EFFECT OF NITROGEN FERTILISER MANAGEMENT ON YIELD AND QUALITY OF FIVE POTATO CULTIVARS

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ABSTRACT

Many studies have investigated the effects of nitrogen fertiliser rates on potato yield and quality, but few have examined the effects on tuber quality of the timing of nitrogen applications. This paper presents the results of an experiment at Lincoln in the 1987/88 season in which five cultivars, Iwa, Tekau, Kaituna, Ilam Hardy and Russet Burbank, were grown under seven nitrogen regimes including nil nitrogen, 150 kgN/ha at planting, and 75 kgN/ha at planting with a further 75 kgN/ha at a range of times from 1 month after planting.

Kaituna was the highest yielding cultivar (79 t/ha) with Iwa, Tekau and Ilam Hardy averaging 64 t/ha. Russet Burbank was affected by virus and only yielded 42 t/ha. Both the nil nitrogen and 'all-at-planting' treatments had lower yields, but the timing of the later applications had no effect on yield. There were numerous interactions between cultivars and yield parameters.

Quality tests were performed 4 weeks after harvest and repeated after a further 3 months storage at 10 °C. Nitrogen caused a reduction in tuber density but its time of application had no effect. Crisp colour (i.e. sugar content) was unaffected by nitrogen. Iwa and Kaituna produced crisps of poor colour but adequate specific gravity. Ilam Hardy showed good crisp colour but undesirably low specific gravity. While these characteristics improved slightly after storage, they were still low. Russet Burbank crisp colour darkened after storage, but specific gravity improved.

INTRODUCTION

About 30% of the New Zealand potato crop (total 295,000 t in 1987) is used by processors to produce crisps, french fries, dehydrated flakes, potato flour, frozen vegetable mixes, hash browns and for canning. This figure was expected to increased to 45% by 1995 (Potato Research Advisory Committee, 1985) to meet both export and domestic requirements, but this projection is now considered to be a little high (R.A. Genet, pers. comm.).

Processors have specific quality requirements. A survey of processors (Hughes and Sheppard, 1983) showed requirements for a dry matter content (DM%) of >20%, sugar content <0.1%, size >50 mm, weight >113g, dirt <2%, physiological damage <1%, machine damage <4% and nil disease. Specific gravity (SG) is used as a rapid measure of DM% and starch content of the tubers. Von Scheele *et al.* (1937) found a 93.7% correlation between DM% and SG. SG is an important parameter because tubers with a high solids content yield a greater amount of product from each unit of fresh weight.

Crisp quality is a complex of many factors, with colour being the most important to processors and the consumer. SG is an important measure of tuber quality, but it has a low correlation with crisp colour rating (Cunningham and Stevenson, 1963; Kunkel and Holstad, 1972). French fries tend to be less affected by those factors which cause colour variation in crisps.

The agronomic factors which most affect potato tuber yield and quality are the availability of water and nutrients. Many researchers have shown that increasing rates of nitrogen (N) fertiliser increase yield but cause a decline in the SG of the tubers (e.g. Kunkel and Holstad, 1972; White and Sanderson, 1983). Timm *et al.* (1963) found that applications of up to 260 kgN/ha increased total yield. At rates greater than 130 kgN/ha however, table yields were not significantly improved, the additional yield increase resulting from more off-grade tubers. N fertiliser increases yield by increasing the rate rather than the duration of tuber bulking (Gunasena and Harris, 1968). Buwalda and Freeman (1987) found that the greatest effect of N supply on the total N concentration in a crop of Ilam Hardy occurred during early growth, up to two months from planting.

There have been many studies of the effects of rates or timing of N fertiliser applications on yield, but few have examined tuber quality responses. With more potatoes destined for processing, the experiment described in this paper was designed to provide information on the effects of different timings of fertiliser application on both tuber yield and quality. Potato cultivars differ in their quality attributes and suitability for processing and may also vary in their responses to nitrogen fertiliser. Five cultivars were tested, some were developed for the fresh market while others are used mainly by the processing trade.

