Effect of fertiliser rate and type on the yield and nitrogen balance of a Pukekohe potato crop

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Abstract

The possibility of reducing the financial and environmental costs of fertiliser application to potatoes (*Solanum tuberosum* L.) by reducing the rate of application of nitrogen (N) fertiliser, and by using slow release or foliar fertilisers to make the fertiliser N more slowly available to the crop but without impacting on yield, was investigated. An experiment at Pukekohe in the winter of 2000 examined the effect of rate and form of N fertiliser on the growth, yield and N balance of a potato crop. The fertilisers used were ammonium sulphate nitrate (ASN) at 242, 350 and 472 kg N/ha, ASN coated with the N-release inhibitor dimethylpyrazole phosphate (DMPP) at 242 and 350 kg N/ha, and the foliar fertiliser Supa N 32 (four applications of 4 kg N/ha as Supa N 32 over 336 kg N/ha applied as ASN). There was no significant increase ($P<0.05$) in tuber yield with N applications over 242 kg/ha, and form of N had no significant effect ($P<0.05$) on tuber yield. Petiole nitrate levels in fertilised treatments were generally over 20,000 mg/kg, excessive according to USA guidelines, so N was not limiting yield. N leaching losses were 82 kg/ha without any N fertiliser application. Leaching under ASN was 167 to 208 kg N/ha. Increasing the ASN rate over 242 kg N/ha resulted in an accumulation of over 200 kg mineral N/ha as nitrate in the soil profile when the crop was harvested. Coating with an N inhibitor reduced leaching by around 30%, but also led to an accumulation of over 250 kg mineral N/ha as ammonium in the soil profile when the crop was harvested. Applying some fertiliser as a foliar spray had no significant effect on leaching or mineral N accumulation. A green manure oat crop, planted after the potato crop was harvested in October, was sampled for yield and N content in January 2001. The oat crop took up 52 kg N/ha in the control plots, and 87 to 133 kg N/ha from the N fertiliser plots, with significantly more being taken up by the ex DMPP plots at equivalent fertiliser rates. This entire N was mulched back into the soil as organic N.

Additional key words: *nitrogen inhibitor, foliar fertiliser, slow release fertiliser, leaching, oats, green manure, petiole nitrate.*

Introduction

Current fertiliser practice for winter grown potatoes in New Zealand is to apply up to 500 kg fertiliser nitrogen (N), on the basis that any deficiency reduces yield. However, research results both in New Zealand (e.g., Martin, 1995b) and overseas (Rourke, 1985) indicate that much of this fertiliser is not taken up by the crop, and could well leach into groundwater either during the growth of the crop or after the crop is harvested. Overseas research has shown that leachable fertiliser levels are higher under potatoes than many other crops (Sylvester-Bradley and Chambers, 1992), and a New Zealand study predicted that winter-grown potato crops in the Pukekohe area are likely to have the greatest impact on groundwater nitrate of any vegetable crop (Crush *et al.*, 1997). Vegetable production has already been identified as a major contributor to the high concentration of nitrate measured in groundwater in the Pukekohe area (Selvarajah, 1999). Regional councils are becoming increasingly concerned about groundwater quality and may place restrictions on applications of fertiliser at levels they consider excessive. Research and farmer trials overseas indicate that applying foliar fertilisers and coating conventional fertilisers with release inhibitors have increased potato yields and tuber size by up to 25% compared to current practice (e.g., Anonymous, 1998). This indicates that there may be opportunities for New Zealand potato growers to use slow release or foliar fertilisers to both increase yields and reduce potential for groundwater pollution.

The objective of this research was to investigate the possibility of reducing the financial and environmental costs of fertiliser application to winter grown potatoes by more closely matching the supply of fertiliser N with crop demand for N by using:

- Reduced rates of conventional fertiliser compared to farmers' practice;
- Conventional fertiliser coated with a release inhibitor to make the fertiliser N more slowly available to the crop; or
- Foliar applications of a liquid fertiliser to ensure rapid uptake of N by the crop.

A trial was undertaken to compare these approaches on a winter potato crop at Pukekohe, planted in May 2000.

