# Site Specific Management of Potatoes

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# ABSTRACT

Potato crops have many characteristics that make them suitable for precision agriculture, such as a high value with costly inputs of pesticides, fertilizer and water. The application of fertilizer and pesticides on potatoes may cause environmental problems and the risks of these can be reduced by using precision farming techniques. This potential for use of precision agriculture technology has not been exploited to any great extent because problems exist which have not been fully resolved. Between 1996 and 1999 a project on the site specific management (or precision farming) of potatoes was undertaken. The goals of the project were to utilize yield monitoring and global positioning technology to generate maps and to measure the variability of the yield of potatoes in a field; to determine the effect of soil type, landscape position, nutrient level, fertility treatments, disease and weeds on the yield of potatoes; to determine yield and variability of crops over several years and relate this to field characteristics and to potato yield and quality; to evaluate the use of remote sensing and digital image analysis to detect nutrient deficiencies and diseases of potatoes; to measure the financial and environmental benefits of site specific management of potatoes; and to measure the movement of nitrogen below the root zone.

A yield monitor was successfully adapted to two farmers' potato harvesters and used to map tuber yields. Difficulties were encountered on parts of fields where soil lumps occurred, usually on areas with a high clay content. Yield maps were also developed from grid sampling. These grid samples were used to determine tuber yield, average tuber size and tuber quality as measured by specific gravity, chipping score and French fry score. Uniformity of irrigation affected tuber size. No relationship was found between chipping and French fry score and the measured factors of soil or water in the field. Grid sampling of the fields also showed variability in soil texture, which was correlated to various soil and plant chemical properties.

Two of six fields had sufficient variability of soil nitrogen to justify the cost of soil sampling and variable rate application. However, petiole $NO_3$-N in the first week of July was significantly negatively related to 0.0-0.60 m depth of soil clay and was not significantly related to soil $NO_3$-N. This means it would be more useful for farmers on these fields to base a site specific nitrogen application on soil clay content than on soil $NO_3$-N content. Soil P was significantly positively correlated to petiole P content but not clay content. Opportunities exist for precision applications of phosphorus particularly on two of the fields that had a history of receiving non-uniform applications of manure. However, phosphorus fertilizer applications based on grid sampling of soil phosphorus should provide some improvement in efficiency of uptake of phosphorus. Potassium levels in the soil from 1997 to 1999 were marginal to adequate on most grid sample sites. In 1997 and 1998 petiole K levels were deficient in the first week of July but became adequate to high in two later samplings. The reason for this is not known. It may be due to lower soil temperatures in early July restricting uptake, rather than the higher soil temperatures in the USA where the standards for petiole K were developed. There is a need to develop local standards for petiole K levels.

Precision fertilizer application is practiced on some potato farms in Canada, but the use of this technology is limited by the cost of soil sampling and analysis to accurately describe the field. If precision agriculture technology is to have widespread adoption in the potato industry, solutions to the obstacles of cost, soil lumps and other problems need to be incorporated into the technology.

# INTRODUCTION

Since 1991, Global Positioning System (GPS) technology and yield monitoring equipment has made it possible to develop detailed yield maps of various crops. Farmers in the USA, Canada and Australia are interested in GPS as a means to increase profits by optimizing fertilizer applications. In western Europe, GPS has been used to avoid environmental contamination from excess application of fertilizers and manure. Other computer technology makes it possible to overlay maps of yields, soil or crops and measure relationships between them.

Since 1994, site specific management of cereal and oilseed crops in Alberta has increased steadily. Today, about 300 farmers in Alberta use yield monitors and some of these prepare yield maps of their fields. Site specific management of inputs can be done in a detailed or in a general manner by dividing the field into a few categories (Bouma et. al., 1995). Variable rate inputs can be applied with the assistance of GPS by a programmable fertilizer or herbicide applicator. Prototype irrigation systems have been developed to apply variable rates of water. (King et. al., 1995).