MATERIALS AND METHODS

The experiment was planted in a Templeton silt loam of medium fertility on the DSIR Experiment Station at Lincoln. The design was a split-plot with cultivars as main plots and N treatments as sub-plots. There were 3 replicates. Five cultivars were tested; three bred at Crop Research Division (Iwa, Tekau and Kaituna), Ilam Hardy, one of the most popular cultivars in New Zealand at present, and an old USA cultivar, Russet Burbank, presently being promoted in New Zealand for processing. Pathogen tested seed tubers were used for all cultivars except Russet Burbank, for which only non-PT seed was available. The N treatments, applied as urea (46%N), were:

N1. Nil N
N2. 150 kgN/ha at planting
N3. 75 kgN/ha at planting + 75 kgN/ha 1 month later
N4. 75 kgN/ha at planting + 75 kgN/ha 2 months later
N5. 75 kgN/ha at planting + 75 kgN/ha 3 months later
N6. 75 kgN/ha at planting + 25 kgN/ha monthly (3×)
N7. 75 kgN/ha at planting + 18.75 kgN/ha monthly (4×)

Treatments N2 to N7 each gave a total of 150 kgN/ha. Soil incubation testing prior to beginning the experiment showed an available nitrogen level of 60 ppm at 0-15 cm depth and 25 ppm at 15-30 cm.

Plots were 3 m wide (4 rows) by 6 m long (20 tubers 30 cm apart) and were separated by buffer rows. 15% potassic super (0:7:7:9) was applied at 1200 kg/ha in the furrows as they were formed the day before planting and the initial N was hand-placed in the furrows. Later N treatments were spread by hand over the mounds. The experiment was planted by hand on 22 October 1987 and then machine moulded. It was re-moulded on 26 November. The pre-emergence herbicide EPTC was applied at 6 l/ha on 20 October and soil incorporated. Metribuzin (at 500 g/ha) was applied on 4 December. A single fungicide spray (mancozeb 2 kg/ha + acephate 0.5 kg/ha) was applied over the area on 21 December. Seven irrigations were scheduled according to a water budget to a total of 225 mm and 184 mm of rain fell during growth of the crop.

The crop was harvested on May 5, 1988, the harvested area in each plot being 8.1 m^2. All samples were machine graded into pig (<45 mm), seed (45-55 mm) and table (>55 mm once misshapen tubers were removed).

The first quality tests were conducted on 1 and 2 June 1988 while further samples of table grade tubers were placed in storage at 10°C. The specific gravity and crisp colour tests were repeated on these tubers on 6 and 7 September 1988. For the quality tests, SG was calculated from the standard equation: weight in air/(weight in air − weight in water). Crisp colour was determined by relative spectral reflectance on an Agtron M-30-A at 640 nm, the higher the reading, the lighter the crisp colour. Sloughing, greying and stem end blackening were scored on the visual appearance of steamed tubers.

Statistical analysis was performed using GENSTAT and Table 1 indicates the analysis of variance used.

TABLE 1: ANOVA table used in the analysis of all results.

	DF
Rep Stratum	2
Rep*Cv Stratum	
Cv	4
Residual	8
Total	12
Rep*Cv*Trt Stratum	
Trt	6
Non vs Some (N1 vs N2-N7)	1
All vs Split (N2 vs N3-N7)	1
Deviations	4
Cv*Trt	24
Dev*Non vs Some	4
Dev*All vs Split	4
Deviations	16
Residuals	60
Total	89
Grand Total	104

TABLE 2: Numbers and mean weights of tubers in table grade.

Treatment		Mean tuber weight (g)	Tubers/m^2
Cultivar:	Iwa	252	27
	Tekau	169	34
	Kaituna	252	34
	Ilam Hardy	251	27
	Russet Burbank	190	18
	SED	9	2
Nitrogen:	N1	202	26
	N2	239	26
	N3	221	29
	N4	223	30
	N5	216	29
	N6	232	28
	N7	227	29
	SED	7	1
	CV%	8.5	12.3

RESULTS

Yield

Iwa, Kaituna and Ilam Hardy produced table-grade tubers of similar size, averaging over 250 g (Table 2). By contrast, Russet Burbank averaged 190 g and Tekau 169 g. Tekau's small tuber size resulted in a greater proportion of tubers in the undersized pig or seed grades, so that while Tekau total yield was equal to Iwa and Ilam Hardy, table yield was significantly lower. Tekau was the slowest cultivar to emerge and the last to senesce. Small tuber size was largely compensated for by having as many tubers per unit area as Kaituna. Kaituna markedly out-yielded all the other cultivars (Table 3) with an average table yield of 70 t/ha and the highest proportion of tubers in the table grade.

