Evaluation of rapid field methods for determining the nitrogen status of potato crops

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Abstract

Petiole nitrate testing is the current method of monitoring the nitrogen (N) status of the potato crop. It has some drawbacks in terms of timeliness and cost. Two faster and cheaper alternatives are petiole sap testing and measuring chlorophyll content of the leaves *in situ* using a chlorophyllometer. These two methods were compared with petiole nitrate testing in a Russet Burbank potato trial at four rates of N fertilizer. Despite some scatter, sap nitrate was roughly linearly related to petiole nitrate over the critical 0 - 20,000 ppm petiole nitrate range. Above 20,000 ppm petiole nitrate, there was little change in sap test readings. Chlorophyllometer readings changed little until petiole nitrate levels were too low to be measured. It is recommended that the sap nitrate test be further investigated as a substitute for petiole nitrate testing. Unless made much more sensitive, the chlorophyllometer is unlikely to be a useful measure of potato plant N status.

Additional key words: *petiole test, sap test, reflectometer, chlorophyllometer*

Introduction

Processors who brought the cultivar Russet Burbank into New Zealand from America adopted a number of American management techniques for growing this cultivar. One of these was the monitoring of crop nitrogen (N) status from the analysis of dried petioles, taken from the fourth leaf from the tip, for nitrate N content (Kleinkopf *et al.*, 1984). The results are used to indicate whether the crop needs additional sidedressings of N fertilizer. Petiole nitrate status is a sensitive indicator of N status, and is closely related to final yields (Gardner and Jones, 1975; Porter and Sisson, 1991). However, for farmers and consultants, this test has two major drawbacks:

1. Time delay: samples must be sent away for analysis, and it may be several days before corrective action can be taken if the petioles test is low in nitrate.
2. Cost: tests are expensive, and this restricts sampling occasions and the number of samples to be sent.

An in-field technique of measuring potato leaf N would have a number of advantages over the current method:

1. Timeliness: the results are known immediately. Therefore much more rapid responses to any deficit can be made.
2. Inexpensive repeatability: therefore a much more comprehensive picture of the N status of the crop can be built up, particularly if there are changes in soil type, aspect, etc, across the paddock. Any erroneous readings, due to a sick or damaged plant, can be spotted easily.
3. Flexibility: the measurements can be taken as often and as frequently as the farmer requires.

Two such potential methods of measuring leaf N in potato crops in the field are:

1. measurement of the nitrate content in expressed sap using a reflectometer.
2. measurement of the chlorophyll in intact leaves using a chlorophyllometer.

Sap nitrate tests with commercially available nitrate test strips are being successfully used by some farmers and consultants for managing N contents in cereals, following extensive research at Massey (Withers and Palenski, 1984). One drawback in the past was that the method was based on a subjective assessment, the time taken for the strips to develop a certain colour. However, Australian farmers now use hand held electronic reflectometers to read the colour change in the test strips objectively. These have been successfully applied to a wide range of crops in Australia, including Russet Burbank potatoes (Williams and Maier, 1990; Williams, 1991).

A more rapid and non-destructive method of measuring plant N status is the chlorophyllometer, which can be clamped onto the leaf *in situ* to give a rapid

measurement content of the leaf chlorophyll status (Hardacre *et al.*, 1984; Wood *et al.*, 1993). Most of the N in the leaf is in the chlorophyll, and an initial sign of N shortage is a lighter green colour in the leaves. The chlorophyllometer measures the leaf greenness, and has been successfully used overseas to schedule side dressings in crops such as rice and maize (Piekelik and Fox, 1992; Turner and Jund, 1994). The speed of this technique, even compared to the sap nitrate test, could mean considerable benefits if it can be successfully applied to potatoes.

This paper describes a preliminary comparison of the petiole sap test and the chlorophyllometer test with the dried petiole nitrate analysis (Kleinkopf *et al.*, 1984) in a crop of Russet Burbank potatoes with seven fertilizer treatments (Martin, 1995).

