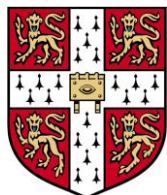


**Evaluation of the soil nitrogen supply system –
Opportunities for further improvements to the
nitrogen economy of the GB potato crop**

**British Potato Council Project Reference
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Using measurements of soil mineral nitrogen to make N fertilizer recommendations for potato crops

General introduction to the programme

In 2000, the seventh edition of *Fertiliser Recommendations for Agricultural and Horticultural Crops (Reference Book 209)* was published. For potatoes, the N recommendations were substantially revised to bring them into line with the results of ongoing research. The new N recommendations used varietal groups (based on determinacy) and length of growing season to make the N recommendations more crop specific.

In earlier editions of *RB209*, a soil's capacity to supply N to crops was estimated using the N Index system, which attempted to quantify the supply of N from residues of the previous crop. Thus, fields in Index 0 (i.e. after cereals) had small N reserves compared with Index 1 soils (i.e. after potatoes) and Index 2 soils (i.e. after long-term leys had been ploughed out). Values for N Index were then combined with soil data to estimate the N fertilizer requirement of the subsequent crop.

In the latest version of *RB209*, the N index system was replaced with the soil nitrogen supply (SNS) Index. This system contains seven Indices (0-6) although these have been amalgamated into three Indices for potato N recommendations. There are two methods to assess a field's SNS Index. The first is the "field assessment method" which is essentially the same as the old N Index system and uses information on previous cropping and soil type. The second method uses measurements of soil mineral nitrogen (SMN) and crop N in the spring. The basis for this was earlier work on cereals and oil seed rape which showed a close relationship between SNS within the crop rooting depth and the amount of N taken up by the crop in the absence of N fertilizer. Thus, for cereals and oil seed rape, the SNS Index was defined as:

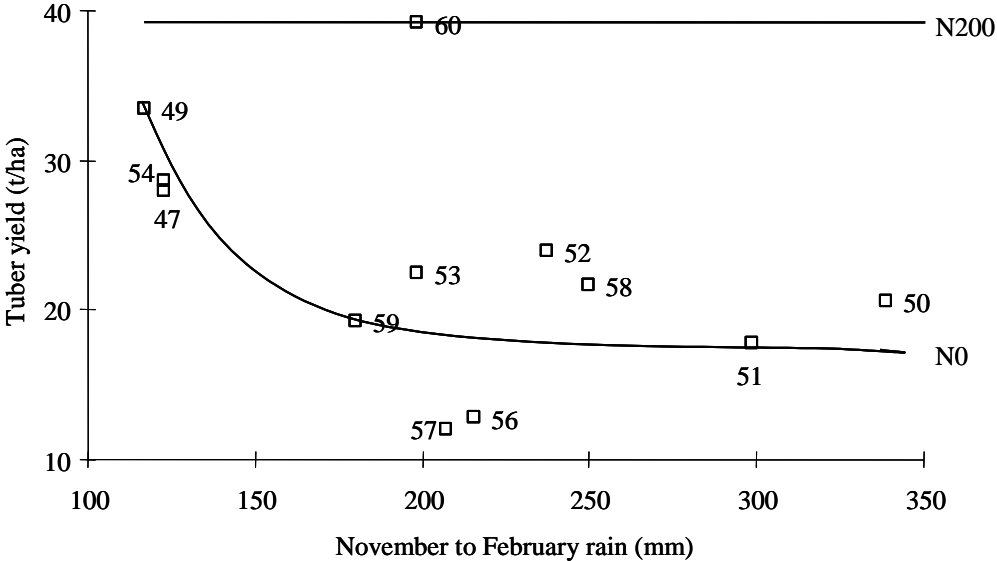
$$\text{SNS Index} = \text{SMN (0-90 cm)} + \text{Crop N} + \text{estimate of N mineralized}$$

Reference Book 209 suggests that on soil with a small organic matter content the estimate of N mineralization may be omitted since the quantity of N involved is negligible. In consequence, a single point measurement of soil and crop N in the spring gives the SNS Index from which the N fertilizer requirement may be calculated.

The SMN analysis method was included in the N recommendations tables for Potatoes even though “there has been little specific research or practical experience on the use of this approach in potatoes”.

In 1914, Russell was probably the first to recognize that soil mineral N affects the fertilizer requirement of arable crops and he noticed that soils contain more nitrate after dry winters than wet winters. Similarly, Van der Paauw (1962) found that after wet winters the response of potatoes to fertilizer N was larger than after dry winters (Figure 1).

Figure 1. Effect of winter rainfall on yields of potato crops given 0 or 200 kg N/ha between 1947-1960. No symbols are shown for the N200 crops, □ N0 crops. Redrawn from Van der Paauw (1962).



These ideas were developed in the Netherlands, where measurements of soil mineral N, made in late winter and early spring, were related to the optimum N application as estimated from N response experiments. The experiments showed that the optimal N application rate decreased as soil mineral N increased and the slope and intercepts of the regressions line were related to soil texture (Figure 2 and Figure 3). From these relationships, the current Dutch N fertilizer recommendations were developed (Table 1). Despite being recommended in the 7th Edition of Reference Book 209, there is little evidence to support use of the SNS measurement system for the UK potato crop. Johnson *et al.* (1992) working with the variety Cara, claimed that the Dutch soil mineral N system made better predictions of the N optima found in response experiments than the more widely used N Index method (MAFF 1988).

Figure 2. Relationship between optimum N application rate and soil mineral N measured in the spring on clay and loam textured soils. Redrawn from Neeteson (1990).

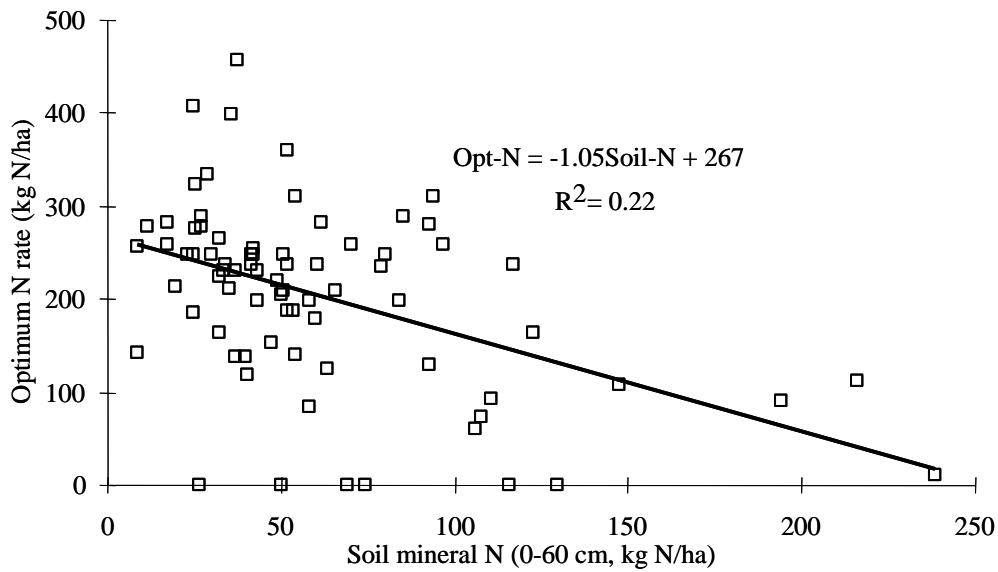


Figure 3. Relationship between optimum N application rate and soil mineral N measured in the spring on sandy textured soils. Redrawn from Neeteson *et al.* (1984, as quoted by Hofman and Salomez 2000).

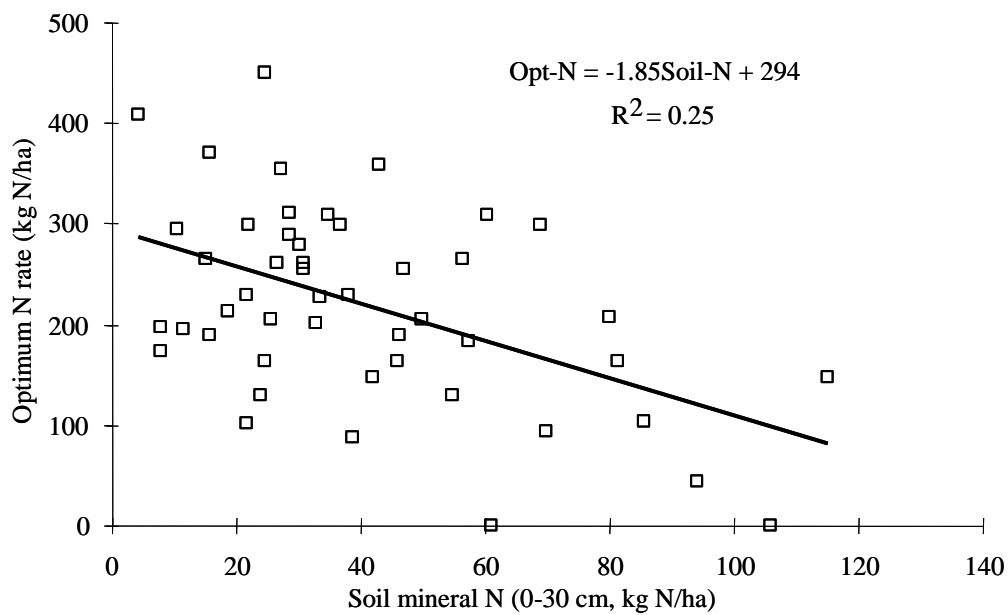
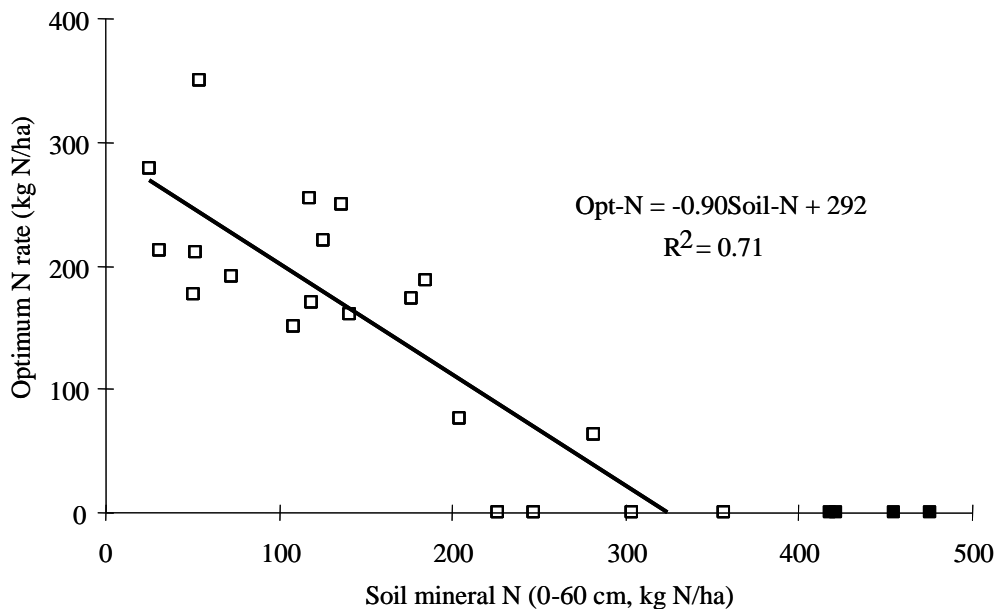