Russet Burbank was the lowest yielding cultivar and the first to senesce. Tuber numbers were very low and nearly 25% of table grade tubers were affected by hollow heart. Hollow heart did not occur to any significant extent in the other cultivars.

The high rate of N fertiliser at planting delayed emergence by up to 10 days, delayed tuber initiation and extended the haulm growing period.

TABLE 3: Yield (t/ha fresh weight) and quality of potato tubers.

	Yield			Quality[1]			
	Total	Table	Pig + Seed	Crisp-Colour 1 month	Crisp-Colour 4 month	Specific-Gravity 1 month	Specific-Gravity 4 month
IWA							
N1	66.3	55.5	8.7	34.3	38.0	1.090	1.072
N2	60.9	52.7	6.7	43.3	45.3	1.084	1.081
N3	66.1	56.5	6.8	35.7	37.0	1.081	1.086
N4	67.2	55.6	7.3	38.7	38.8	1.079	1.080
N5	65.4	53.0	8.0	36.3	41.3	1.081	1.083
N6	60.5	50.7	5.6	36.7	38.3	1.080	1.077
N7	67.7	55.7	6.0	35.7	39.0	1.080	1.072
TEKAU							
N1	61.6	41.1	18.8	47.4	45.0	1.088	1.089
N2	59.8	44.3	14.5	44.0	40.0	1.081	1.073
N3	66.0	46.2	18.5	41.8	43.0	1.085	1.074
N4	61.9	44.8	15.9	42.7	45.0	1.082	1.076
N5	67.5	50.8	15.6	42.0	45.3	1.083	1.093
N6	66.5	48.8	17.0	44.3	44.7	1.086	1.097
N7	64.2	48.4	14.0	40.3	40.3	1.082	1.088
KAITUNA							
N1	72.7	61.1	8.9	34.0	34.3	1.082	1.086
N2	70.9	63.0	5.9	35.0	32.0	1.079	1.082
N3	81.4	73.1	5.1	33.0	44.0	1.080	1.086
N4	86.4	75.6	7.4	32.0	35.7	1.080	1.085
N5	80.0	72.3	5.9	34.0	35.7	1.081	1.080
N6	78.9	69.5	5.5	33.3	35.0	1.082	1.072
N7	83.5	74.7	6.2	34.7	39.3	1.081	1.068
ILAM HARDY							
N1	48.8	40.9	4.8	40.6	46.7	1.077	1.084
N2	61.6	52.9	4.1	44.0	49.3	1.070	1.076
N3	65.7	57.2	4.0	42.3	40.0	1.068	1.081
N4	70.9	64.1	4.6	43.0	46.7	1.073	1.079
N5	65.4	57.1	4.2	41.7	48.0	1.072	1.086
N6	68.6	61.1	3.9	45.0	45.0	1.070	1.084
N7	60.6	54.8	4.2	42.7	49.0	1.069	1.084
RUSSET BURBANK							
N1	36.3	17.0	18.4	46.3	41.0	1.083	1.086
N2	43.0	33.7	7.3	48.3	41.3	1.076	1.081
N3	43.3	27.0	15.5	45.0	33.3	1.078	1.081
N4	42.5	30.0	10.9	44.3	42.7	1.078	1.079
N5	39.9	24.8	14.0	45.7	39.0	1.078	1.086
N6	43.7	30.0	13.1	41.7	40.7	1.079	1.084
N7	44.5	29.7	13.8	43.3	44.0	1.078	1.084
SED	5.1	4.4	1.3	2.9	2.0	0.003	0.004
CV%	9.9	10.6	16.5	8.7	8.3	0.3	0.6
Interactions:							
CV*Non-Some	*	**	**	NS	NS	NS	***
CV*All-Split	NS	*	***	NS	***	NS	NS
Cv*Splits	NS	NS	*	NS	**	NS	***

[1]Values above 40 for colour and 1.080 for SG are considered acceptable for processors.