Methods

The experiment was carried out on the Crop & Food Research farm at Lincoln in the 1992-1993 season and is fully described by Martin (1995). Because of space limitations, only the results from the rates of N application, averaged over the timing treatments, are presented here. The rates of N applied were nil, 75 kg N/ha, 150 kg N/ha, and 300 kg N/ha.

A 'Nitraquik' test kit for measuring sap nitrate (containing test strips, standard solution and a reflectometer), made in the United Kingdom, was purchased from Aghitec in Australia.

Sampling for petiole and sap nitrate commenced in mid December, when tuber initiation was first noted, and continued at fortnightly intervals until late March, by which time most of the tops were dying off. Ten petiole samples from the fourth leaf from each of three rows in each plot were collected, bulked according to treatments, and taken to the laboratory. Half of the bulked sample was used for the sap nitrate test; three reflectometer readings were taken from each bulked sample on the same day as sampling. The other half of the bulked samples was oven dried at 80°C overnight before forwarding to R.J. Hill Laboratories in Hamilton. All treatments were sampled except at the last sampling when only the two treatments with any green leaf left were sampled.

A chlorophyllometer, based on the design of Hardacre *et al.* (1984), was purchased from Mosaic Systems in Palmerston North. Late delivery of the chlorophyllometer meant that sampling did not start until mid January, and insufficient green leaf was available at the last petiole sampling for chlorophyllometer readings to be taken. So only five sets of chlorophyllometer readings were taken. There was no time for calibration against chlorophyll extracted from potato leaves. The factory setting was, therefore, used throughout..

After the petioles were collected (and on the same or next day if weather conditions permitted), chlorophyllometer readings were taken on the fourth leaf from each of five plants in each plot. Care was taken to ensure that the same part of the leaf was tested each time.

Results

Petiole samples were taken on eight occasions. The petiole analyses over the season are shown in Figure 1. Superimposed on Figure 1 are the zones for excessive, adequate, inadequate and deficient levels adapted fromKleinkopf *et al.* (1984). The petiole analysis could not measure petiole nitrate below 2000 ppm. Figure 1 indicates that the 150 kg/ha application was closest to

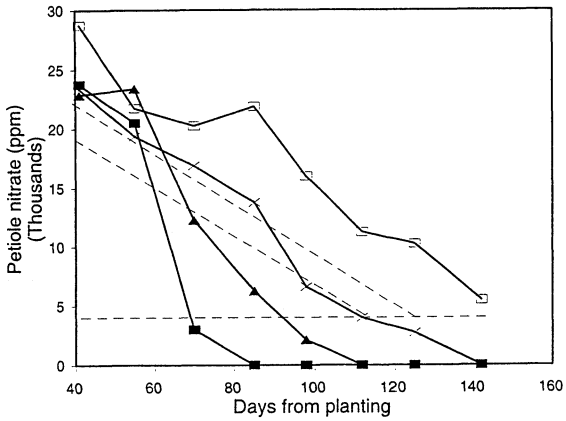

Figure 1. Changes in dried petiole nitrate concentration over time under 4 rates of N fertilizer. ■ = no fertilizer N, ▲ = 75 kg N/ha, × = 150 kg N/ha, □ = 300 kg N/ha. The background levels separated by the dotted lines are those recommended for potatoes in Idaho (Kleinkopf *et al.*, 1984): N levels are excessive above the upper dotted line, adequate between the two sloping lines, inadequate between the lower sloping line and the horizontal line, and deficient below the bottom horizontal line.

adequate levels throughout the season, whereas lower N rates were inadequate or deficient after the first two samplings and 300 kg N/ha was excessive throughout the season.

Equivalent results for sap nitrate are shown in Figure 2, which shows that sap test readings initially increased over time, especially with 300 kg N/ha, but then declined in a similar way to petiole nitrate readings. The sap test could not measure sap nitrate below about 10 units.