Materials and Methods

The trial was carried out on a southwest facing site (5° slope) on Pukekohe Hill. The soil type was a mixture of Patamahoe and Whatitiri clay loams, which are deep granular soils derived from volcanic ash. The site had a long history of intensive vegetable production, and in recent years had been double cropped with winter potatoes and summer green feed crops that were mulched back into the soil. Soil fertility information at planting for the 0-15 cm depth indicated low to very low levels of carbon (2% organic C) and N (19 kg mineralisable N/ha), but high to very high levels of P, K, and Mg (quick test values of 159, 30 and 25 respectively), and a pH of 5.7. These analyses are typical of Patamahoe and Whatitiri soils used for long-term intensive vegetable production.

The trial had seven fertiliser treatments, detailed in Table 1. They included a zero-N fertiliser control and the standard grower practice of 300 kg N/ha applied at planting, followed by 172 kg N/ha when the plants had emerged (subsequently referred to as F472). The F350 and F242 treatments had a lower total N application rate, with the timing of the post-emergence applications altered to more closely match crop demand. N-fertiliser in the F472, F350 and F242 treatments was applied as ammonium sulphate nitrate (ASN: 26% N, 14% S).

Treatments I350 and I242 were the same as F350 and F242, but the ASN was treated with the N-inhibitor dimethylpyrazole phosphate (DMPP). DMPP is an ammonium stabiliser and so holds the fertiliser N in the ammonium form for longer before allowing it to convert to nitrate. This inhibitor is manufactured by the Compo Division of BASF in Germany and is marketed under the trade name Entec. There was 1% DMPP in the treated ASN.

Table 1. Rate (kg N/ha) and timing of N fertiliser applications. F = N fertiliser (ASN[1]), I = inibitor (DMPP[2]) coated ASN fertiliser, S = N fertiliser applied as solid (ASN) and foliar (Supa N 32[3]).

	Application date							
Treatment	2 May	14 Jun	19 Jun	9 Jul	10 Jul	31 Jul	3 Aug	20 Aug
Control	0	0	0	0	0	0	0	0
F472	300	172	0	0	0	0	0	0
F350	180	57	0	0	57	0	57	0
F242	150	46	0	0	46	0	0	0
I350	180	57	0	0	57	0	57	0
I242	150	46	0	0	46	0	0	0
S350 -solid	180	52	0	0	52	0	52	0
-liquid	0	0	4	4	0	4	0	4

[1] ammonium sulphate nitrate: 26% N, 14% S
[2] dimethylpyrazole phosphate
[3] 50/50 mixture of urea and ammonium nitrate

The remaining treatment (S350) included four applications of a liquid foliar fertiliser (Supa N32), with the ASN fertiliser application rate reduced to keep the total N application to 350 kg/ha. Supa N32 contains 32% N as a 50/50 mixture of urea and ammonium nitrate. The fertiliser was applied as a 10% solution using a hand held boom.

The fertiliser treatments were replicated four times and arranged in a randomised block design. Each plot was 20 m long and 6 plant rows wide. The rows were 81 cm apart and tubers (cv. Ilam Hardy) were planted 20 cm apart, giving a planned 600 plants/plot. The trial was planted on 2 May and harvested on 16 October.

All plots received a base fertiliser application of 200 kg P/ha, 175 kg K/ha, 67 kg Mg/ha and 60 kg S/ha (applied as a blend of superphosphate, triple superphosphate, potassium chloride and calcined magnesite). All fertiliser applied at planting (base and N fertiliser) was applied by hand to the furrows immediately after planting and before the soil was mechanically moulded. All post-emergence solid fertiliser was broadcast by hand evenly over ridges.

Measurements of crop N uptake were made on 14 June, 10 July, 3 August, 3 September and 16 October. At each sampling time 20 plants from each plot were hand harvested from a 2 m length of two adjacent rows. The plant foliage, roots and tubers were separated, washed, dried, weighed and analysed for N content on a LECO CNS-2000 analyser. At the final harvest the tubers were also graded for their marketability before being weighed.

Ten leaf petioles per plot were collected using the standard technique, outlined by Martin (1995a), on 19 June, 3 July, 17 July, 31 July, 14 August, 27 August and 11 September, and analysed for nitrate N at ARL Laboratories, Napier.

Two soil samples were collected from each plot to a depth of 60 cm immediately before planting and immediately after harvest. The samples were dried, extracted with 2M KCl, and the resulting solution measured for nitrate and ammonium N on an RFA-300 Continuous Flow Analyser.