Total tuber yield averaged 63 t/ha of which 51 t/ha was of table (processing) grade. Table 3 shows that individual treatment yields ranged from 17 to 76 t/ha of table grade tubers, with more variability between cultivars than nitrogen treatments.

Total yield was influenced by a significant interaction between cultivars and none vs some treatments. This was caused by Iwa and Tekau showing little treatment differences while Ilam Hardy and Russet Burbank had significantly lower yields in N1 compared with the other N treatments. In contrast again, Kaituna yields were similar in N1 and N2, and the split N treatments were higher. There were no significant differences within the split N treatments.

There was a highly significant interaction between cultivars and none vs some treatments in table grade yields, mainly because Iwa had its highest yield in N1 while the other cultivars had lower yields in N1 than in the split N treatments. There was also a significant cultivar interaction with all vs split, caused by Russet Burbank having its top table yields in N2 while the other cultivars yielded less in N2 than in N3-N7. The interaction disappears if Russet Burbank is removed from the analysis.

Russet Burbank had a very low undersized (pig + seed grades) tuber yield in N2, and this was responsible for many of the interactions. On removal of Russet Burbank from the analysis again, the very highly significant interaction between cultivars and all vs split disappears, as does the highly significant cultivar by none vs some interaction. The significant interaction in the yield of undersized tubers within the split N treatments remained, however, and this must therefore be attributed to each cultivar having it's lowest undersize yield in a different treatment, indicating high variability in the numbers of small tubers produced. The high CV% confirms this.

Quality

Differences in tuber quality were greater between cultivars than between nitrogen treatments. Results for specific gravity and crisp colour tests are presented in Table 3. All tubers sprouted during storage, and these sprouts were removed before testing. Tuber weights were therefore likely to have been reduced although they were not measured. Tubers were also slightly "soft". The correlation in the first tests between DM% (Table 4) and the calculated DM% from SG data (Table 3) using the formula given by von Scheele (1937) was only 40.5%.

In the first crisping tests, the only significant nitrogen treatment effect was that N2 was of lighter colour ($P = 0.003$) than the split applications, which were equal to N1. Cultivar differences were very highly significant, however, Russet Burbank producing the lightest crisps while Kaituna had the darkest. In the repeat tests, three months later, colour values were erratic, resulting in highly significant interactions between cultivars and the split N treatments, and very highly significant interactions between cultivars and N2 versus N3-N7.

The initial tests showed that applications of nitrogen fertiliser, regardless of its timing, reduced tuber specific gravity. Tekau was the cultivar with the highest SG (1.084) while Ilam Hardy was the lowest (1.071). Storage again made results erratic, with very highly significant interactions between cultivars and the split timings of N fertiliser. Overall, crisp colour lightened after storage, except in the Russet Burbank, while SG improved markedly in Ilam Hardy and Russet Burbank.

TABLE 4: Dry matter content (DM%) of tubers about 1 month after harvest and sloughing, greying and stem end blackening of steamed tubers. Scores are on a scale of 1-8, 8 indicating the absence of the character.

Treatment		DM%	Sloughing	Greying	Stem-end-blackening
Cultivar:	Iwa	20.8	6.1	6.7	6.7
	Tekau	21.9	6.7	5.7	6.3
	Kaituna	20.9	6.5	6.2	6.4
	Ilam Hardy	19.3	6.6	6.7	6.7
	Russet Burbank	21.0	6.9	6.2	6.7
	Significance	*	NS	**	NS
	SED	0.6	0.2	0.2	0.2
Nitrogen:	N1	21.7	6.3	6.5	6.7
	N2	20.8	6.6	6.1	6.5
	N3	20.5	6.7	6.4	6.6
	N4	20.8	6.5	6.3	6.5
	N5	20.5	6.8	6.3	6.6
	N6	20.5	6.6	6.2	6.6
	N7	20.5	6.4	6.3	6.5
	Significance	*	NS	NS	NS
	SED	0.4	0.2	0.1	0.2
Cultivar X Nitrogen		NS	NS	NS	NS
	CV%	4.6	8.1	5.9	6.7

The steaming test results are presented in Table 4. Greying was the only steaming quality parameter to show any significant differences between cultivars, and Tekau was the poorest performer. The nitrogen treatments had no effects. These tests were not repeated after 3 months storage.