Chlorophyllometer readings are shown in Figure 3 and showed little variation between treatments.

A linear relationship was obtained between sap nitrate and petiole nitrate for rates of N fertilizer over the more critical range of petiole nitrate levels (below around 20,000 ppm), but there was some scatter in the readings (Fig. 4). Above 20,000 ppm the relationship between sap and petiole nitrate was poor but there appeared to be little change in sap nitrate levels with increasing petiole nitrate levels. However these mainly occurred at the first two samplings, and may reflect a higher N concentration in leaf petioles in young plants. There appeared to be no effect of fertilizer rate on the relationship between sap and petiole nitrate, so the variation in the readings was not due to treatments.

Figure 5 plots chlorophyllometer readings against petiole nitrate readings. There was little change in chlorophyllometer readings until petiole nitrate levels had fallen below 2000 ppm, i.e., until they were not detectable by the analytical method used. The chlorophyllometer did not measure any difference in leaf

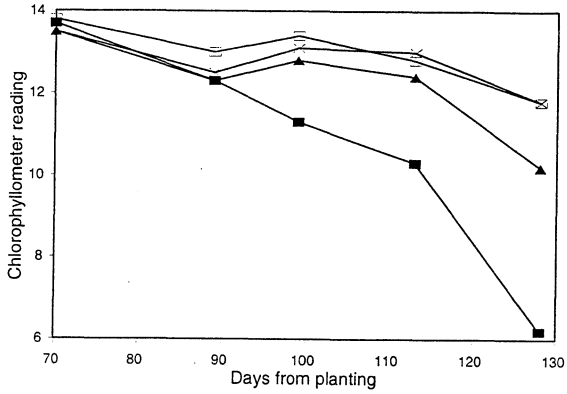

Figure 3. Changes in chlorophyllometer reading over time under 4 rates of N fertilizer. Legend as in Figure 1.

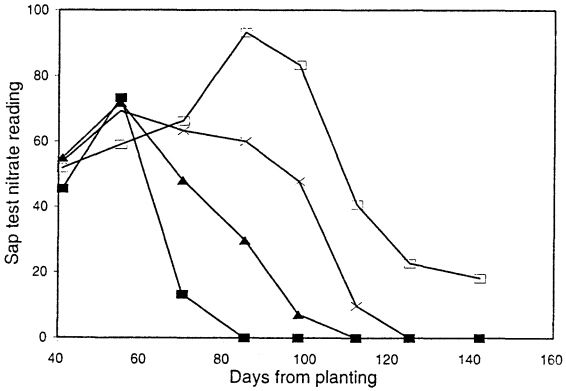

Figure 2. Changes in petiole sap concentration over time under 4 rates of N fertilizer. Legend as in Figure 1.

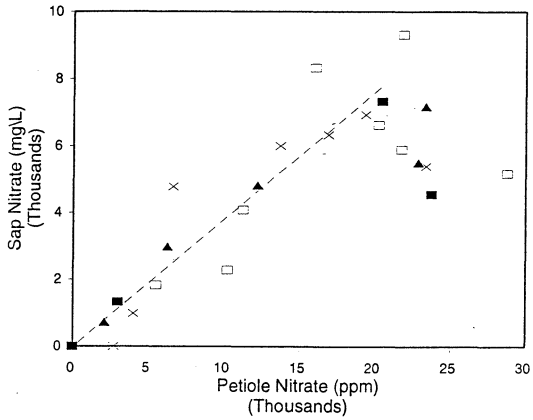

Figure 4. Petiole sap nitrate readings compared to dried petiole nitrate concentration from the same sampling under 4 rates of N fertilizer. Legend as in Figure 1. The regression line is sap nitrate N = 80 + 0.38 petiole nitrate N (r^2 = 0.84 P<0.001).