On 1 May and at harvest the soil in each plot was sampled to a depth of 15 cm by taking 6 cores per plot with a standard soil corer. In addition, the 15-30 cm and 30-60 cm layers were sampled in each plot by digging 2 holes per plot to a 60 cm depth and sampling down the sides of the hole. The samples were dried, extracted with 2M KCl, and the resulting solution measured for nitrate and ammonium N on a RFA-300 Continuous Flow Analyser.

Nitrate leaching losses were determined from nitrate concentrations in the soil solution and from drainage calculations (Francis *et al.*, 1992). Soil solutions were obtained from ceramic solution samplers installed at 60 cm depth. Four samplers were installed in each plot immediately after planting. Care was taken to install the samplers halfway down the ridges. Solution samples were taken after each significant rainfall event (>20 mm), and were analysed for nitrate N on an RFA-300 Continuous Flow Analyser. The amount of drainage was calculated from a water balance based on measured initial soil moisture, daily rainfall and evapotranspiration (Francis *et al.*, 1992). These meteorological data were obtained from the NIWA climate database (Station C74283 2006 Pukekohe EDR). Visual estimates of the proportion of the soil surface covered by the crop leaves were used to account for differences in evapotranspiration between the treatments using the method of Francis *et al.* (1992).

The trial area was subsequently planted with an oat green manure crop. A line of black oats was drilled at 100 kg/ha in 15 cm rows in late November, and was mulched in the first week of February. No fertiliser was applied to the crop. Immediately prior to mulching, the plots were scored for height and density. For yield estimates, two or three 0.3 m^2 samples were cut to ground level in five randomly selected plots and oven-dried. The dry weights were calibrated against the visual height and density scores to calculate the dry matter yields in the other plots. For N contents, 20-30 tillers taken at random from each plot were couriered to Lincoln, then dried at 60°C, ground and analysed for N using a LECO CNS-2000 analyser.

Results

Weather and drainage

The rainfall (598 mm) at Pukekohe Research Station (5 km from the trial site) in the winter of 2000 was close to the long term average of 616 mm, although June, July and August were around 12 mm wetter than average, and May and September around 25 mm drier.

Mean temperatures were over 1°C higher than average from May to July, but around 0.9°C cooler in August and September. There were a number of significant rainfall events, and the calculated cumulative drainage was around 400 mm more than used by the crop for growth (Fig. 1).

Tuber yield

About 85% of the crop had emerged by the end of May, and tubers were initiated during late June/early July. All tops had completely died down by the final harvest on 16 October. Applying N fertiliser increased yield over the control, but rates and form of N fertiliser higher than 242 kg N/ha had no effect significant effect on yield. The control treatment yielded significantly less than the N treatments due to the combined effect of a smaller total weight of tubers and a smaller proportion of marketable tubers (those over 40 g or not grossly deformed) (Table 2). However, tubers in this treatment had higher dry matter content than treatments receiving N fertiliser, except treatment I242. There was no difference among N treatments in yield, marketable yield or dry matter content of tubers.

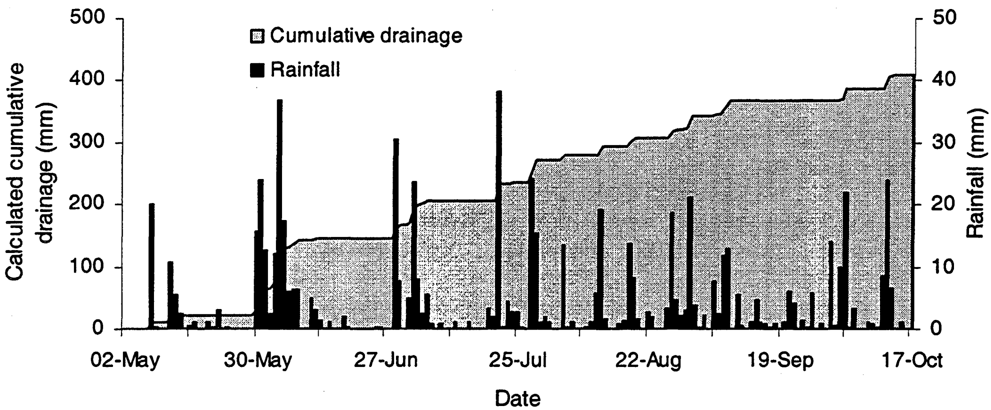

Figure 1. Rainfall events (Pukekohe Research Station) and cumulative drainage calculated using the method of Francis *et al.* (1992).

