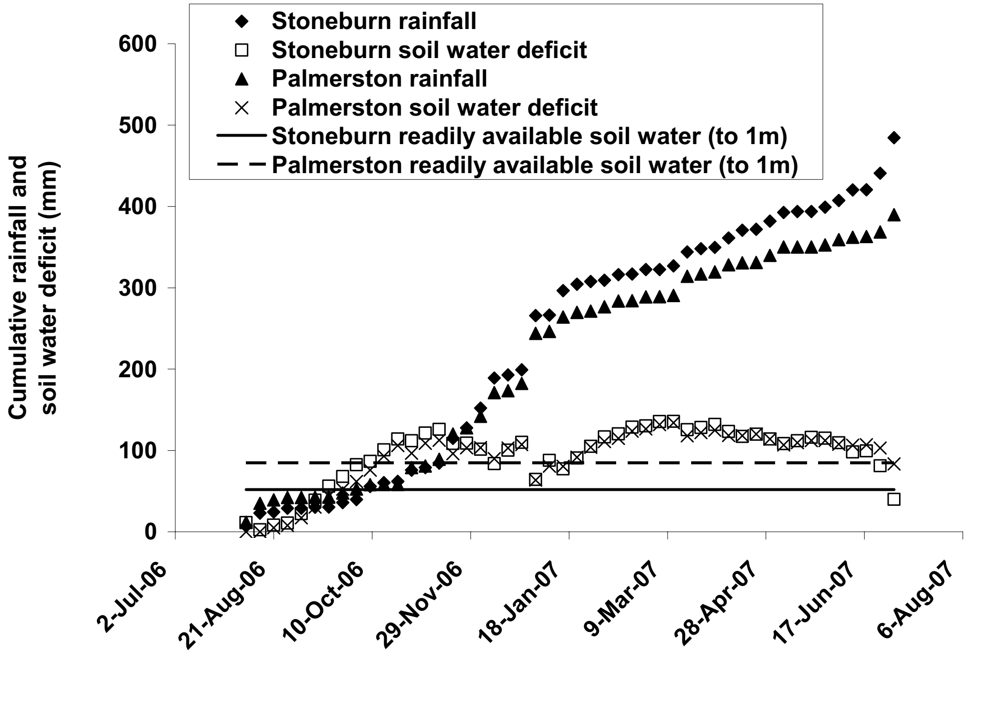


Table 1 Soil fertility measurements.

	Palmerston	Stoneburn
pH	6.1	5.8
Olsen P (mg/kg)	17	9
Quick test K	3	10
Sulphate S (ppm)	9	8
Organic carbon (%)	3.5	4.7
Total nitrogen (%)	0.34	0.40
C:N ratio	10.2	11.7
Potentially available N, August (kg/ha)	156	122
Potentially available N, November (kg/ha)	202	170

Table 2 Effects of pre-sowing urea applications on brassica crop measurements in March 2007, 3 months after sowing.

	Pre-sowing urea application rate (kg/ha)					LSD
	0	100	200	300	400	(P=0.05)
Palmerston (Turnip/kale)						
Dry Matter (%)	17.7	16.7	17.6	16.9	15.8	1.31
Yield (kg DM/ha)	3920	4340	4270	4860	5060	828
Crop N (% of DM)	2.25	2.37	2.35	3.12	3.30	0.37
N in Crop (kg/ha)	91	108	105	153	167	29
Plant Number (/m^2)	60.1	52.5	57.6	49.8	49.1	6.5
Stoneburn (Swede)						
Dry Matter (%)	18.9	19.2	18.1	17.7	18.0	1.9
Yield (kg DM/ha)	870	940	1190	1500	1690	555
Crop N (% of DM)	3.13	3.25	3.50	3.73	3.63	0.408
N in Crop (kg/ha)	28	31	42	55	61	21.2
Plant Number (/m^2)	9.2	9.4	9.1	10.5	11.7	3.56

as did the amount of N harvested. Plant number declined with increasing rates of urea.

Dry matter percent of the swede crop at Stoneburn in March (Table 2) was unaffected by increasing urea application but DM yield increased when increasing amounts of urea were applied. The concentration of N in the forage increased significantly as the amount of urea applied increased, as did the amount of N in the crop. Plant numbers were not significantly affected by urea application.

Dry matter concentration of all parts of the crop decreased with the increased amounts of urea at the Palmerston site in early July (Table 3). Dry matter yield of turnip leaf increased significantly with urea addition, but no other significant changes in DM yield were measured. The relative contribution of the kale was 23-25% of total yield.

The crop N concentration (adjusted for the ratios of various crop components) increased linearly as the amount of N added as urea increased (Table 3). The increase in the amount of N in the crop was not significant, but the utilisation of estimated available N (available soil N measured in August + all fertiliser N) by the crop declined significantly as the amount of urea increased (Table 3).

At the Stoneburn site in July 2007, DM percent of both leaf and bulb were unaffected by increasing urea application (Table 4). The DM yield of swede leaf and swede bulb both significantly increased at the two higher application rates of urea (Table 4). Yields at application rates of 100 and 200 kg urea/ha before sowing were similar to the control (Table 4).