Table 1. Current Dutch N fertilizer recommendations (Anonymous 1998 quoted by Hofman and Salomez 2000)

	N recommendation = $a - b \cdot \text{SMN}$		Sampling depth for SMN (cm)
	a parameter	b parameter	
Ware potatoes			
Clay and loam soils	285	1.1	0-60
Sandy soil	300	1.8	0-30
Starch potatoes	275	1.8	0-30
Seed potatoes	140	0.6	0-60

In addition, Johnson *et al.* (1992) also claimed that measurements of profile-available water content were better predictors of optimum N than either the N index system or the soil mineral N system. However, these conclusions need to be treated with caution since the amounts of variation, explained by the regression equations, were probably not significantly different. Furthermore, in several experiments the estimated optimal N rate for the Cara crops exceeded 250 kg N/ha and, since this variety seldom requires more than c. 120 kg N/ha, this suggests methodological problems in its calculation. Johnson and Chambers (1998) present data from a limited number of experiments that show the optimal N application rate was inversely related to the amount of soil mineral N (0-60 cm) measured in the spring (Figure 4).

Figure 4. Relationship between optimum N application rate and soil mineral N measured in the spring. Redrawn from Johnson and Chambers (1998). Regression line fitted by Cambridge University Farm omitting ■.



A common feature of the published Dutch and UK studies is the large amount of unexplained variation associated with the regression equations which makes predictions derived from these equations unreliable. For example, using the data of Johnson and Chambers where the r^2 was 0.71, a soil mineral N measurement of c. 110 kg N/ha could be associated with optimal N application of between 150 and 250 kg N/ha. Neeteson (1990), stated that N fertilizer recommendations based on measurements of soil mineral N can be used successfully under average conditions, but concludes, “the recommendations, however, are too crude to be applicable to specific situations”. However, since all crop, soil type and season combinations are specific the use of mineral N measurements appear, at present, to be highly suspect.

A possible explanation for the weak relationships found in published studies is the large variation of soil mineral N during the spring. Fowler (1993) demonstrated this variation and its consequences on subsequent fertilizer recommendations for a field at Cambridge University Farm (Table 2).

Table 2. Variation in soil mineral N and predicted optimal N application with sampling time in comparison with measured optimal N applications for Cara and Estima. Adapted from Fowler (1993)

Date	Soil mineral N (kg N/ha)		Predicted N opt using 285-1.1SMN _(0-60cm)
	0-90 cm	0-60 cm	
8 January	39	35	246
28 January	69	65	214
11 February	99	81	196
4 March	169	161	108
23 March	133	125	148
13 April	109	98	177
27 April	116	101	174

Actual optima at final harvest were *c.* 240 kg N/ha for Estima and *c.* 120 kg N/ha for Cara

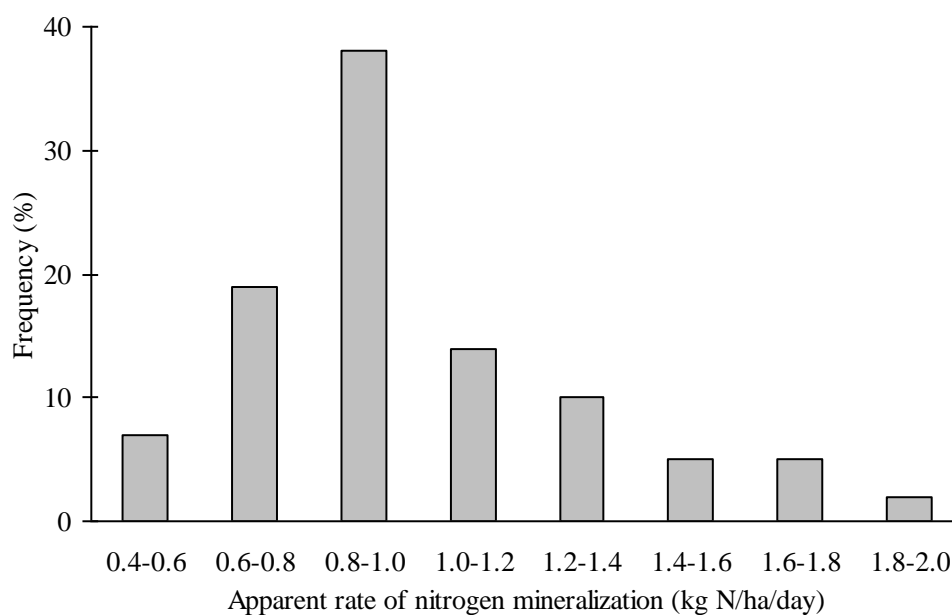
The reasons for the variation in soil mineral N are complex and some of the variation is solely spatial. However, much of the variation is probably caused by a combination of sampling time in relation to the cultivations used to establish the potato crops. It is well known that soil cultivations tend to increase the rate of N mineralization, and a recent review paper by Silgram and Shepherd (1999) has shown that cultivations such as ploughing can increase soil mineral N by upto 65 kg N/ha when compared with zero or reduced tillage systems used to establish cereal crops. However, there are several reasons why the cultivations used to establish potatoes may stimulate more N to be mineralized and why measurements of soil mineral N may be more variable and these are summarised in Table 3.

The SNS measurement system assumes that on soils with low or average organic matter concentration the amount of N mineralized during the growing season “will be small and not practically significant”. For soils with larger organic matter concentrations the 7th Edition of Reference Book 209 gives some standard values of probable N mineralization. Neeteson (1990) estimated the apparent rate of N mineralization in 61 potato response experiments and found that the average rate was *c.* 1 kg/ha/day. However, there was significant variation in the data (Figure 5). Assuming a length of season of 100 days, Neeteson’s data would suggest that between 50 and 190 kg N/ha could be mineralized from the soil organic matter. The size of this variation is large enough to have an agronomically significant affect on optimal N application rates.

Table 3. Factors associated with the establishment of potato crops that may result in increased nitrogen mineralization and increased variability in measurements of soil mineral nitrogen

Factor	Cereals	Potatoes
Use of organic manures	About 15 % of winter cereals receive organic manures.	About 40% of maincrop potatoes receive organic manures.
Number of cultivations	Variable, but typically sequence is plough, shallow seedbed cultivation(s) and plant.	Variable, but typical sequence is plough, power harrow, draw-up ridges/beds, de-stone and plant.
Depth of cultivations	Relatively shallow, typically 20-25 cm.	Relatively deep, typically 35 to 40 cm but upto 50 cm in some circumstances.
Timing of cultivations	Typically occur in 4-8 week period in autumn. Soils will be cooling down after cultivations. Soils often relatively dry.	Depending on soil type, often protracted and could occur over 7 month period from September to March. After spring cultivations, soil will tend to be warming up and relatively moist.
Timing of soil sampling	In early spring, soils are cool and samples taken several months after cultivations.	In early or late spring and soils warming up. Maybe before, during or after cultivation sequence.

Figure 5. Variation in apparent rate of N mineralization in 61 potato experiments. Redrawn from Neeteson (1990).



In summary, there is a weak negative relationship between the optimal N application for potatoes and measurements of soil mineral N made in the spring. However, due to variation, this relationship appears to be of little practical use in making accurate fertilizer N recommendations and therefore, its inclusion in RB209 has to be questioned. In response to these concerns, the British Potato Council funded work at Cambridge University Farm (CUF) to investigate whether the SMN analysis method could be used to improve the accuracy of N use in the potato crop.

The relationship between crop nitrogen requirement and soil nitrogen supply in Norfolk and Lincolnshire

Introduction

The objectives of these four experiments were to establish if significant improvements to current N recommendations could be achieved by incorporating measurements of soil mineral N (SMN) or soil nitrogen supply (i.e. SMN plus crop N) made during the early part of the growing season.

Materials and Methods

Relevant details of the four N response experiments are given in Table 4. The experiments on Johnsons West and Robins Wood were at South Pickenham Estates, Norfolk on land rented by Greens of Soham. The experiments on Field 15 and Field 57 were on land farmed by J E Piccaver and Company (JEPCO), Gedney Drove End, Lincolnshire.