Table 2. Mean final harvest tuber yields and dry matter (16 October harvest) and mean maximum total crop N uptake (4 September harvest).

Treatment	Tuber yield (t/ha)	% market[1] tubers	Market yield (t/ha)	Non-market yield (t/ha)	Tuber DM (%)	Crop N uptake (kg/ha)
Control	12.73	56.30	7.24	5.49	19.44	37.5
F472	29.95	83.20	24.98	4.98	17.98	129.6
F350	29.69	80.40	23.91	5.79	18.02	124.1
F242	28.49	83.80	24.15	4.35	17.98	123.4
I350	25.81	81.30	21.00	4.82	18.15	107.1
I242	28.33	81.40	23.04	5.29	18.63	101.3
S350	27.75	81.90	22.75	5.00	18.32	117.0
LSD $_{(P<0.05)}$ (df=18)	4.756	9.99	5.29	1.96	0.92	17.9

[1] tubers over 40 g and not grossly deformed

Petiole N levels

Compared to the guidelines for petiole analysis published in the USA (Kleinkopf *et al.*, 1984), only the control treatment from July onwards had N values that were considered inadequate to deficient (Fig. 2). All the other treatments had levels that the guidelines classify as excessive, although the I242 treatment was approaching optimum guideline levels by September. The inhibited release fertiliser produced plants with significantly lower petiole nitrate levels than those receiving equivalent rates of ASN throughout the trial.

Crop N uptake

Maximum N uptake in the fertiliser treatments occurred at the 4 September sampling. At the 242 and 350 kg N/ha rates, the contrast between ASN (124 kg N/ha) and DMPP (104 kg N/ha) was significant ($P<0.05$), but there was no significant difference among ASN and foliar applications. The control treatment had a considerably lower N uptake throughout, reaching 35 kg N/ha at the 4 September sampling.

Soil N at planting and harvest

At planting there was 51 kg/ha of mineral N in the soil (Table 3), about one-third of which was in the top 30 cm and two-thirds in the 30-60 cm layer. Over 90% of this mineral N was present as nitrate.

At harvest there were large differences in soil N between treatments. Total N levels in the 0-60 cm zone in the control treatment at harvest were half those at planting. In all other treatments, 0 – 60 cm soil N levels were increased, from 2.5 times to over 8 times the level at planting. Increasing ASN application increased 0 – 60 cm soil N at harvest, although the difference between the 350 and 472 kg N/ha rates were not significant ($P<0.05$). At the 242 And 350 kg N/ha rates, DMPP treatments had significantly higher total N than ASN treatments, but the foliar N application was not significantly different to the F350 treatment.

In the ASN and ASN plus foliar treatments the increase in soil N from planting to harvest was mainly in nitrate N (85% of the total). The nitrate accumulated at all depths with very large amounts accumulating in the 30-60 cm layer under the F472 and F350 treatments. In contrast, ammonium was the dominant form of N in the inhibited treatments (79%) and accumulated mainly in the 0-15 cm depth. Note that under these treatments some nitrate accumulated further down the profile although the amounts were less than under the uninhibited fertiliser treatments.

Applying some N as foliar fertiliser had no effect on soil ammonium or nitrate levels as the soil mineral N content in the S350 split treatment was similar to the F350 treatment.

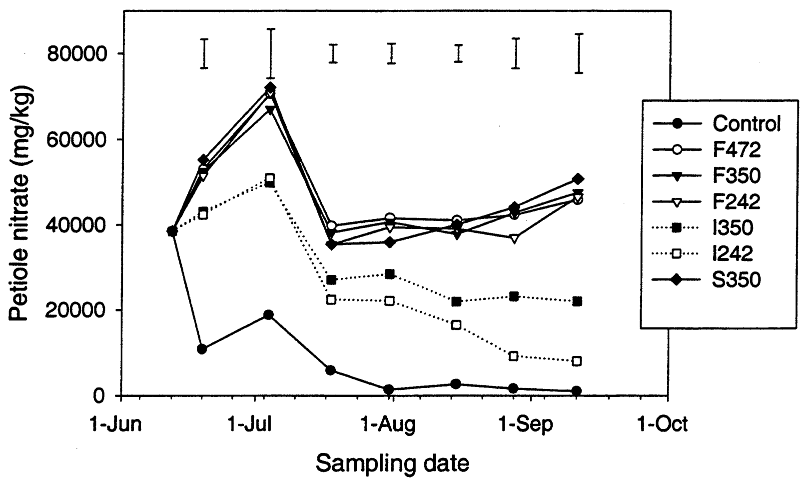

Figure 2. Mean petiole nitrate levels in the seven fertiliser treatments. Treatment details are in Table 1. Vertical bars are LSD 5% (df=18) obtained from ANOVA for each date separately.