DISCUSSION

Dyson and Watson (1971) showed that N fertiliser slowed the early growth of King Edward tubers rather than delayed their initiation, and Jefferies and MacKerron (1987) report that nitrogen did not affect the timing of tuber initiation. Ivins and Bremner (1965), however, found tuber initiation to be delayed by high levels of nitrogen, and this is the more commonly accepted effect (R.A. Genet, pers. comm.). The results of this experiment confirm the latter hypothesis. N2 tubers were larger and fewer than the other treatments so initiation must have been reduced by high levels of N early in plant development. A lack of nitrogen (N1) meant lower total and table yields and more undersized tubers, indicating insufficient N to complete bulking.

The timing of split applications of nitrogen had no significant effect on tuber yield. Therefore, split application is better than a high level at planting, unless fewer, larger tubers are required. This may be the case with a cultivar like Tekau.

The potato cultivars tested in this experiment varied in their yield responses to the N treatments. The two earlier maturing cultivars, Ilam Hardy and Russet Burbank, responded most to N fertiliser. The level of Russet Burbank's response (table yield in N1 of 17 t/ha compared with 33 t/ha in N2) suggests that yields may have been even higher if more N fertiliser was applied. Average yields in New Zealand are 30 t/ha. This experiment therefore produced a relatively high yield, although up to 100 t/ha is theoretically possible (Genet, 1985).

The low Russet Burbank yields must be attributed partly to early leaf senescence and partly to the associated presence of virus which reduced apparent green leaf area. Tubers were smaller than the other cultivars, except Tekau, and fewer in number, confirming that they failed to bulk. The large population but small size of Tekau tubers is typical of the cultivar (Genet, 1988).

There were no trends evident with the timing of the second N application on any of the quality parameters. SG and DM% were reduced by N but the timing had no effect on this drop. After storage, the differences in these parameters between the treatments with and without nitrogen varied in an unpredictable manner.

Storage temperature greatly influences crisp colouring: low temperature storage increases the sugar levels and thus increases crisp browning (Burton, 1978). The tubers from this experiment were initially stored in an open shed and were therefore exposed to a wide range of temperatures which may have caused a partial breakdown of starch to sugars. Crisp colour was darker overall than would have been expected. The 10 °C storage temperature used between tests was warm enough to cause a slight improvement in overall crisp colour.

After 3 months storage at 10 °C tubers were badly sprouted, which would be highly undesirable for processors, both because of the inconvenience of removing the sprouts and because of yield loss. Chemicals could have been applied to the tubers to reduce this sprouting, however.

Previous work with the cultivars used in this experiment investigated the effect of N rates. SGs tended to fall with increasing rates of N, with Iwa and Ilam Hardy showing the greatest decline (J.P. Lammerink, unpublished). In the experiment reported here, Ilam Hardy and Iwa were also the cultivars to show the greatest decline in SG with N fertiliser. Lammerink also found that smaller tubers had higher DM% than larger ones and this may explain in part the higher values for Tekau in this experiment.

CONCLUSIONS

Nitrogen fertiliser increased the yield of potato tubers. This increase was greater when N application was split rather than all applied at planting. There was, however, no effect of the timing of the second application on yield.

SG and DM% decreased with nitrogen fertiliser but there were no variations with its timing. Crisp colour was lightest when all the nitrogen was applied at planting but this difference was no longer apparent after tuber storage for 4 months. The quality of steamed tubers did not vary greatly with nitrogen timing.

The recommended split for N fertiliser application resulting from this experiment is half at planting and half 1-3 months later.

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