Table 4. Details of the N response experiments at South Pickenham and Gedney Drove End

	Johnsons West	Robins Wood	JEPCO Field 15	JEPCO Field 57
N rates tested (kg N/ha)	0, 80, 160 & 240	0, 80, 160 & 240	0, 60, 120, 180 & 240	0, 60, 120, 180 & 240
Number of blocks	4	4	6	6
Variety	Hermes	Hermes	Desiree	Cara
Seed size (mm)	35-45	35-45	45-50	50-55
Tuber count (No/50 kg)	985	985	610	535
Row/bed width (cm)	183	183	91	91
Plant spacing (cm)	35	36	40	40
Previous Crop	Carrots	Winter wheat	Daffodils	Winter Wheat
Sand (%)	83	86	22	39
Silt (%)	12	10	45	43
Clay (%)	5	4	33	18
Organic matter (%)	2.4	1.9	3.9	3.3
Soil texture	Loamy sand	Loamy sand	Clay loam	Sandy silt loam
Date of Planting	6 March	10 March	25 May	25 May
Date of 50% emergence	18 May	17 May	-	-
1 st soil sampling	17 April	17 April	12 April	12 April
2 nd soil sampling	14 May	14 May	25 May	25 May
3 rd soil sampling	26 September	26 September	26 June*	26 June*
4 th soil sampling	-	-	3 September	11 October
Final harvest	26 September	26 September	3 September	11 October**

* N0 crop sampled to estimate N uptake. **Burnt off 17 September

The experiments at South Pickenham were machine planted whilst those at JEPCO were hand planted. All experiments were hand harvested (2.75 and 2.93 m² at South Pickenham and

JEPCO respectively). The crops at South Pickenham were irrigated, using CUF irrigation scheduling, whereas the JEPCO crops were unirrigated. Crop protection chemicals were applied according to best commercial practice. The crops at South Pickenham were periodically hand weeded to remove thistles.

Results and Discussion

Crop yields

South Pickenham

Both Hermes crops at South Pickenham had similar plant, stem and tuber populations (Table 5 and Table 6). Nitrogen fertilizer had a significant effect on stem population at Johnsons West, but there was no corresponding effect on the number of tubers > 10 mm (Table 6). When the standard errors are taken into account, both crops gave similar average tuber fresh weight (FW) and dry weight (DW) yields.

Table 5. Effect of N application rate on number of plants, stems, tubers and tuber yield of Hermes grown at Robin's Wood, South Pickenham

	Mean	kg N/ha				S.E.
		0	80	160	240	
Number of plants (1000/ha)	46.2	43.7	47.3	44.7	49.2	2.39
Number of stems (1000/ha)	83.1	81.1	81.0	86.5	83.8	4.49
Number of tubers > 10 mm (1000/ha)	426	396	445	423	442	21.0
Tuber FW yield > 10 mm (t/ha)	48.1	34.7	48.9	53.4	55.3	2.28
Tuber DM concentration (%)	24.7	25.5	25.2	23.9	24.2	0.37
Tuber DW yield > 10 mm (t/ha)	11.8	8.8	12.3	12.7	13.4	0.64

Table 6. Effect of N application rate on number of plants, stems, tubers and tuber yield of Hermes grown at Johnson's West, South Pickenham

	Mean	kg N/ha				S.E.
		0	80	160	240	
Number of plants (1000/ha)	47.4	46.5	48.2	50.1	44.7	2.14
Number of stems (1000/ha)	82.2	71.1	92.9	89.2	75.6	5.09
Number of tubers > 10 mm (1000/ha)	392	383	398	439	349	23.2
Tuber FW yield > 10 mm (t/ha)	50.1	37.1	48.0	60.3	55.0	2.26
Tuber DM concentration (%)	23.8	25.0	24.0	22.9	23.4	0.39
Tuber DW yield > 10 mm (t/ha)	11.9	9.3	11.5	13.8	12.9	0.47

The optimum N application rate was defined as the smallest N application above which there was no statistically significant increase in tuber yield. For both crops, the optimum N application was no more than 160 kg N/ha. Tuber dry matter (DM) concentration was significantly decreased by N.

JEPCO

The experimental crop of Desiree performed very poorly. It produced few stems and tubers, had a very small yield and all measurements were associated with large standard errors (Table 7). In consequence, it was not possible to determine an optimum N application rate for this experiment. The poor performance was probably due to a re-ridging operation in the experiment that de-sprouted some tubers and decreased uniformity of spacing. This experiment will not be discussed further and the results are included only for completeness. Nitrogen fertilizer had no statistically significant effect on the number of stems and tubers, yield or DM concentration of Cara grown in Field 57 at JEPCO (Table 8). When the size of the standard error is taken into account the optimum N application rate for this site was 0 kg N/ha.

Table 7. Effect of N application rate on number of stems, tubers and tuber yield of Desiree grown at Field 15

	Mean	kg N/ha					S.E.
		0	60	120	180	240	
Number of stems (000/ha)	88	81	92	84	87	96	8.2
Number of tubers > 10 mm (000/ha)	166	158	166	173	163	169	10.1
Tuber FW yield > 10 mm (000/ha)	17.2	15.5	18.8	17.9	15.8	18.1	1.39
Tuber DM concentration (%)	21.2	22.6	20.6	21.2	20.9	20.7	0.76
Tuber DW yield (t/ha)	3.65	3.52	3.88	3.79	3.29	3.76	0.342

Table 8. Effect of N application rate on number of stems, tubers and tuber yield of Cara grown at Field 57

	Mean	kg N/ha					S.E.
		0	60	120	180	240	
Number of stems (000/ha)	142	144	133	137	150	147	7.2
Number of tubers > 10 mm (000/ha)	343	364	332	352	333	336	16.6
Tuber FW yield > 10 mm (000/ha)	43.0	40.8	44.8	43.6	41.9	43.8	1.98
Tuber DM concentration (%)	20.7	20.9	20.7	21.0	20.8	20.2	0.36
Tuber DW yield (t/ha)	8.89	8.48	9.28	9.15	8.71	8.83	0.387

Soil mineral nitrogen

South Pickenham

Soil samples taken on 17 April and 14 May show that Robins Wood had slightly more SMN than Johnsons West (Table 9 and Table 10). In both fields, the increase in SMN between the two sampling dates was small. Since there was little crop uptake during this period, this may be a consequence of the small organic matter contents of these soils limiting N mineralization. Although it cannot be proved conclusively, there was little evidence for N leaching on these sandy soils since the amount of N in the sub-soils (30-60 & 60-90 cm) remained more or less

constant between the two sampling dates. At final harvest, 160 kg N/ha had little effect on SMN residues at Johnsons West but increased residues at Robins Wood.

Table 9. Variation in soil mineral N (kg N/ha) during the growing season at Robin's Wood, South Pickenham

Depth	17 April		14 May		26 September		
	0	S.E.	0	S.E.	0	160	S.E.
0-30 cm	14	0.5	43	8.3	7	10	0.6
30-60 cm	42	15.7	39	1.4	7	15	1.8
60-90 cm	55	12.0	56	9.2	4	19	4.4
0-90 cm	111	27.3	138	9.7	18	44	5.4

Table 10. Variation in soil mineral N (kg N/ha) during the growing season at Johnson's West, South Pickenham.

Depth	17 April		14 May		26 September		
	0	S.E.	0	S.E.	0	160	S.E.
0-30 cm	18	1.2	39	6.0	15	12	2.8
30-60 cm	35	1.8	31	3.5	9	14	0.8
60-90 cm	34	3.2	28	3.0	7	10	1.4
0-90 cm	87	5.6	99	5.0	32	36	3.1

JEPCO

On 12 April, the SMN contents of both Field 15 and 57 were small (Table 11 and Table 12). However, by the time of planting (25 May), the SMN content of Field 15 had increased three fold whilst the SMN content of Field 57 was almost unchanged.

Table 11. Variation in soil mineral N (kg N/ha) during the growing season at JEPCO Field 15 (Desiree)

Depth	12 April		25 May		26 June		3 September		
	0	S.E.	0	S.E.	0	S.E.	0	160	S.E.
0-30 cm	20	2.8	82	15.1	58	17.3	12	27	6.6
30-60 cm	16	2.5	51	5.6	68	14.4	13	14	1.0
60-90 cm	15	2.8	30	3.1	24	4.2	8	10	1.0
0-90 cm	52	7.5	163	18.7	150	30.6	32	51	7.1

Table 12. Variation in soil mineral N (kg N/ha) during the growing season at JEPCO Field 57 (Cara)

Depth	12 April		25 May		26 June		3 September		
	0	S.E.	0	S.E.	0	S.E.	0	160	S.E.
0-30 cm	21	3.6	30	3.6	82	13.6	45	26	10.3
30-60 cm	21	3.5	21	2.4	40	5.3	55	37	10.3
60-90 cm	18	2.7	13	1.5	16	0.8	17	17	1.6
0-90 cm	60	9.4	65	6.5	138	19.0	116	80	21.4

A crop sampling on 26 June showed that Desiree had taken up 9 (\pm 1.1) kg N/ha whilst Cara had taken up 25 (\pm 2.2) kg N/ha and when combined with the SMN values both fields had very similar values for crop+soil N. Despite producing a very poor Desiree crop, the SMN residues in Field 15 were small and not affected by N application rate. The SMN residues in Field 57 were larger but also independent of the amount of N applied.

The objective of this series of experiments was to test whether measurements of soil nitrogen supply could improve N recommendations. Table 13 compares the actual optimal N rate with recommendations made by the field assessment method and by the SNS method.