Table 3. Mean soil ammonium, nitrate and total N (kg/ha) at planting (averaged across treatments) and at harvest for three sampling depths.

	0-15 cm		15-30cm		30-60 cm		0-60 cm		
Treatment	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	Total
At planting	0.7	3.9	1.2	12.4	1.4	30.8	3.3	47.1	50.5
At harvest									
Control	3.7	7.5	0.1	5.3	0.2	9.5	4.0	22.3	26.0
F472	36.3	75.7	0.6	47.1	0.0	129.0	37.0	251.8	289.0
F350	28.1	71.4	0.4	51.6	0.0	92.6	28.5	215.6	244.0
F242	27.4	47.3	0.8	19.2	0.1	40.5	28.3	107.0	135.0
I350	323.8	16.7	23.5	43.3	0.1	40.3	352.4	100.3	443.0
I242	262.1	15.4	17.3	30.8	0.9	28.2	280.2	74.4	355.0
S350	35.9	78.7	1.1	43.9	0.0	115.6	37.0	238.2	275.0
$LSD_{(P<0.05)}$ df=18	40.56	23.21	18.24	21.61	0.877	49.27	49.14	75.0	93.5

Soil N leachate

The cumulative amounts of N leached during the winter are shown in Figure 3. Leaching losses began within a month of planting with quite large losses occurring during the heavy rain periods that occurred in early June and again in early July (Fig. 1). Approximately half of the total amount of N leached was lost during the first two months of the trial.

The amount of N leached from the control plots (no N fertiliser) was 82 kg N/ha (Fig. 3). Application of fertiliser N more than doubled the amount of N leached with 208-219 kg N/ha leached from the F350 and F472 treatments. At the final sampling on 3 October, leaching losses from the inhibited treatments were 131 kg N/ha, 63 kg N/ha lower (significant at P<0.05) than from equivalent uninhibited rates. The same paired

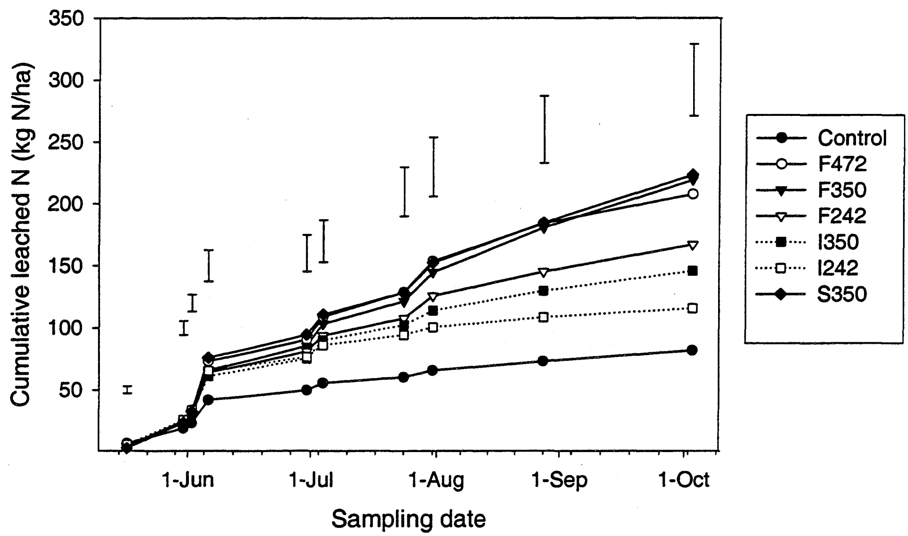

Figure 3. Mean cumulative leachate N levels under the seven fertiliser treatments. Treatment details are in Table 1. Vertical bars are LSD 5% (df = 18) obtained from ANOVA for each date separately.

contrast at the late August sampling was also significant ($P<0.05$) showing that the DMPP N inhibitor can reduce nitrate leaching. There was no significant difference between ASN and ASN plus foliar treatments in the amount of N leached over the winter, indicating that applying some of the N as a foliar spray did not reduce leaching.