The crop N concentration (adjusted for the proportions of the crop) increased linearly with the increase in urea application rate (Table 4). The amount of N in the crop also increased linearly with increasing urea application. The utilisation of estimated available N (available soil N measured in August + all fertiliser N) by the crop was not significantly affected by the rate of urea application.

Discussion

Conditions during the trial were dry (Fig. 1), with annual rainfall being approximately two thirds of the long term average and therefore leaching losses were likely to be low. When data for each urea input were entered into

Table 3 Effects of pre-sowing urea applications on brassica crop measurements in July 2007, when the crop was utilised, 7 months after sowing (Palmerston site).

	Pre-sowing urea application rate (kg/ha)					LSD
	0	100	200	300	400	(P=0.05)
Dry Matter (%)						
Kale Leaf	18.4	18.6	17.3	16.9	17.0	0.47
Kale Stem	22.7	21.8	21.7	20.0	19.3	1.19
Turnip Leaf	14.3	14.1	13.5	13.1	13.1	1.10
Turnip Bulb	10.4	10.2	10.3	9.6	8.9	0.78
Yield (kg DM/ha)						
Kale Leaf	592	695	783	751	702	212
Kale Stem	905	1003	1101	956	882	284
Turnip Leaf	808	814	1004	1139	1267	396
Turnip Bulb	4325	3935	4579	3691	3783	1313
Total Dry Matter yield	6630	6447	7467	6537	6634	1539
Nitrogen status						
Crop N (% of DM)	1.67	1.74	1.65	2.09	2.08	0.33
Crop N (kg N/ha)	118	114	127	137	136	32.5
Nitrogen utilisation (kg crop N/kg available[1] N)	0.72	0.54	0.49	0.45	0.39	0.23
Nitrogen utilisation (kg crop N/kg soil available[2] N)	0.57	0.58	0.52	0.76	0.74	

[1] Available N = available soil N measured in August + all fertiliser N
[2] Soil available N = soil incubation N measured in November

Table 4 Effects of pre-sowing urea applications on brassica crop measurements in July 2007, when the crop was utilised, 7 months after sowing (Stoneburn site).

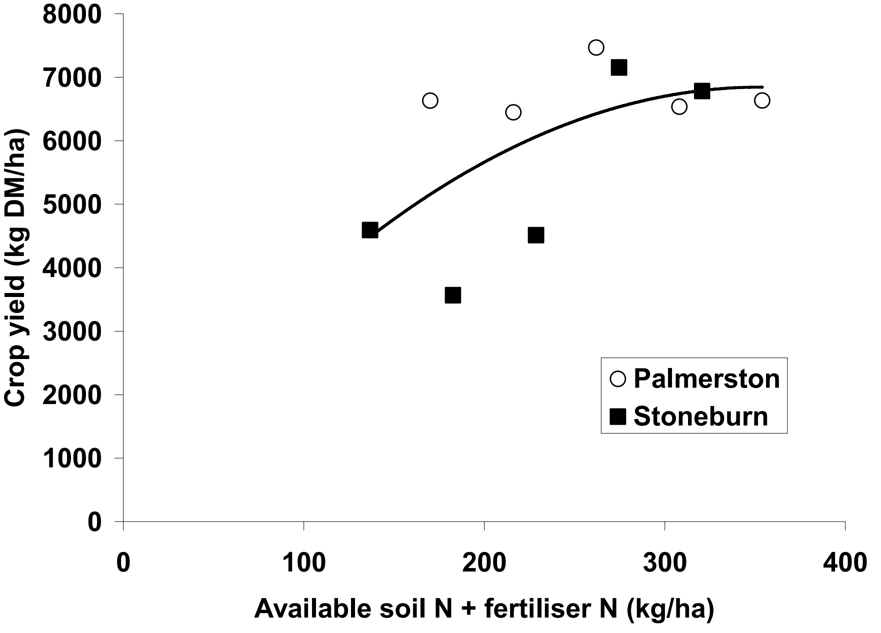
	Pre-sowing urea application rate (kg/ha)					LSD
	0	100	200	300	400	(P=0.05)
Dry Matter (%)						
Swede leaf	18.0	18.5	18.7	18.0	18.4	0.99
Swede bulb	13.7	14.3	14.0	13.6	13.4	0.99
Yield (kg DM/ha)						
Swede leaf	518	387	517	911	833	267
Swede bulb	4074	3178	3996	6244	5951	1958
Total	4592	3566	4513	7155	6783	2160
Nitrogen status						
Crop N (% of DM)	1.98	2.10	2.04	2.34	2.61	0.40
Crop N (kg N/ha)	94	78	93	168	169	57.4
Nitrogen utilisation (kg crop N/kg available[1] N)	0.68	0.42	0.40	0.61	0.53	0.25
Nitrogen utilisation (kg crop N/kg soil available[2] N)	0.52	0.59	0.52	1.03	0.89	

[1] Available N = available soil N measured in August + all fertiliser N
[2] Soil available N = soil incubation N measured in November

Overseer® nutrient budgets, no leaching and runoff losses were predicted at either site. Therefore the nitrogen applied was unlikely to be leached.