Table 13. Comparison of N recommendations calculated using the field assessment method, the SNS method based on measurements at planting or 50% emergence and the optimal N application rate estimated from experiments

	Robins Wood	Johnsons West	Field 15	Field 57
Variety	Hermes	Hermes	Desiree	Cara
Variety Group	2	2	3	4
Length of season (days)	130	131	75	89
SNS Index – field assessment method	0	1	1	1
Recommendation (kg N/ha)	200-250	200-250	120-160	60-90
SNS Index – SNS method @ planting	3	2	5	1
Recommendation (kg N/ha)	160-180	160-180	60-80	60-90
SNS Index – SNS method @ emergence	4	3	5	5
Recommendation (kg N/ha)	160-180	160-180	60-80	0-40
N optimum from experiment (kg N/ha)	160	160	-	0

For the three fields where the optimal N rate was measured, the field assessment method overestimated the N requirement by 40-90 kg N/ha. For Hermes grown at South Pickenham, both the early and late sampling SNS system appeared to perform well. For Cara the SNS sampling at planting overestimated the fertilizer recommendation by 60-90 kg N/ha, however, the sampling at emergence appeared to be much more reliable.

Conclusions

Whilst the results from these experiments look promising, it is too early to tell whether the SNS system is more reliable than the field assessment method. The results from Field 57 show that N recommendation changed with time of sampling and this has been found in earlier studies at CUF. Conceptually, later samplings should be better than earlier samplings since the flushes of N mineralization associated with cultivations should have subsided and the probability of N loss from leaching should be reduced. However, results from the

Cultivation Experiments at CUF show that the effects of cultivation on rate of mineralization may persist throughout the growing season.

Effect of cultivations on soil mineral nitrogen and crop nitrogen uptake at Cambridge University Farm

Introduction

The objectives of these experiments were to investigate the effects of cultivations on the amounts of SMN, to establish the proportion of SMN taken up by the crop and to estimate the efficiency with which the potato crop uses N fertilizer.

Materials and Methods

Two experiments were carried out in 2001 in Dry Field at Cambridge University Farm. The experiments were adjacent, had the same treatments and replication but differed in randomization and the dates of cultivations and planting. Each block contained five treatments: an uncultivated stubble and four cultivated treatments comprising all combinations of planted and unplanted, with and without 100 kg N/ha. The treatments were replicated six times and allocated at random to blocks. Details of the cultivations, planting and sampling dates are given in Table 14.

Table 14. Details of soil type, dates of cultivations and sampling for Cultivation Experiments 1 and 2 at Cambridge University Farm

Texture	Sand 58%, Silt 26%, Clay 16%, sandy loam, 7.5% organic matter		
Nutrient status	pH 7.3, 104 mg P/l (Index 6); 731 mg K/l (Index 5); 149 mg Mg/l (Index 3)		
	Cultivation Experiment 1		Cultivation Experiment 2
Date	Operation	Date	Operation
11 May	Soil sampled	2 July	Soil sampled
11 May	Plots ploughed (<i>c.</i> 25 cm depth)	9 July	Plots ploughed (<i>c.</i> 25 cm depth)
29 May	Soil sampled	25 July	Plots power harrowed (<i>c.</i> 20 cm depth) and ridged
29 May	Plots power harrowed (<i>c.</i> 20 cm depth) and ridged	27 July	Plots planted and N applied
5 June	Soil sampled	30 July	Soil sampled
5 June	Plots planted and N applied	24 August	Soil sampled
19 July	Soil sampled		
5 October	Harvest (12 plants), 122 DAP	5 October	Harvest (12 plants), 70 DAP
5 October	Soil sampled	5 October	Soil sampled

The variety was Cara (25-35 mm seed; count 2262/50 kg) which was hand planted at 25 cm spacing into ridges 76 cm apart. A single harvest (2.28 m²) was taken on 5 October to measure yield and N uptake. The crops were unirrigated but received fungicides and aphicides

according to best practice. Weeds were controlled by a combination of Reglone applied pre-emergence and hand weeding through the growing season.

Results and Discussion

Soil mineral nitrogen

In Experiment 1, mineralization of N in the uncultivated plots increased the amount of SMN in the top 90 cm from 37 kg N/ha on 11 May to 168 kg N/ha by 5 October (Figure 6 and Table 15). This is equivalent to an average rate of net mineralization of *c.* 0.9 kg N/ha/day. Ploughing, power harrowing and ridging significantly increased the amount of SMN at each sampling and the average rate of net mineralization in the cultivated (but unplanted and unfertilized) plot was 1.8 kg N/ha/day. Thus, measurement of SMN was affected by time of sampling, particularly in cultivated soils. This suggests that relating fertilizer requirement to a point measurement of SMN will invariably result in imprecise recommendations. At the start of Experiment 2 (2 July), the amount of SMN in the top 90 cm of the uncultivated plots was 110 kg N/ha (Table 16) which was similar to the amount found on 19 July in Experiment 1 (103 kg N/ha) and suggests the soils were relatively homogenous between the two experiments. Likewise, the quantity of SMN found in the uncultivated plots on 5 October in Experiment 2 was similar to that found in Experiment 1. In Experiment 2, the average, net mineralization rates were *c.* 0.7 and 1.2 kg N/ha/day in the uncultivated and cultivated plots respectively.

Figure 6. Increase of soil mineral N (0-90 cm) with time at Dry Field, Cambridge University Farm. □ Stubble, Experiment 1; ■ Cultivated, Experiment 1; △ Stubble, Experiment 2; ▲ Cultivated, Experiment 2. The cultivated plots were unplanted and received no N. A common line has been drawn for the stubble treatments in Experiments 1 and 2.

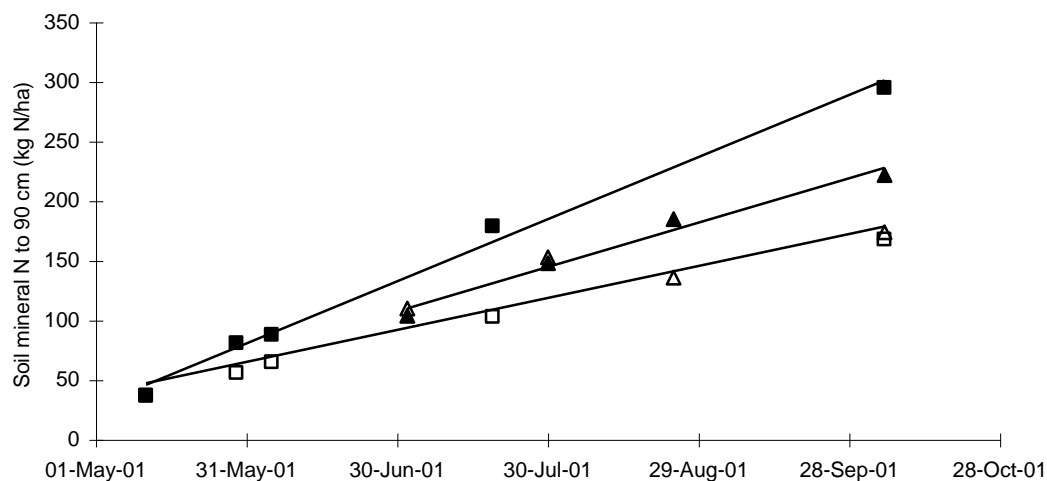


Table 15. Variation in soil mineral N (kg N/ha) in Cultivation Experiment 1, Dry Field, Cambridge University Farm

Depth (cm)	11 May		29 May			5 June			19 July		
	Stubble	S.E.	Stubble	Cultivated	S.E.	Stubble	Cultivated	S.E.	Stubble	Cultivated	S.E.
0-30	18	2.7	22	46	6.4	31	48	3.0	60	89	7.7
30-60	11	1.6	21	21	4.8	19	22	1.9	29	65	10.0
60-90	9	2.1	12	13	0.9	15	18	1.5	15	25	4.7
0-90	37	6.1	56	81	7.9	65	88	3.5	103	179	16.7

Depth (cm)	5 October						S.E.
	Stubble 0 kg N/ha	Unplanted 0 kg N/ha	Unplanted 100 kg N/ha	Planted 0 kg N/ha	Planted 100 kg N/ha		
0-30	69	91	380	25	36		50.6
30-60	62	124	123	27	27		8.4
60-90	37	80	53	17	21		10.1
0-90	168	295	556	69	84		50.3

Table 16. Variation in soil mineral N (kg N/ha) in Cultivation Experiment 2, Dry Field, Cambridge University Farm

Depth (cm)	2 July			30 July			24 August		
	Stubble	Cultivated	S.E.	Stubble	Cultivated	S.E.	Stubble	Cultivated	S.E.
0-30	66	52	6.7	79	72	8.5	75	108	8.0
30-60	27	32	1.9	52	53	8.6	43	56	8.7
60-90	17	21	1.9	23	24	3.9	18	20	2.1
0-90	110	104	6.6	153	148	16.5	136	185	15.3

Depth (cm)	5 October						S.E.
	Stubble 0 kg N/ha	Unplanted 0 kg N/ha	Unplanted 100 kg N/ha	Planted 0 kg N/ha	Planted 100 kg N/ha		
0-30	63	94	275	38	111		31.0
30-60	58	76	142	24	50		13.1
60-90	54	53	76	22	51		10.9
0-90	174	222	492	84	212		39.1

In both experiments, cultivations stimulated the mineralization of N from the soil organic matter, with the May cultivations apparently having a larger affect than the July cultivations. At present we do not know why this should be the case but may be due to soil temperature or moisture content at the time of cultivation.

When applied to cropped soils, 100 kg N/ha increased the size of SMN residues at harvest in Experiment 2 only. Applying N to uncropped soils greatly increased the size of N residues in Experiments 1 and 2. A balance sheet study (Table 17) showed that in both experiments, applying 100 kg N/ha to unplanted plots increased SMN residues at harvest by more than 200 kg N/ha and suggests that addition of N may result in an increase in the rate of N mineralization. However, why this effect should not occur in planted plots is far from clear. It is possible that the cropped soils were on average drier than the uncropped and this reduced the N mineralization rate. It is also possible that due to crop cover, fluctuations in top-soil temperature and moisture content were smaller in cropped plots than uncropped plots and this reduced the overall N mineralization rate. The efficiency of N uptake (calculated as change in N uptake/amount of N applied) was *c.* 32% in Experiment 1 and 24% in Experiment 2. These values are quite small when compared with other experiments and are a consequence of an inappropriate N rate for the length of growing season. For both Experiment 1 and 2, the optimum rate of N for maximum tuber yield and dry matter production was 0 kg N/ha. Experiments on potatoes and other crops have shown that once the optimum N rate has been exceeded SMN residues at harvest increase rapidly. Full season crops that have received the optimum N rate usually have uptake efficiencies of 50-60% and leave relatively small amounts of SMN at harvest.