Oat yield and N uptake (excluding roots)

Depending on the previous fertiliser treatment, the greenfeed oats produced 3030-4550 kg above ground dry matter/ha during the 10 weeks they were grown (Table 4). Significant quantities of root material would have also been produced, but these were not measured in this study. Oat yields may have been affected by a severe outbreak of rust on the crop. Despite this there were differences in oat yield, N content and N uptake among the treatments. These differences reflected the mineral N content of the soil when the potatoes were harvested. Oat yield and N concentration were significantly lower in the control than in other treatments, and were significantly lower in the F242 treatment than the other fertilised treatments.

Table 4. Mean oat dry matter yield, % N in dry matter and N yield.

Treatment	Yield (DM (kg/ha))	% N in DM	N yield (kg/ha)
Control	3030	1.71	52
F472	4380	2.88	126
F350	4360	2.66	116
F242	3800	2.28	87
I350	4600	2.89	133
I242	4350	2.50	109
S350	4550	2.63	120
LSD $_{(P<0.05)}$ df=18	510	0.208	16.7

N balance

Table 5 summarises the amounts of N leached from the potato crop and recovered by the potatoes, and the change in soil mineral N between planting and harvest of the potatoes. Their sum shows that more N was measured in the leachate, soil and plants than was applied in the fertiliser.

No attempt was made to measure mineralisation of soil organic N during this trial. The N balance for the control treatment suggests that at least 92 kg N/ha was mineralised, indicating that mineralisation is a significant process in these soils.

Discussion

The winter grown potato crop in this trial yielded approximately 30 t tubers/ha. This is a relatively low yield compared with crops sown later in the winter or in spring. Consequently the crop only took up a maximum of 130 kg N/ha. This was less than the lowest rate of N fertiliser applied to the crop and considerably less than the approximately 250 kg N/ha found in another potato crop at Pukekohe (Williams *et al.*, 2000) and the approximately 300 kg N/ha in crops at Lincoln (Martin, 1995b; Martin *et al.*, 2001). However, petiole N levels were very high, and %N in the tops and tubers was higher than at trials at Lincoln (Martin, unpublished data), suggesting that the low yields were not due to poor N uptake. This crop was

Table 5. N fertiliser applied, N fertiliser lost to leaching and to the plant, difference between initial and final soil test N, and amount of extra N in the soil at the final potato harvest not accounted for (all in kg/ha).

Fertiliser treatment	N fertiliser applied (a)	N leached (b)	Maximum plant N uptake (c)	Measured change in soil mineral N (d)	Extra N in soil at final harvest (b+c+d-a)
Control	0	82	38	-25	95
F472	472	208	130	238	104
F350	350	219	124	193	186
F242	242	167	123	84	132
I350	350	146	107	392	295
I242	242	116	101	304	279
S350	350	224	117	224	215

planted and harvested earlier than the crop of Williams *et al.* (2000), and lower soil and air temperatures were probably the major constraint to growth.

This raises the question: "how much N fertiliser should be applied to May sown potato crops?" The results from this trial show that the current practice of applying more N fertiliser than to later sown crops to compensate for lower soil temperatures is inefficient. In fact, as crop yield was lower, less fertiliser was needed rather than more. The crop took up 100 kg N/ha or less, and so the additional N remained in the soil where it is subject to leaching. Furthermore, mineralisation of soil organic N appears to make some contribution to the N supply, further reducing the reliance on N fertiliser. The yield from the control plots clearly showed that the potato crop required some N fertiliser but there was no yield advantage in applying more than 242 kg N/ha. Even this rate appears to be too high, as there were still significant quantities of mineral N remaining in the soil at harvest, and leaching losses were double the amount leached from the control. In this trial (and others, e.g., Williams *et al.*, 2000) we have yet to establish the minimum rate of N required by winter grown potato crops in the Pukekohe region.

The inhibited fertiliser treatment showed potential for potatoes in Pukekohe, with less N leached during the growth of the potato crop. Less N was also taken up by the crop, but this did not affect yield. The very large amount of soil mineral N remaining at harvest suggests that the N application rates were too high. This residual N may be taken up by a subsequent crop as ammonium N or, more likely, once nitrification is complete, as nitrate, which is more readily taken up by plants or leached. Significantly more N was taken up by the subsequent oat crop from the plots that had received inhibited fertiliser (Table 4), but this was small in relation to the amount of N left in the soil after the potatoes (Table 5). So there was a considerable amount of mineral N left for the following winter crop or for leaching into the groundwater.