Losses to volatilisation are more likely when urea is surface applied in this dry environment. The extent of volatilisation is determined by the soil moisture status, rainfall around the time of application, temperature, application rate and pH changes of the soil near the urea pellet (Genermont & Cellier 1997). Estimates of volatilisation losses when 30 to 50 kg N/ha have been applied as urea to pasture in August and September were between 5 and 11% (Black *et al.* 1984; Theobald & Ball

Figure 2 A relationship between available N (available soil N tested in August plus fertiliser N) and crop yield.



1984; Black *et al.* 1985), though when 200 kg N/ha was applied losses increased to 16% in spring (Theobald & Ball 1984). Rainfall was recorded on day 2 and day 4 after fertiliser application at the Palmerston site (3.4 and 4.5 mm respectively), while 4.5 mm of rainfall was recorded on the day of application at the Stoneburn site. This had the potential to decrease volatilisation losses by 30-35% (Stevens *et al.* 1989). Conditions during application were favourable as temperatures were low (4.6 to 10.5°C at Stoneburn and Palmerston respectively), soils were near field capacity (Fig. 1), conditions were relatively calm (2 and 2.8 m/s at 9 am at Stoneburn and Palmerston respectively) and rainfall occurred within 2 days of application. Under these conditions, losses of 5-15% may be expected.

The average yields recorded here are similar to those recorded in dryland conditions with summer turnips and rape (6-6.6 t/ha) (MacMillan & Brown 1973) and winter turnips (5.9 t/ha) and swedes (5.5 t/ha) (Stephen 1973; Cossens 1982). The response to N fertiliser in the turnip and kale crop at the Palmerston site was 6.1 kg DM/kg N applied as urea at the March harvest. However, no response was found in July. At the Stoneburn site the swede crop initially responded similarly (4.8 kg DM/kg N) in March, but had a greater response of 17.3 kg DM/kg N applied as urea by July. This was tempered by a strong establishment of weed grasses, mainly Yorkshire Fog, at the 100 and 200 kg urea treatments that lowered swede production, but would have added to total dry matter yield.

The difference between the two crops may be due to the early maturing nature of the turnips. The mean dry matter production in March was 4500 kg DM/ha for the turnips compared to 1200 kg DM/ha for the swede crop. A significant loss of leaf was noted at the Palmerston site by July, relating to the early maturation of the turnip crop. Increasing available N beyond approximately 200 kg/ha by adding fertiliser N to turnips has been found to increase leaf growth at the expense of root growth (Greenwood *et al.* 1980). When farmers want to grow a turnip crop for winter then adding significant amounts of fertiliser N before sowing would appear to reduce the effective mid-winter root yields as demonstrated in Table 3.

Large variations in the response to N applied as fertiliser have been noted in both turnip (Greenwood *et al.* 1980; Cossens 1982) and swede crops (Gately & McBride 1972; Stephen & Kelson 1975; Greenwood *et al.* 1980). The amounts of available N required by both turnips and swedes have been characterised by growing them in depleted soils and adding fertiliser N at rates of up to 700 kg N/ha (Greenwood *et al.* 1980). These authors concluded that yield, and particularly root yield, was maximised for turnips when between 200 and 300 kg N/ha was available whereas swedes had a maximum yield at 97 kg fertiliser N, based on the assumption from control plots that the soil supplied 56 kg N/ha (Greenwood *et al.* 1980). Our study on these soil types with the inclusion of potentially available soil N measured in August suggests that the less responsive turnips may have a lower N requirement than the swedes (Fig. 2).

The nitrogen requirements of kale crops have been modelled to predict how much extra nitrogen fertiliser may be needed, based on the potentially available soil N (Wilson *et al.* 2006). Key findings were that kale had a high requirement for N, was relatively inefficient at taking N up from the soil, but was more effective at taking up N that was applied into the soil rather than broadcast. This apparent inefficiency of N uptake by brassicas has been indicated as a key cause for relatively slow early growth of these crops and for their lack of response to late applications of N (Greenwood *et al.* 1989). These authors suggested that all of the N should be applied at or before sowing to meet the need of the developing leaf. During storage root development in autumn the requirement for N is less and the rate of N requirement may well be met by mineralisation of soil N. Poor utilisation of nitrogen in the early stages of crop growth may also explain the low yields of the swede crop when 100 and 200 kg urea was applied, as the re-establishing grasses may have utilised the available nitrogen more efficiently, resulting in a poor crop response to applied N.

Conclusions and Recommendations

Research findings suggest that an available soil nitrogen sample should be taken before deciding on how much nitrogen fertiliser to use. Furthermore adding urea to pasture in early spring before a double spraying regime for brassica crops to be sown in December can help boost the crop yields to a level similar to that achieved with N fertiliser applied later in the season. Brassica crop yields in the dry East Otago environment provided peak yields at between 200 and 300 kg of total available N, including available soil N and fertiliser nitrogen.

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