Crop yield and N uptake

In both experiments, application of N had no effect on the number of stems. In Experiment 1 each plant produced 2.5 stems compared with 3.5 stems in Experiment 2. It is not known whether these effects are significantly different but they are consistent with measurements in other studies which show increases in stem population as the time from emergence of the seed crop to the replanting of its progeny tubers increases. The average total DM yields were 9.9 and 3.6 t/ha in Experiments 1 and 2 respectively and, in both experiments, use of N fertilizer had no effect on total DM yield (Table 18). However, in both experiments, applying 100 kg N/ha significantly reduced the harvest index and this effect was much larger in Experiment 2. As a consequence, tuber DW yields > 10 mm were not significantly affected by N in Experiment 1 but were significantly reduced by N in Experiment 2. Use of N fertilizer also

significantly decreased tuber DM concentration in both experiments. In Experiment 1 the average tuber FW yield was 32 t/ha and not affected by N treatment, whilst in Experiment 2, the average FW yield was 5.2 t/ha and was reduced by N. Total N uptake averaged 150 and 138 kg N/ha in Experiments 1 and 2 respectively.

Conclusions

These two experiments have shown that the relatively shallow cultivations used to establish the potato crops doubled the mineralization rate and these effects persisted throughout the season. At present, we do not know whether the effect of time of cultivation on the subsequent rate of mineralization is consistent, or what factors may be causing this to happen. However, if N mineralization rate is affected by the timing of cultivation then such factors would need to be considered for future N recommendation systems.

Table 17. Nitrogen budget for Cultivation Experiments 1 and 2 in Dry Field Cambridge University Farm. Soil mineral N was measured to 90 cm. All values as kg N/ha

		Unplanted	Unplanted	Planted	Planted
		0	100	0	100
1	Fertilizer applied				
Experiment 1					
2	Soil mineral N at planting	88	88	88	88
3	Soil mineral N at harvest	295	556	69	84
4	Crop N uptake	0	0	134	166
5	N in crop & soil at harvest (3+4)	295	556	203	250
6	Increase in crop & soil N during season (5-(1+2))	207	368	115	62
Experiment 2					
2	Soil mineral N at planting	148	148	148	148
3	Soil mineral N at harvest	222	492	84	212
4	Crop N uptake at harvest	0	0	126	150
5	Total in crop & soil at harvest (3+4)	222	492	210	362
6	Increase in crop & soil N during season (5-(1+2))	74	244	62	114

Table 18. Effect of N application rate on haulm yield, number of stems and tubers and tuber yield of Cara in Cultivation Experiments 1 and 2, Dry Field, Cambridge University Farm

	Cultivation Experiment 1				Cultivation Experiment 2			
	Harvested 122 days after planting				Harvested 70 days after planting			
	Mean	kg N/ha		S.E.	Mean	kg N/ha		S.E.
	0	100			0	100		
Haulm DW yield (t/ha)	3.79	3.13	4.45	0.221	2.92	2.77	3.07	0.117
Number of stems (000/ha)	129	125	133	8.4	182	180	183	11.2
Number of tubers > 10 mm (000/ha)	324	305	343	38.0	242	287	197	15.7
Tuber FW yield > 10 mm (t/ha)	32.4	32.8	31.9	1.90	5.2	7.1	3.4	0.36
Tuber DM concentration (%)	18.9	19.7	18.0	0.25	13.6	14.0	13.1	0.18
Tuber DW yield > 10 mm (t/ha)	6.12	6.48	5.75	0.334	0.72	0.99	0.44	0.054
Total DW yield (t/ha)	9.90	9.61	10.20	0.438	3.63	3.75	3.51	0.136
Harvest Index	61.9	67.4	56.4	1.50	19.8	26.6	12.9	1.51
Total N uptake	150	134	166	14.6	138	126	150	4.9

Effects of nitrogen supply on yields and nitrogen utilization of Lady Rosetta and Russet Burbank at Taunton and Cambridge University Farm

Introduction

The objectives of these two experiments were to investigate the proportion of SMN taken by the crop, the amount of N mineralized from the soil organic matter during the growing season and the efficiency with which fertilizer N was used by the crop.

Materials and methods

Relevant details of the two experiments are given in Table 19. Both experiments used plots within the BPC Reference crops at Cambridge and Taunton and were hand planted and harvested. At Taunton, the experimental design comprised all combinations of two varieties (Lady Rosetta and Russet Burbank) and two N application rates (0 and a commercial rate dependent on variety). In the treatments receiving no N, only one half of the plot was planted and the remainder of the plot was used to monitor changes in SMN in uncropped and unfertilized soil. Each treatment combination was replicated eight times and allocated at random into blocks.

Table 19. Details of N experiments at Cambridge University Farm and R. J. King, Taunton

	Cage Field, Cambridge University Farm, Cambridgeshire		Bull Park, R.J. King and Sons, Taunton, Somerset	
Texture	Sandy loam		Clay loam	
Previous crop	Winter barley		Peas	
Irrigation (mm)	0 or 116 (treatment)		35	
Date of planting	14 May		21 May	
Row width (cm)	76		86	
Plant spacing (cm)	25		22	
Date of 1 st crop and soil sample	11 June		14 June	
Date of 2 nd crop and soil sample	21 August		21 August	
Date of 3 rd crop and soil sample	25 September		24 September	
	Russet Burbank	Lady Rosetta	Russet Burbank	Lady Rosetta
N applied (kg N/ha)	0 & 140	0 & 160	0 & 120	0 & 140
Seed size (mm)	25-35	25-35	25-35	25-35
Count (Number per 50 kg)	2203	2410	2203	2410
Classification	SE2	SE2	SE2	SE2
Date of 50% emergence	12 June	14 June	12 June	13 June

At Cambridge, there were four replicate blocks that tested all combinations of two irrigation treatments (none and scheduled), two varieties (Lady Rosetta and Russet Burbank) and two N application rates (0 and a commercial rate dependent on variety) in a randomized split plot design with irrigation as main plots. Ground covers were measured weekly from emergence until final harvest in September.

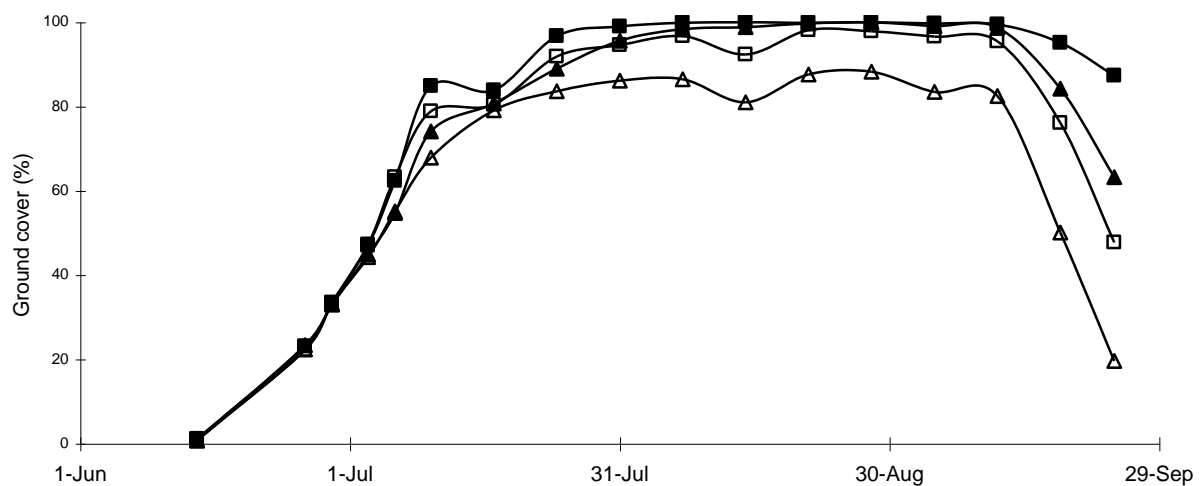
Results and Discussion

Emergence, ground covers, crop yields, N uptake and soil N

Taunton

The date of 50% emergence was *c.* 15 June for Lady Rosetta and 14 June for Russet Burbank. Applying commercial rates of N fertilizer decreased the time taken to 50% emergence by *c.* 0.5 days. The pattern of ground cover development for each variety grown with and without N fertilizer are given in Figure 7. Without N Lady Rosetta did not achieve complete ground cover. Crop senescence in all treatments started in early September, however, the rate of senescence was slowest in Russet Burbank that received 120 kg N/ha.

Figure 7. Effects of variety and N on pattern of ground cover development at R. J. King Taunton. □ Russet Burbank 0; ■ Russet Burbank 120 kg N/ha; △ Lady Rosetta 0; ▲ Lady Rosetta 140 kg N/ha.



At the early sampling on 14 June, both Lady Rosetta and Russet Burbank contained *c.* 4 kg N/ha compared with an average of 182 kg N/ha in the top 60 cm of soil. The SNS for both varieties was thus *c.* 186 kg N/ha (Table 20). Yield and integrated ground cover data from the second harvest (21 August, 92 DAP) are shown in Table 21. The number of stems was larger in Russet Burbank than in Lady Rosetta but the stem population was not affected by use of N.