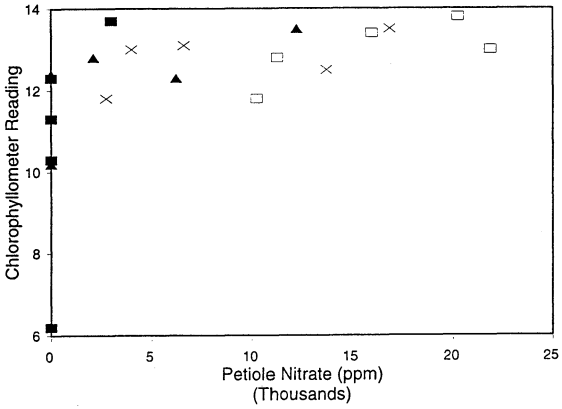

Figure 5. Chlorophyllometer readings compared to dried petiole nitrate concentration at the same sampling time under 4 rates of N fertilizer. Legend as in Figure 1.

chlorophyll until after differences in leaf colour were apparent to the naked eye.

Discussion

Although there was a linear relationship between petiole analysis and petiole sap analysis, there was considerable scatter among the points. MacKerron *et al.* (1995) reported similar results. They found a wide variation in sap nitrate with time of day, probably due to sap nitrate levels reflecting a combination of N uptake by the plant and the rate of transpiration. The latter varies with soil moisture status, time of day and atmospheric conditions. In this trial, samples were taken about the middle of the day, and MacKerron *et al.* (1995) recommend a similar early afternoon sampling - they found that this was most closely related to current and final N uptake. Recommendations for leaf sampling for petiole nitrate also include collection at a certain time of day for consistent results (Alec McErlich pers. comm.). It is likely that sampling time will be more critical for sap testing. New Zealand has a more variable climate than some other potato-growing areas in the world, and so more frequent testing may be required to account for daily differences in transpiration rate. In addition, Palenski Brown and Kemp (1989) found that sap test readings depended not only on the current temperature, but also on any recent major fluctuations in temperature, which they suggest may have longer term effects on sap flow.

MacKerron *et al.* (1995), in a critical examination of sap testing for potatoes, found that the test did not relate well to either short term N uptake or to N taken up throughout the season. It cannot yet be recommended for adjusting top dressings of N fertilizer. However, the results in this paper suggest that the method shows promise, and could possibly be developed into a rapid test to supplement or replace petiole nitrate testing.

Detectable green colour changes in the leaf, as measured by the chlorophyllometer, did not occur until petiole N levels were practically undetectable. So the chlorophyllometer failed to pick up the decline in plant N status recorded by the two petiole methods, but did indicate when the crop was very low in N. In most treatments, this condition did not occur until the crop was maturing and the tops senescing. N applications at this time would have been too late to have had any effect on yield. There was no time to calibrate the machine when it arrived, and so it was used with the factory calibration. Calibration may have improved the ability of the chlorophyllometer to differentiate chlorophyll levels in the leaves (Wood *et al.*, 1993). However, it is probably unreasonable to expect a farmer or consultant to spend time calibrating the machine, and the calibration may vary with any factor that affects leaf greenness, such as cultivar, season and husbandry (Wood *et al.*, 1993), particularly if the factor affects leaf thickness (Peng *et al.*, 1993). Poor relationships between petiole nitrate testing and chlorophyllometer readings in potatoes have also been reported by Fitzgerald and Morrow (1992) and Vos and Bom (1993). The general view from the literature is that the chlorophyllometer will readily identify severe N deficiency in crops, but not how much fertilizer N is needed in more marginal fertility situations (Piekielik and Fox, 1992; Minotti *et al.*, 1994; Turner and Jund, 1994).

Conclusions

The sap test offers promise as a more rapid, alternative N test for potatoes. More research is needed to reduce or explain some of the scatter in the relationship between sap test readings and petiole nitrates.

The chlorophyllometer has little prospect of becoming a useful measure of the N status of the potato plant, unless recalibration makes it much more sensitive to small changes in leaf chlorophyll.

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