Potatoes are a high value crop requiring a lot of inputs, such as fertilizer, pesticides and irrigation. Potatoes are often grown on coarse textured soils that have low nutrient holding capacity and are high in field variability. Excess nitrogen can delay maturity of the crop and contribute to groundwater contamination. With the use of site specific management zones, with soil texture as a variable, the contamination of water can be reduced (Delgado and Duke, 2000; Whitley et. al., 2000). Insufficient nitrogen will reduce yield and increase the severity of early blight in potatoes. Phosphorus fertilizer applications for potatoes are higher than other crops, which represents an appreciable cost to farmers who are often growing potatoes on rented land. High phosphorus application may cause excess soil phosphorus, the major agricultural factor that contributes to water contamination. This results in the rapid growth and decay of algae in lakes, streams and rivers causing eutrophication and fish death. Recommendations for phosphorus requirements of potatoes by Tindall et. al. (1991) exceed those measured in a precision agriculture experiment by Davenport et. al. (1999). Traditional research under small plot conditions does not account for field variability and is usually conducted on uniform sites. The production of irrigated potatoes in southern Alberta has increased from about 9,000 ha in 1992 to

18,000 ha in 2000 and further increases are expected. If potatoes are grown in a one crop per four years rotation, 72,000 ha will be required or more than 13% of the irrigated land in Alberta. This expansion means fields are being used which are less than optimum for potato production.

Potato processors are concerned about uniform quality of tubers. By controlling storage conditions, processors can alter the sugar content of a storage bin of potatoes to an optimum level for processing. However, this is difficult in a storage bin of potatoes where the original quality is not uniform. For processing, the size and shape of tubers are important. As well, a high specific gravity in potatoes means there is more dry matter for making chips or French fries and the tubers will store well. However, two producers of French fries have encountered problems with some Alberta tubers having excessively high specific gravities, which interfered with processing. Other factors that are detrimental are the presence of disease or hollow heart.

Potato fields are closely monitored during the growing season. Many growers sample leaf petioles and monitor each field on a weekly or biweekly basis for nitrogen nutrition. During the growing season when required, fertilizers are added by fertigation or pesticides are applied to control diseases, insects or weeds. Most observations are based upon repeated sampling of a specific area within the field. The area sampled may only be representative of a portion of the field. Growers need to have some idea of the variability within a field when applying inputs to the field (King et. al., 1999; Verhagen, 1997).

A yield monitor for potatoes consisting of load cells mounted under the harvester belt was first built by Harvestmaster (Campbell, 1999) and tested by the USDA near Prosser, Washington in 1995 (Rawlins et. al., 1995; Schneider et. al., 1997). The harvester position in the field was continually located by means of a differential global positioning system. C. McKenzie and M. Green observed these tests and concluded it merited evaluation on Alberta fields as a means to measure tuber yield and correlate this to soil and crop conditions. Since that time, other yield monitors have been developed consisting of load cells on a weigh wagon (Godwin et. al., 1999) or with a camera and computer to identify tubers from other irregular objects (Wooten et. al., 2000).

## OBJECTIVES

1. To use a potato harvester equipped with a yield monitor and global positioning technology to generate maps and to measure the variability of the yield of potatoes in a field;
2. To determine the effect of soil type, landscape position, nutrient level, fertility treatments, disease and weeds on the yield of potatoes;
3. To determine yield and variability of crops over several years and relate this to field characteristics and to potato yield and quality;
4. To evaluate the use of remote sensing and digital image analysis to detect nutrient deficiencies and diseases of potatoes;
5. To measure the financial and environmental benefits of site specific management of potatoes;
6. To measure the movement of nitrogen below the root zone.

## DEVIATIONS FROM OBJECTIVES

Remote sensing data with spectral analysis was obtained in the first year (1996) of the project on one field at Hays and in the fourth year (1999) at Hays and Fincastle. In 1997 and 1998 false color infrared imagery data was obtained on two fields. This type of infrared imagery was not useful for detailed analysis. In 1998 satellite multispectral imagery was obtained from Resource 21 and it was not feasible to do detailed analysis.

Yield of potatoes and yields of the previous crops on these fields was only obtained on two fields in 1997. Some of the other crops were sugarbeets for which a yield monitor was not available. Some of the grain was harvested with an older model combine, which was not suitable for attaching a yield monitor. Some grain fields were harvested with a custom operator who was not agreed upon until commencement of harvest. This did not provide an opportunity to install a yield monitor, so these fields were not monitored.

Nitrogen movement below the root zone was difficult to distinguish from residual nitrogen, which was also present in the till parent material. Only estimates of nitrogen movement through the soil profiles could be made.