At this early harvest, tuber fresh weight yields were similar in all treatments, and thus the optimal N application rate would be zero. Tuber DM concentrations were larger in Lady Rosetta than in Russet Burbank and whilst N fertilizer decreased tuber DM in Russet Burbank, it had no significant effect on DM concentration in Lady Rosetta. Both varieties had similar tuber DM yields irrespective of N application rate.

Table 20. Crop N (kg/ha) on 14 June and variation in soil mineral N (0-60 cm, kg N/ha) at R. J. King, Taunton

Crop N	Bare	Lady Rosetta		Russet Burbank		S.E.
	0 kg N/ha	0 kg N/ha	140 kg N/ha	0 kg N/ha	120 kg N/ha	
14 June		4.2		3.9		0.18
Soil N						
14 June		188		176		7.2
20 August	224	49	877	55	89	101.2
24 September	112	63	525	48	147	113.7

Table 21. Effect of N application rate on number of stems and tubers, tuber and total yield and N uptake of Lady Rosetta and Russet Burbank at R. J. King, Taunton on 21 August

	Lady Rosetta		Russet Burbank		S.E
	0	140	0	120	
Total number of stems (000/ha)	93	88	111	122	9.7
Number of tubers > 10 mm (000/ha)	361	336	371	368	17.5
Tuber FW yield > 10 mm (t/ha)	41.1	40.9	41.1	41.8	1.61
Tuber DM concentration (%)	22.8	23.4	22.5	19.2	0.46
Tuber DW yield > 10 mm (t/ha)	9.4	9.5	9.2	8.0	0.32
Total DW yield (t/ha)	11.4	12.0	11.4	11.4	0.44
Integrated ground cover (% days)	4233	4641	4649	4854	51.0
Total N uptake (kg N/ha)	120	182	107	189	7.4

The final harvest at Taunton was on 24 and 25 September (126 and 127 days after planting). The number of stems and tubers > 10 mm were generally similar to those found at the earlier harvest (Table 22). When compared with the earlier harvest, tuber FW yield for both varieties had increased and both varieties had similar yields. Applying N fertilizer resulted in a significant increase in tuber FW yield of Russet Burbank but not Lady Rosetta. However, at this later harvest, DW yields for both varieties were significantly increased when N was applied.

Table 22. Effect of N application rate on number of stems and tubers, tuber and total yield and N uptake of Lady Rosetta and Russet Burbank at R. J. King, Taunton at final harvest on 25 September

	Lady Rosetta		Russet Burbank		S.E
	0	140	0	120	
Total number of stems (000/ha)	84	87	89	117	6.2
Number of tubers > 10 mm (000/ha)	351	362	340	359	17.3
Tuber FW yield > 10 mm (t/ha)	46.0	48.9	44.3	52.6	1.49
Tuber DM concentration (%)	27.6	28.5	28.4	25.5	0.40
Tuber DW yield > 10 mm (t/ha)	12.7	13.9	12.6	13.4	0.37
Total DW yield (t/ha)	14.2	15.8	14.1	16.0	0.47
Integrated ground cover (% days)	6704	7812	7661	8179	87.6
Total N uptake (kg N/ha)	122	188	107	202	6.6

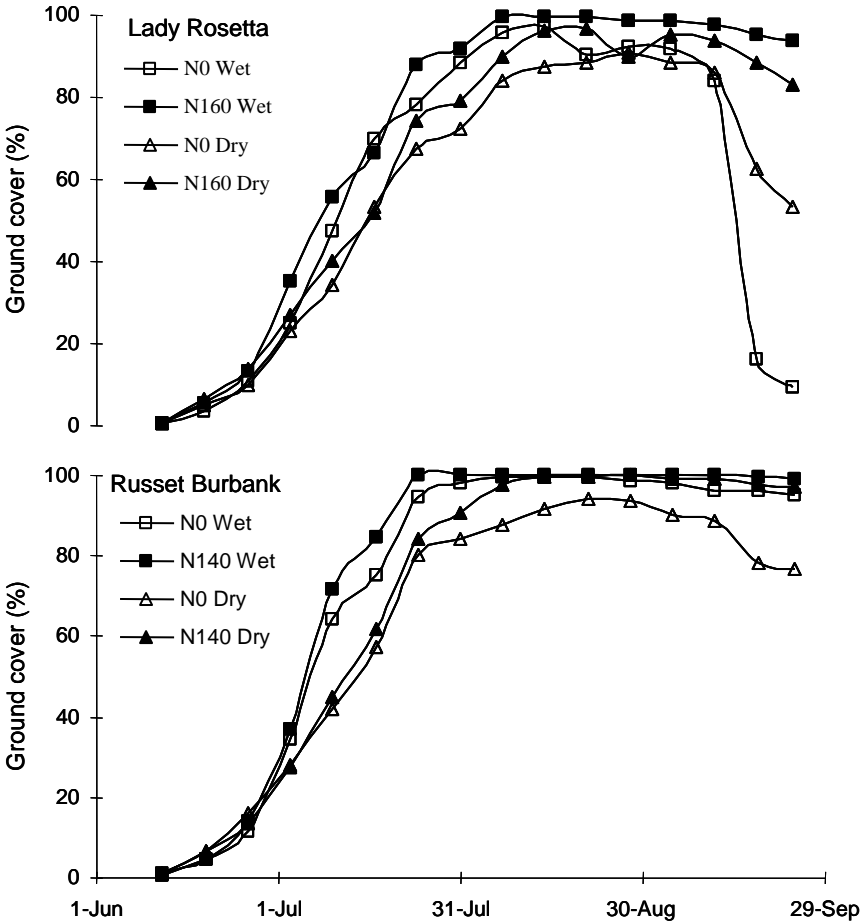
When measured on 20 August the amount of soil mineral N in unplanted plots had increased to 224 kg N/ha but this value had decreased to 122 kg N/ha at final harvest on 24 September (Table 20). Owing to crop N uptake, the amount of N in the unfertilized and planted plots averaged 52 kg N/ha on the 20 August and 55 kg N/ha on 24 September. Compared with the unfertilized crop, applying 120 kg N/ha to the Russet Burbank crop did not significantly increase the amount of N in the soil at either harvest. However, applying 140 kg N/ha to Lady Rosetta increased the amount of soil mineral N to 877 kg N/ha on 20 August and 525 kg N/ha at final harvest. At present, there is no logical explanation why applying N should result in disproportionately large increases in SMN in plots of Lady Rosetta but not in Russet Burbank. However, it is possible that these large fluxes of soil mineral N were due to stimulation of nitrification by root exudates. Recent work by Wheatley *et al.* (2001) has demonstrated that addition of simple organic compounds to soils increased rates of nitrification by upto 650% when compared with untreated, control plots. Work will continue at CUF in 2002 to see if the effects seen in the 2001 experiments are repeatable and, if possible, to elucidate some underlying mechanisms.

Cambridge

At Cambridge, the date of 50% emergence was 12 and 14 June for Russet Burbank and Lady Rosetta respectively. For both varieties, omitting N delayed emergence by *c.* 2 days. The patterns of ground cover development for Lady Rosetta and Russet Burbank are shown in Figure 8. For Lady Rosetta, ground covers were increased by applying 160 kg N/ha and by use of irrigation. The crops receiving no N started to senesce in early September whilst those receiving a commercial N application maintained a near complete ground cover until harvest in late September. For Russet Burbank, with the exception of the unirrigated N0 treatment, all treatments attained 100% ground cover and maintained it until final harvest. The

unirrigated N0 treatment attained *c.* 90% ground cover and started to senesce in early September.

Figure 8. Pattern of ground cover development for Lady Rosetta and Russet Burbank at Cage Field, Cambridge University Farm.



On 11 June, the Lady Rosetta and Russet Burbank contained an average of *c.* 4 kg N/ha and the soil (0-90 cm) 151 kg N/ha (Table 23). At final harvest on 25 September (134 DAP), the amount of SMN in the soil averaged 95 kg N/ha and was not affected by either variety or irrigation.

Table 23. Crop N (kg/ha) on 11 June and variation in soil mineral N (0-90 cm, kg N/ha) at Cage Field, Cambridge University Farm

	Lady Rosetta		Russet Burbank		S.E.
	Dry	Wet	Dry	Wet	
Crop N					
11 June	3.6		4.1		0.15
Soil N					
11 June	136	166	143	160	16.7
25 September	100	89	95	95	11.4

Yield and integrated ground cover data from the first harvest (21 August, 99 days after planting) are given in Table 24. Both varieties produced a similar number of stems (mean 92 000/ha) and tubers >10 mm (248 000/ha) and the number of stems and tubers was not affected by irrigation or N application rate. Tuber FW yields >10 mm averaged 27 t/ha and there were no significant effects due to variety, irrigation or rate of N application. Thus, for this early harvest the optimal rate of N application for both varieties was zero. Averaged over all treatments the tuber DM concentration was 21.8 %. Overall, Lady Rosetta had a larger tuber DM concentration than Russet Burbank and when N was applied, tuber DM concentration was reduced in Russet Burbank but not in Lady Rosetta. Irrigation had no effect on tuber DM concentration in either variety. Total DM yield averaged 8.4 t/ha and was not affected by any treatment. At this early harvest, N application increased the average, total N uptake from 112 to 159 kg N/ha, but there were no significant effects due to variety or use of irrigation.

At final harvest (25 September, 134 days after planting), the number of stems and tubers was similar to those found at the earlier harvest (90 000 and 250 000/ha respectively, Table 24). When averaged over all treatments, the tuber FW yield had increased to *c.* 40 t/ha. Compared with the 0 N treatment, applying the commercial rate of N increased the average tuber FW yield from 36.8 to 43.5 t/ha. However, there were no effects due to variety or use of irrigation. For all treatments, the mean tuber DM concentration was 24.1% and, as found in the earlier harvest, Lady Rosetta had a larger DM concentration than Russet Burbank. Use of N decreased the dry matter concentration in Russet Burbank but not in Lady Rosetta, whilst use of irrigation had no significant effect on DM concentration in either variety. Tuber and total DM yields averaged 9.7 and 12.1 t/ha respectively and both were significantly increased by use of N, however, variety and irrigation had little effect. The average total N uptake of crops receiving no N was 114 kg N/ha and this was increased to 177 kg N/ha when commercial rates were applied.

