# The Potato Calculator: A tool for scheduling nitrogen fertilizer applications

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## Abstract

A simulation model based decision support system, the Potato Calculator (PC), was tested in farmer crops over three years. The purpose of the PC is to provide an accounting system for growers to keep track of the N in their system, and apply additional N fertiliser according to crop need. Two aspects of the PC were tested. 1) the yield and environmental consequences of the PC guided fertiliser advice, and 2) the accuracy with which the PC could predict yield and environmental impacts. In the first two years PC guided advice gave 2.8 t FW/ha lower yields than those obtained by growers using conventional management. In year 3, two changes were made to the PC. 1) a small change to the model that allowed a greater N concentration in tubers, and 2) a change in the criteria for scheduling N from supplying N so that simulated yield was not reduced, to supplying N to ensure N uptake was not limited. The PC guided management in year 3 gave yields equal to conventional management, with a 129 kg/ha reduction in N fertiliser use and reduced soil mineral N at the end of the season. Simulated yields tended to be higher than observations, but in most cases yield variations were matched in simulations.

***Additional keywords:*** simulation model, decision support system.

## Introduction

In New Zealand there is increasing concern that farming and its intensification is a major source of nitrate contamination of aquifers (Williams, 2004). Public concern is shared by the farming community, but farmers are worried this concern may translate into regulation of their crop management and profitability of their operations. This has created interest in nutrient budgeting tools that include environmental accounting. A Sustainable Farming Fund project was funded between July 2002 and June 2005, part of whose purpose was the dissemination and testing of such a tool, the Potato Calculator (PC). An overarching purpose was to provide the means by which growers could improve their N management and profitability.

At the start of the project processing potato growers in Canterbury scheduled N applications based on monitoring of petiole N (Kleinkopf *et al*., 1984). While this shows if the crop needs nitrogen, it is reactive and N deficit may limit yield before N fertiliser can be applied. Such monitoring gives no information on how much N should be applied and may result in insufficient (reducing yield) or excessive N application (creating leaching risk). On the basis of experience, growers are more likely to over- than under-apply fertiliser. In contrast, the PC is a decision support system that uses a model to simulate potato growth, anticipate future N requirement, and schedule N applications to meet this requirement while minimising the possibility of leaching.

The potato model at the heart of the PC is a simple model that grows a canopy of leaves, accumulates and partitions biomass and nitrogen between different plant components and remobilizes biomass and nitrogen to the tubers as the canopy dies. A detailed description of the workings and development of the potato simulation model are given by Jamieson *et al*. (2004). Briefly, the PC uses the same soil physical and N evolution models and similar principles of plant N economy as the wheat model Sirius (Jamieson *et al*., 1998; 2000). The software shell is very similar that developed for the Sirius Wheat Calculator (Armour *et al*., 2002).

The potato calculator takes input data for a site (soil information, emergence date and basal fertilizer) and uses long term mean data from the nearest weather station to run the model and predict crop N requirements and schedule N fertilisation. This is then updated with actual fertiliser application and weather data throughout the potato growth season to give updated N schedules.

This paper describes a test of the PC over three years on five properties. The test compared the impact of management advice using the PC with conventional advice and compared experimental results with those simulated by the potato calculator.

## Materials and methods

The experiment was conducted over three years within commercial potato crops of five different growers in the South Canterbury area. These fields were prepared, planted and managed as normal and all fields received a basal application of 100 kg N/ha. A trial area was marked out in each field and a randomised block design was established with three treatments:

| | |
|---|---|
| Basal N | no additional N. |
| PC N | N applied as scheduled by the potato calculator. |
| Grower N | N applied as for conventional grower practice. |

Each treatment was replicated three times in the first year (2002-03) and four times in the last two years (2003-03, 2004-05). Nitrogen applications were spread by hand to the grower and PC N treatments. In the first two years, the PC scheduled N fertilisation on the basis that no additional yield would be given from additional N. This criterion was changed in the third year to the basis that no additional N uptake would be given by additional N. This increased the amount of N scheduled as the potato model predicts excess N will be taken up by tubers (increases N%) but will not increase yield.