The ideal slow release fertiliser formulation would make the N available over the four months of the crop. Formulations designed to vary the rate of release of fertiliser N are available overseas (Dan Drost, pers. comm.). It would be useful to test such formulations in the Pukekohe environment to identify those best suited to the range of crops and leaching conditions there.

However, relying on a slow release fertiliser to be effective in a situation where N rates are much higher than required by the crop is risky. A more sensible approach would be to appeal to farmers to reduce N applications to their crops, possibly in combination with applying N at different times (Williams *et al.*, 2000). Data from this trial and others show the importance of minimising nitrate leaching during the first two months after planting and before the crop is established. Further work is required to evaluate slow release fertiliser at lower rates than used in this trial. An economic evaluation of the cost:benefit ratio of these products is also required.

The inhibitor used in this trial inhibits the conversion of ammonium to nitrate. This would include ammonium produced by mineralisation of soil organic N. This indicates that mineralisation may have resulted in the release of around 280-300 kg N/ha, the amount of N unaccounted for in Table 5). In the other treatments this ammonium may have been converted to nitrate and lost through denitrification, another process not measured in this experiment but thought to occur at high rates in soils where very high N fertiliser rates are used, e.g. in vegetable production systems (Ryden and Lund, 1980). It appears that only part of this mineralised N became available in time for the growing crop, as only 92 kg/ha was accounted for in the control treatment.

The foliar fertiliser had an effect on the crop similar to the split applications of solid fertiliser. Given that only low N rates can be applied as a foliar spray without burning the leaves, the benefit from such fertilisers is only likely to occur when the crop is becoming deficient in N. In this trial, the treatment that included the foliar fertiliser yielded no better than treatments receiving 100 kg less N/ha. As with slow release fertilisers, foliar fertilisers are unlikely to improve crop performance when the crop already contains very high levels of N. Any future work with foliar fertilisers should be carried out under more marginal N supply conditions.

Residual nitrate N left in the soil at harvest can be leached out of the soil if it is left fallow. A better option is to grow a cover crop like greenfeed oats, which is a good N scavenger (Francis and Williams, 1997). In this study the oat cover crop recovered 87-133 kg N/ha from the soil in the fertiliser treatments – a significant amount of N that may have otherwise been lost. It also provided up to 4500 kg above ground DM/ha and an unmeasured amount of below ground DM, providing a valuable contribution of organic matter to the soil. The entire N taken up by the oat crop was mulched into the soil. This N has the potential to become available to the subsequent crop, but its actual availability and the pattern of availability are unknown.

This trial has raised some questions about the suitability of current soil N tests on soils derived from volcanic ash. The current oat crop was mulched in, and so the 133 kg N/ha was returned to the soil. As the previous cropping history was of high N application rates to winter potatoes followed by mulched in green manure crops, presumably with roughly similar N levels, then why were the N levels so low at the start of the experiment? Conversely why were soil N levels at harvest much higher than expected from the other components of the soil N balance? Very low initial soil N levels have been found in other trials at Pukekohe (C Tregurtha, pers. comm.), suggesting that the soil tests currently used do not accurately reflect the soil N available to the plant or at risk of leaching.

Conclusions

The rates of N fertiliser currently applied by the farmer at this site in this season could have been more than halved without affecting crop yield. Rates and forms of fertiliser, which differed from the minimum application rate of 242 kg N/ha, had no effect on yield or crop N uptake.

N uptake and crop yields were low in this trial, but petiole and plant N analyses indicated high levels of N in the plant, so N was not limiting yield in fertilised treatments.

N leaching losses were high even without any N fertiliser application, but were increased by 250% by the ASN and ASN plus foliar treatments. Inhibited fertiliser treatments reduced leaching by 33% compared to ASN fertiliser.

All N fertiliser applications increased the level of mineral N in the soil at harvest, especially in the inhibited fertiliser treatments. For the control and ASN fertiliser treatments, around 80% of the N were in the nitrate form, whereas after applications of inhibited fertiliser 79% were in the ammonium form.

The subsequent oat crop took up 52 kg N/ha in the control plots, but up to 133 kg N/ha from the N fertiliser plots, with significantly more being taken up by the inhibited plots. This entire N was mulched back into the soil as organic N.

This study raises some questions about the best type of soil test for predicting plant available and leachable N on this soil type.

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