Table 24 Effect of irrigation and N application rate on number of stems and tubers, tuber fresh and dry weight yield, total dry weight yield, integrated ground cover and total N uptake for Lady Rosetta and Russet Burbank grown at Cage Field, Cambridge University Farm on two sampling dates

	Unirrigated				Irrigated				S.E.	S.E.
	Lady Rosetta		Russet Burbank		Lady Rosetta		Russet Burbank		Same irrigation	Different irrigation
21 August	0	140	0	120	0	140	0	120		
Total number of stems (000/ha)	92	86	91	87	84	94	94	112	10.9	10.0
Number of tubers > 10 mm (000/ha)	257	234	255	191	258	278	249	262	34.0	32.2
Tuber FW yield > 10 mm (t/ha)	30.0	24.9	32.7	23.6	25.4	27.3	24.9	26.5	4.68	4.46
Tuber DM concentration (%)	22.3	23.1	22.8	18.7	22.7	23.1	22.8	19.0	0.48	0.43
Tuber DW yield > 10 mm (t/ha)	6.8	5.8	7.5	4.4	5.8	6.3	5.7	5.0	1.07	1.01
Total DW yield (t/ha)	9.3	8.1	9.5	7.3	7.8	9.0	7.7	8.4	1.17	1.10
Integrated ground cover (% days)	3360	3689	6784	4038	3926	4230	4421	4636	116.6	231.6
Total N uptake (kg N/ha)	136	155	115	143	107	178	92	162	15.2	13.9
24 September										
Total number of stems (000/ha)	91	83	86	115	77	87	78	102	8.5	7.7
Number of tubers > 10 mm (000/ha)	260	234	299	223	228	263	244	246	24.4	22.4
Tuber FW yield > 10 mm (t/ha)	41.5	39.7	34.2	43.5	34.7	44.6	37.0	46.1	2.60	2.96
Tuber DM concentration (%)	24.7	25.3	25.2	22.0	24.3	25.0	25.0	21.6	0.53	0.54
Tuber DW yield > 10 mm (t/ha)	10.3	10.1	8.5	9.6	8.4	11.2	9.2	10.0	0.70	0.78
Total DW yield (t/ha)	12.4	12.4	10.8	12.4	10.3	14.1	11.4	13.3	0.88	0.94
Integrated ground cover (% days)	6090	6799	6755	7404	6250	7541	7729	8030	181.1	342.2
Total N uptake (kg N/ha)	122	171	118	169	107	189	111	176	12.0	11.5

Nitrogen mineralization and uptake

The efficiency of uptake of N fertilizer for Lady Rosetta and Russet Burbank was calculated using the difference method:

$$\text{Efficiency} = (\text{N uptake of crop receiving N} - \text{N uptake of crop receiving no N}) / \text{N applied}$$

For both Taunton and Cambridge, the efficiency of N uptake was larger at the final harvest in September than at the harvest taken in August (Table 25). At Taunton, Russet Burbank used N fertilizer more efficiently than Lady Rosetta. Similar results were also found at Cambridge University Farm, although due to the large standard errors these differences were not statistically significant. Similarly, use of irrigation resulted in a numerical increase in N uptake efficiency but this difference was not statistically significant.

Table 25. Effect of variety (R. J. King, Taunton) and variety and irrigation (Cambridge University Farm) on the efficiency of N fertilizer use (%) at two harvests

		Mean	Lady Rosetta		Russet Burbank		S.E.
Taunton	21 Aug	56	44		68		7.0
	25 Sep	63	47		79		8.4
		Mean	Lady Rosetta		Russet Burbank		S.E.
			Dry	Wet	Dry	Wet	
Cambridge	21 Aug	32	12	44	20	50	19.8
	25 Sep	42	31	52	37	47	14.1

The relationship between N uptake and SNS measured at *c.* 50% emergence is shown in Table 26. For both sites, SNS measured at 50% emergence was a poor predictor of either tuber or total N uptake of unfertilized crops when measured at harvests in August or September. At Taunton, the average recovery of SNS was *c.* 63% whilst at Cambridge it was 74%. The effects of irrigation and variety on SNS recovery were small and unlikely to be statistically significant.

Table 26. Relationship between SNS (kg N/ha) measured at 50% emergence and tuber and total N uptake (kg N/ha) of unfertilized crops at R. J. King, Taunton and Cambridge University Farm in August and September

			Mean	Lady Rosetta		Russet Burbank	
Taunton	14 Jun	SNS	183	187		179	
	21 Aug	Tuber	73	78		67	
	21 Aug	Total	114	120		107	
	25 Sep	Tuber	98	105		91	
	25 Sep	Total	115	122		107	
			Mean	Lady Rosetta		Russet Burbank	
				Dry	Wet	Dry	Wet
Cambridge	11 Jun	SNS	155	139	169	147	164
	21 Aug	Tuber	58	64	55	66	49
	21 Aug	Total	112	136	107	115	92
	25 Sep	Tuber	87	101	88	80	79
	25 Sep	Total	114	122	107	118	111

Conclusions

A key component of the SNS measurement system, as proposed for cereals, is that the N uptake of crops that receive no N is similar to the SNS measured in the spring. In addition, the cereal SNS system assumes that the crop recovers 60% of the N fertilizer applied. The data from the experiments at Cambridge and Taunton show the total N uptake of full-season crops is a variable fraction of the SNS supply measured in the spring. Furthermore, the efficiency of use of N fertilizer varies from site to site and, at Taunton, was also affected by variety. Whilst further studies are needed, these data suggest that the SNS system is not sufficiently robust to give improvements in potato N recommendations.

Effects of nitrogen fertilizer on growth and yield of contrasting varieties at Cambridge University Farm

Introduction

The objective of this experiment was to compare the measured N requirement of four contrasting potato varieties with those calculated by the field assessment method and by measurements of soil mineral N at the start of the season.

Materials and Methods

Four contrasting varieties (Cara, Courlan, Estima and Hermes) were grown in factorial combination with four rates of N (0, 100, 200, 300 kg N/ha) in a randomized block design with three replicates. The experiment was planted by hand into preformed ridges (76 cm centres) on 24 May, fertilizer N was then applied and the ridges raked-up. Emergence was recorded twice weekly (up to 100%) and ground cover recorded weekly. A single final harvest of twelve plants (2.28 m²) was taken on 10 October and the weight of tubers in 10 mm grades recorded. As in other experiments, the optimum N application rate was defined as the smallest N application rate above which there was no statistically significant increase in tuber yield. Further details of the experiment are given in Table 27.

Table 27. Experimental details of nitrogen and variety experiment at Cage Field, Cambridge University Farm

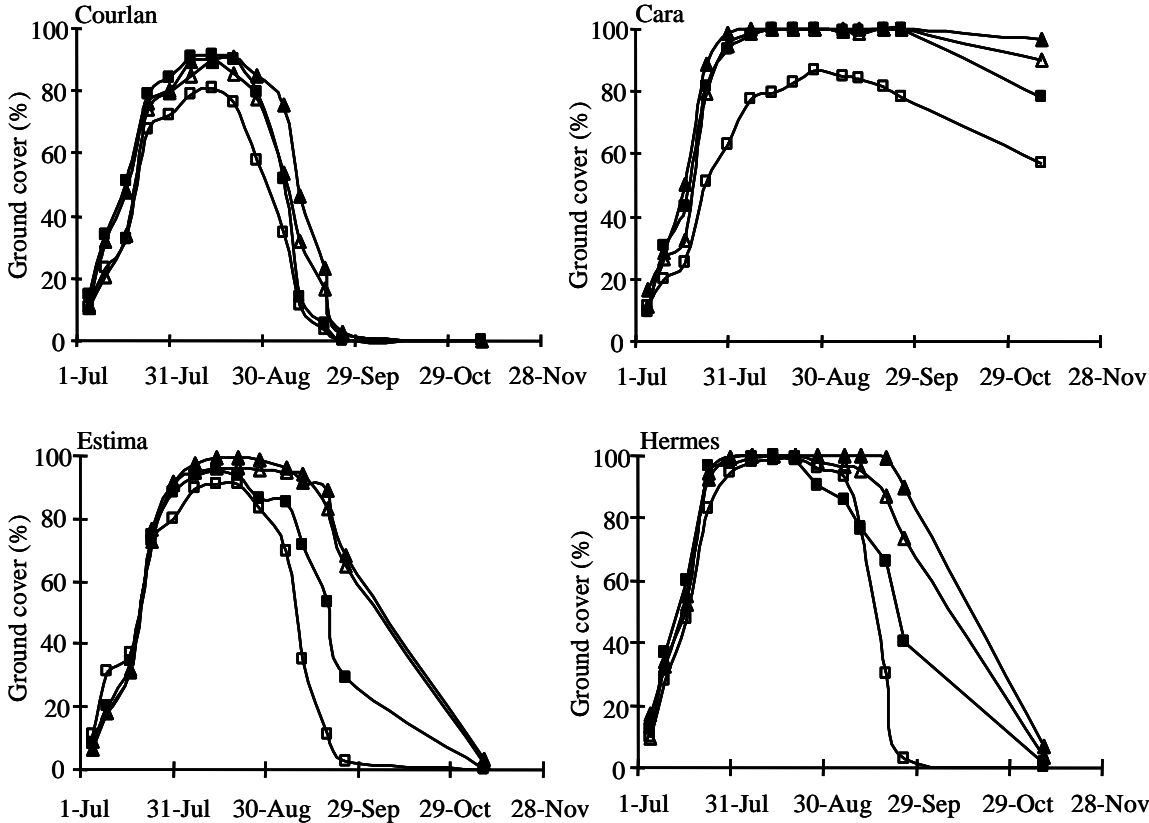
Cage Field, Cambridge University Farm, Cambridgeshire				
Texture	Sand 66%, Silt 19% , Clay 15% , sandy loam, 6.1% organic matter			
Nutrient status	pH 7.7, 71.8 mg P/l (Index 5), 556 mg K/l (Index 4) 142 mg Mg/l (Index 3)			
Previous crop	Winter barley			
Irrigation (mm)	76			
Date of planting	24 May			
Date of 1 st soil sample	24 April			
Date of 2 nd soil sample	31 May			
Date of final harvest	10 October			
	Cara	Courlan	Estima	Hermes
Seed size (mm)	25-35	25-35	25-35	25-35
Count (number per 50 kg)	2203	2112	2203	2054
Classification	SE2	E1	SE2	SE2
Date of 50% emergence	23 June	25 June	23 June	25 June