At harvest time a 5 m length of a single row was harvested by hand, tubers were hand graded and yield and dry matter content were measured. In addition to the crop performance data, detailed measurements of soil profile mineral N content were made before the crops were planted and at harvest to calculate N balance. Treatment effects were analysed using ANOVA with replicates and growers as blocks.

## Results

### Trial outcomes

The basal N treatment (105 kg N/ha) produced a mean yield of 69.6 t FW/ha over the 2002-03 and 2003-04 years of this experiment (Table 1). The PC N treatments received an additional 60 kg N/ha and produced 2.9 t/ha more ($P<0.01$) FW than the basal treatment. The marginal response to the additional N in the PC treatment above the basal N treatment was 48.3 kg FW/kg N. The grower N treatment produced a further 2.8 t FW/ha more ($P<0.01$) than the PC N treatment but an additional 132 kg N/ha was applied to achieve this increase. As a result the marginal response to the additional N above the PC N treatment was 21.2 kg FW/kg N for the Grower N treatments. The N% of tubers increased ($P<0.001$) from 1.36% in the basal N treatment to 1.62% in the Grower N Treatment. Overall the amount of N removed by tubers in the grower treatment was 27 kg/ha more ($P<0.001$) than the PC N treatment which was 31 kg/ha more than the basal N treatment (Table 1).

In the 2004-05 year the basal N application (100 kg N/ha) had a yield of 63.0 t FW/ha (Table 2). The revised N application criteria in the PC N treatment meant they received on average 20 kg/ha more N than in the previous two years (185 kg/ha in total). The PC N treatment produced 4.3 t FW/ha more (P<0.01) than the basal treatment. However, the yield of the grower N treatment (68.6 t FW/ha) was no greater than the PC N treatment in this year in spite of receiving 129 kg/ha more N. The Grower N treatment did have a higher (P<0.001) tuber N% (1.88%) than the PC and basal N treatments (1.63-1.73%) and 20 kg/ha more (P<0.001) N was removed in harvested tubers as a result (Table 2). However, this difference did not account for all of the additional N applied and the soil residual N after harvest was increased (P<0.01) by the higher N application rates of the PC N and grower N treatments (Table 2).

**Table 1. Nitrogen application (kg/ha), tuber yield (t FM/ha), marginal N response (kg FW/kg N) and residual soil N (kg/ha) from 2002-03 and 2003-04.**

| | Basal N | PC N | Grower N | LSD |
|---|---|---|---|---|
| N applied | 105 | 165 | 297 | |
| Tuber yield | 69.6 | 72.5 | 75.3 | 2.63 (df=93) |
| Marginal N response | | 48.3 | 21.2 | |
| Tuber N (%) | 1.36 | 1.50 | 1.62 | 0.073 |
| Tuber N (kg/ha) | 222 | 253 | 280 | 19.8 |

**Table 2. Nitrogen application (kg/ha), tuber yield (t FM/ha), marginal N response (kg FW/kg N) and residual soil N (kg/ha) from 2004-05.**

| | Basal N | PC N | Grower N | LSD |
|---|---|---|---|---|
| N applied | 100 | 185 | 314 | |
| Yield | 63.0 | 67.3 | 68.6 | 3.55 (df=53) |
| Marginal N response | | 50.6 | 7.0 | |
| Tuber N (%) | 1.63 | 1.73 | 1.88 | 0.066 |
| Tuber N (kg/ha) | 224 | 252 | 272 | 18.7 |
| Soil Residual N | 66.6 | 72.3 | 115.4 | 13.64 |

**Model performance**

The ability of the potato calculator accurately to schedule N applications depends on the ability of the underlying simulation model to accurately predict crop yield and N uptake. The model was run retrospectively for each of the treatments with actual weather and nitrogen data for each treatment and predicted yields were compared with measured yields (Figure 1). Generally, the model performed well, but tended to give slight over estimations in most instances and gave large over-estimates for one grower in two of the three years. These overestimations suggest there is some factor limiting yield below potential (disease, water stress, nutrient deficiency) that the model is not accounting for. There was also good agreement between observed and predicted soil N at the conclusion of experiments in the 2004-05 year showing the model was able to predict crop N removal well.