In 1999, at the Hays site, treatments of compost and manure were applied in strips, to determine whether or not they would affect the incidence of *Rhizoctonia* and scab on tuber surfaces.

### Soil Salinity

Using Global Positioning techniques (Cannon et. al., 1994), soil salinity was mapped on a field with an EM38 meter (McKenzie et. al., 1989) in order to compare growth of potatoes to soil salinity (McKenzie et. al., 1997). This method would evaluate the potential of mapping a field for soil salinity and limiting planting of potatoes only on those areas with less than a critical salinity level. A salt tolerant crop could be planted on the remainder of the field. This objective was not included in the original objectives.

## RESEARCH DESIGN AND METHODS

### Fields Monitored

In April 1996, two cooperating farmers were selected who agreed to provide one potato field each year for four years. Each irrigated field consisted of half a center pivot or 27 to 31 ha. The farmers were using a three-year rotation. This meant in the fourth year the project would return to the field monitored in the first year. The fields for one farm were located about 12 to 13 km south of Hays, Alberta, and fields for the other farm were from 3 to 10 km north of Fincastle, Alberta.

The legal location, soil type, number of grid sampling points, type of irrigation system and variety of potatoes grown for the fields monitored are given in Table 1. A sampling grid was set up on each field (Fig. 1). In 1996, this grid was established in the spring after seeding of potatoes. In 1996, the single soil samples taken were used to determine soil texture and water holding capacity. In the next three years, the grid was established in the fall of the preceding year with a set of composite soil samples from about 12 cores taken before fertilizer was applied. These samples (Table 2) were used to determine texture, water holding capacity and soil fertility. The grid sampling points were located with differential GPS.

The choice of potato cultivars and field practices were left up to the individual farmer cooperators. Field practices and cultivars can be considered as typical for irrigated potato production in southern Alberta. The cultivars Snowden and Frito Lay 1625 are both chipping types while the Russet Burbank are fryers (Table 2). They are all considered as "late" varieties. Farmer experiences are that Russet Burbank have demonstrated better response to higher nitrogen fertilizer applications thus, they are fertilized more heavily. Frito Lay 1625 are also noted for their extensive rooting (vertical and horizontal) so they may be able to better exploit soil fertility. Farmers used their normal methods of seeding, cultivation, irrigation, pest control and harvest of their potato fields. The farmers' fertilizer applications are given in Table 3. Soil nitrogen, phosphorus, potassium values in 1996 were obtained from the farmers' records and in 1997, 1998 and 1999 were obtained from the grid samples (Table 4) and from the farmers' or fertilizer company's records. Soil phosphorus was determined by the Kelowna method (Van Lorop, 1988) and soil potassium was determined by the ammonium acetate methods in 1999. In 1997 and 1998, soil potassium was determined by the Kelowna method (Van Lorop, 1988), which gives lower values than the ammonium acetate method.

**Table 1. Legal location and legal description of potato fields monitored and date first irrigated.**

| Year/Site | Legal Land Location | Soil Type | First Irrigated | Pivot Irrigated |
|---|---|---|---|---|
| **1996** | | | | |
| Hays | E½ NE 9 12 14 W of 4 | from 0-120 cm<br>Aeolian loamy sand overlying fine lacustrine till | 1978 | 1994 |
| Fincastle | E½ NW 7 11 14 W of 4 | Chin light loam<br>Fluvial lacustrine | 1956 | 1984 |
| **1997** | | | | |
| Hays | W½ NE 9 12 14 W of 4 | from 0-120 cm<br>Aeolian loamy sand overlying fine lacustrine till | 1978 | 1994* |
| Fincastle | W½ NW 27 10 15 W of 4 | Cavendish loamy sand and dune sand | 1956 | 1987 |
| **1998** | | | | |
| Hays | W½ SE 9 12 14 W of 4 | from 10-120 cm<br>Aeolian loamy sand overlying fine lacustrine till | 1978 | 1994* |
| Fincastle | E½ NW 27 10 15 W of 4<br>E½ SW 34 10 15 W of 4 | Cavendish loamy sand and dune sand | 1956 | 1987 |
| **1999** | | | | |
| Hays | E½ NE 9 12 14 W of 4 | from 10-120 cm<br>Aeolian loamy sand overlying fine lacustrine till | 1978 | 1994* |
| Fincastle | E½ NW 7 11 14 W of 4 | Chin light loam<br>Fluvial lacustrine | 1956 | 1984 |
| Vauxhall | S½ SW 5 13 6 W of 4<br>E½ 5 13 6 W of 4 | Clay loam to loam overlying<br>Clay loam to clay till at about 1 m | 1921 | 1995 |