Results and Discussion

Emergence, ground covers and yield

All varieties attained 50% emergence between 23 and 25 June and there was no effect of rate of applied N. There were large effects of variety and N on the extent of the canopies. No variety produced a complete canopy without additional N fertilizer (Figure 9). Cara, Estima and Hermes produced complete canopies when 100 kg N/ha was applied whereas Courlan needed 300 kg N/ha to produce a complete canopy. Cara produced the most persistent canopy, maintaining a complete canopy into October when only 100 kg N/ha was applied. The crop canopies of Hermes were more persistent than Estima while the ground cover of Courlan started to senesce in mid to late August irrespective of N application rate.

Figure 9. Effect of N fertilizer on ground cover of Cara, Courlan, Estima and Hermes grown at Cage Field, Cambridge University Farm. □ 0 kg N/ha, ■ 100 kg N/ha, △ 200 kg N/ha, ▲ 300 kg N/ha.



The effects of N and variety on integrated ground cover are shown in Table 28. When the standard error is considered, Cara required *c.* 100 kg N/ha to produce the largest integrated ground cover compared with 200 kg N/ha needed by Estima and Hermes. Courlan required *c.* 300 kg N/ha to produce the largest integrated ground cover.

Table 28. Effect of N application rate on integrated ground cover (% days) of Cara, Courlan, Estima and Hermes grown at Cage Field, Cambridge University Farm

	N application rate (kg N/ha)				Mean
	0	100	200	300	
Cara	6450	8264	8260	8604	7894
Courlan	3900	4875	4680	5322	4694
Estima	4998	5967	6845	7021	6208
Hermes	6039	6888	7556	7958	7110
Mean	5347	6499	6835	7226	6477

S.E. for comparing main effects of variety or N, 185.9; for comparing Variety*N, 371.8

At final harvest on 10 October the average tuber fresh weight yield > 10 mm was 41 t/ha (Table 29). For Cara, Courlan and Estima, the optimum N application rate was *c.* 100 kg N/ha. For Hermes the optimum rate appeared to be between 100 and 200 kg N/ha. The absence of a significant yield response to larger applications of N was probably a consequence of the late planting and relatively short growing season. Due to this short season there was little opportunity for increases in light interception and, in turn, yield to be increased as result of the increased canopy persistence. Furthermore, in short seasons, high rates of N application to varieties that produce extensive canopies may restrict yield since additional canopy production adversely affects the partitioning of assimilate. In Cara, a substantial canopy was still present at the final harvest, especially at the higher rates of N and, therefore, in this variety, rates of N > 100 kg N/ha adversely affected the partitioning of dry matter.

Table 29. Effect of N application rate on tuber FW yield > 10 mm of Cara, Courlan, Estima and Hermes at Cage Field, Cambridge University Farm

	N application rate (kg N/ha)				Mean
	0	100	200	300	
Cara	38.3	50.8	50.6	47.3	46.8
Courlan	23.3	31.5	30.5	33.4	26.7
Estima	32.5	47.6	45.4	49.2	43.7
Hermes	33.7	38.7	47.1	51.3	42.7
Mean	32.0	42.2	43.4	45.3	40.7

S.E. for comparing main effects of variety, and N 1.58; for comparing Variety*N, 3.15.

Soil nitrogen and optimal N application rate

Soil mineral N was measured on two occasions. The first sampling (24 April) was done after the field was ploughed, but before ridges were drawn up using the power-ridger. The second sampling (31 May) was done a few days after planting (but before emergence) on plots of Estima and Cara that had received no N. Between these two dates the quantity of soil mineral

N increased from 55 kg/ha to 167 kg N/ha (Table 30). The average rate of net N mineralization was *c.* 3 kg N/ha/day. In the Cultivation experiment, on an adjacent field at CUF, a similar series of cultivations resulted in mineralization rates of *c.* 2 kg N/ha/day. It is not known whether this difference in the rate of mineralization was due to differences in the timing of the cultivations or the organic matter status of soils. Experiments planned for 2002 at Cambridge and other locations should help resolve this question.

Table 30. Soil mineral nitrogen (0-90 cm, kg N/ha) on two occasions at Cage Field, Cambridge University Farm

24 April		51 (\pm 5.1)		
	Mean	Cara	Estima	S.E
31 May	167	184	149	25.6

Estimates of the optimal amount of N derived from the field assessment method, the SNS method and from the N response experiment are shown in Table 31 and Table 32. In Table 31, the length of season was measured from 50% emergence to final harvest and, since this ignores canopy senescence, the N recommendations for Courlan and Estima were too large. For Cara and Hermes, the field assessment method gave a reasonably accurate prediction of the N requirement as did the SNS method based on the early sampling. However, a recommendation based on the later sampling would have been too small.

Table 31. Comparison of N recommendation made by the field assessment method and the soil nitrogen supply method with the optimal N application rate estimated from experiments. Length of season measured from 50% emergence to final harvest

Variety	Cara	Courlan	Estima	Hermes
Variety Group	4	1	1	2
Length of season (days)	110	110	110	110
SNS Index – field assessment method	1	1	1	1
Recommendation (kg N/ha)	80-140	240-270	240-270	160-220
SNS Index – SNS method 23 April	0	0	0	0
Recommendation (kg N/ha)	80-140	240-270	240-270	160-220
SNS Index – SNS method 31 May	5	5	5	5
Recommendation (kg N/ha)	0-40	160-180	160-180	80-120
N optimum from experiment (kg N/ha)	100	100	100	100-200

Calculating the N requirement using time from 50% emergence to the onset of senescence reduced the length of season by 45 days and reduced the amount of N recommended for

Courlan, Estima and Hermes (Table 32). Despite this reduction, the N recommendations for Estima and Courlan were still too large when based on the field assessment method and the SNS measurement system using the April soil sample. For Courlan and Estima, the N recommendations based on the second soil sampling were closer to the optima estimated at final harvest.

Table 32. Comparison of N recommendation made by the field assessment method and the soil nitrogen supply method with the optimal N application rate estimated from experiments. Length of season measured from 50% emergence to onset of senescence

Variety	Cara	Courlan	Estima	Hermes
Variety Group	4	1	1	2
Length of season (days)	110	65	65	65
SNS Index – field assessment method	1	1	1	1
Recommendation (kg N/ha)	80-140	180-220	180-220	140-190
SNS Index – SNS method 23 April	0	0	0	0
Recommendation (kg N/ha)	80-140	180-240	180-240	140-190
SNS Index – SNS method 31 May	5	5	5	5
Recommendation (kg N/ha)	0-40	100-120	100-120	60-80
N optimum from experiment (kg N/ha)	100	100	100	100-200

Conclusions

Due to the short season that restricted the response to N fertilizer, this experiment was unable to differentiate the optimal N application for contrasting varieties. The field assessment method overestimated the N requirements of Courlan and Estima even when a shorter length of season was used in the calculation. Nitrogen recommendations based on measurements of SNS were not robust: their accuracy appeared to be solely dependent on the time at which the soil sample was taken.

Summary and conclusions from 2001 season

The soil nitrogen supply (SNS) measurement system assumes that there is a robust relationship between measurements of SNS made in the spring and crop N uptake measured at final harvest. In addition, the SNS system for cereals assumes that fertilizer N is used with 60% efficiency and that mineralization of N during the growing season is both small and predictable.

In 2001, the British Potato Council funded nine experiments that were designed to test different components of the SNS measurement system. The experiments used varieties, soil types and management systems similar to those used to produce much of the national crop. The following conclusions must be treated with caution since they are based on the results of a single years experiments and it is probable that seasonal effects are important.

After adjusting for length of season and variety, measured values of SNS were poorly related to the optimal N application rate. The reliability of predictions made using SNS measurements was dependent on the time of sampling and, as a consequence, may be of little practical use unless the causes of this variation are better understood. The recovery of SNS by potatoes was variable and appeared to be affected by site, variety and use of irrigation. Similarly, factors such as site, variety and irrigation also affect the apparent efficiency of utilization of N fertilizer. After a single year's work, it is not clear if these effects are repeatable or what influence season has on the recovery of SNS or the efficiency of fertilizer usage.

The cultivation experiments at CUF and the experiments with Lady Rosetta and Russet Burbank at CUF and Taunton showed that even on soils with a moderate amount of soil organic matter, large and variable amounts of N may be mineralized. The cultivation experiments at CUF used relatively shallow cultivations yet resulted in a near doubling of the mineralization rate and these effects persisted throughout the season. These experiments also showed that time of cultivations was important in determining the mineralization rate. At present, these effects are not allowed for in the SNS measurement method.

Future work should initially concentrate on attempting to elucidate simple empirical relationships between measurement of SNS, crop N uptake and fertilizer N requirement on a range of soil types and management systems. However, more robust N fertilizer

recommendations are likely to result from a more fundamental understanding of the impact of crop management on soil processes and on crop physiology.

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