## Discussion

A major purpose of the project was to provide potato growers with a credible nutrient management tool to effect an improvement in their N-fertiliser management. The first part of the effort was aimed at establishing credibility. In the early part of the project we did not encourage the participating growers to use PC-guided management because we lacked

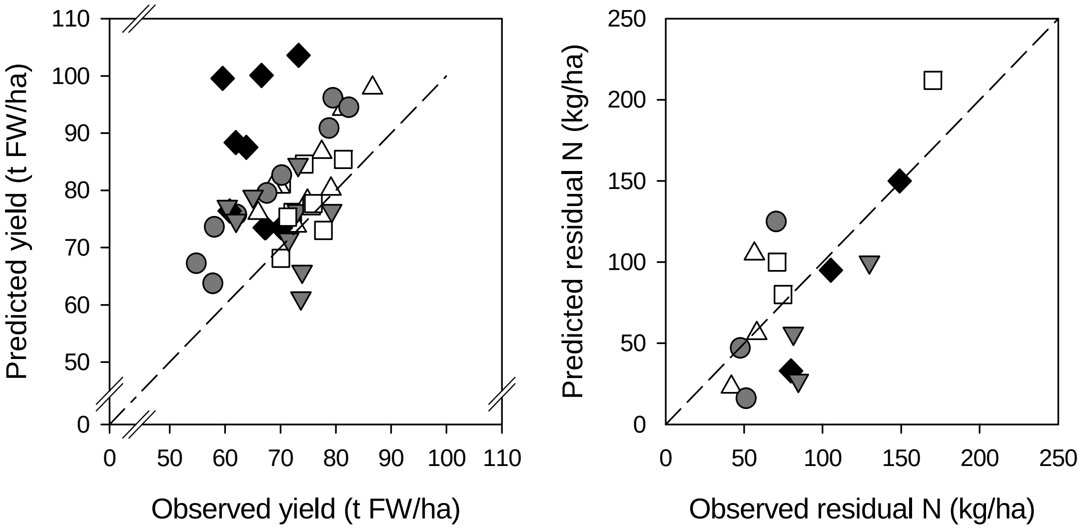


**Figure 1. Predicted and observed tuber yield for the 2002-03 to 2004-05 seasons and residual soil N after harvest for 2004-2005 season. Symbols represent different growers, and the line represents Y = X.**

confidence ourselves that the PC was entirely reliable. That lack of confidence was justified by the results. The model underlying the PC underestimated the amount of N needed to keep the canopy green throughout the life of the crop. That led to lower than optimum N applications and the yield reductions noted in Table 1. We traced this problem to an underestimate in the maximum tuber N concentration, set in the model initially at 1.6% of the tuber biomass from data collected by Martin *et al.* (2001). This is less than the concentrations observed in the experiment (Tables 1 & 2). Accordingly, we increased the maximum tuber N content to 2.0% of tuber biomass, increasing the size of a major plant sink. Additionally, we changed the criterion for additional N applications from requiring that N would result in no simulated yield reduction, to requiring that residual N at harvest was minimised. This gave the results in Table 2, and thereby established the credibility of the PC. As an indication of that acceptance, South Canterbury growers are now testing the PC at the paddock scale, (J. Jackson, McCain Foods Ltd, Pers. Comm.).

## Conclusions

In most conditions, the PC provided accurate predictions of yield response to season and N supply, although it had a tendency to overestimate yields. It also provided good predictions of residual soil N at harvest – the N that contributes to leaching risk in the following winter. Importantly, the use of the PC as a scheduling tool has been shown to allow reductions in N fertiliser without yield penalty.

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