* pivot converted from high pressure to low pressure in 1997

**Table 2. Sampling sites, irrigation systems, field size and variety of potatoes grown.**

| Year/Site | # of grid sampling sites | Type of pivot Irrigation system | Field area (ha) | Cultivar of Potatoes |
|---|---|---|---|---|
| **1996** | | | | |
| Hays | 40 | High pressure | 28 | Snowden |
| Fincastle | 8 | High pressure corner | 30 | Frito Lay 1625 |
| **1997** | | | | |
| Hays | 47 | Low pressure | 29 | Snowden |
| Fincastle | 53 | High pressure corner | 31 | Russet Burbank |
| **1998** | | | | |
| Hays | 48 | Low pressure | 29 | Snowden and others |
| Fincastle | 63 | High pressure corner | 30 | Russet Burbank |
| **1999** | | | | |
| Hays | 53 | Low pressure | 28 | Snowden |
| Fincastle | 51 | High pressure corner | 31 | Frito-Lay 1625 |
| Vauxhall | 33 | 2 low pressure | 115 | Russet Burbank |

## Soil Moisture and Water Tables

Alberta Agriculture Food and Rural Development (AAFRD) Irrigation Branch staff from Taber and Brooks monitored soil water at each of the grid sampling points with a neutron probe. Soil moisture was determined to a depth of 1.0 m. Available moisture limits were calculated from particle size data according to Oostervelt and Chang (1980). A rain gauge was installed at each sampling point and rainfall and irrigation measurements were made approximately biweekly.

In 1997 and 1998 the groundwater was measured with 3 to 6 piezometer nests in each field (Rodvang, 1998 and 1999). The goal was to characterize groundwater flow and chemistry on the sites and determine whether agricultural nitrate occurred in the groundwater. Soil samples were collected during drilling and groundwater samples were collected during the season.

## Fertilizer and Soils

Soil available nitrogen (N), phosphorus (P), and potassium (K) and soil pH maps were made for the 1997, 1998 and 1999 fields based on data collected the previous October from the sampling grid (Table 4). Soil texture maps were made from all fields based on grid samples (Fig. 2), which were used to develop relationships between texture and nutrient availability. In 1999, at Fincastle and Hays, soil calcium carbonate levels were determined and used to prepare maps at both sites.

## Fertilizer Treatments

In 1997, 1998 and 1999, strip fertility experiments were set out. In 1997, the treatments (Table 5) applied were centered around the N2 treatment (farmer rate) (Table 3). Each strip was 8 rows or 6.7 m wide on the Snowden field and 8 rows or 7.3 m wide on the Russet Burbank field. In 1998, the fertilizer strips were in addition to the farmers' fertilizer rates (Table 6). Each strip was 6 rows wide or 5.03 m at Hays and 5.49 m at Fincastle. This represented one pass of the potato harvester. Yields were acquired and positioned on the fertilizer strips in 1997 and 1998 with GPS and a yield monitor on the farmers' potato harvesters.

In 1999, fertilizer plots were set out at Hays. Each plot was 12 rows or 10.1 m wide by 400 m long and was replicated twice. Compost manure and fertilizer treatments (Table 7) were broadcast on the plots in October of 1998. The plots were not fertilized by the farmer, except for 41 kg/ha N at seeding and a fertigation application of 50 kg/ha N during the growing season. The potatoes were hilled and seeded by the farmer in April of 1999. Snowden potatoes were grown and the field was fertigated (Table 3) and irrigated similar to the remainder of the field. Counts of visibly diseased plants on 600 m rows in each treatment were made in August of 1999.

**Table 3. Farmers' soil fertility (N, P and K) before fertilization and N, P and K fertilizers applied and depth of soil samples (kg/ha).**

| | | **Hays (kg/ha)** | **Fincastle (kg/ha)** |
|---|---|---|---|
| 1996 | Soil N Fall 95[?] | (29) 0.0-0.30 m | (73) 0.0-0.60 m |
| | Fertilizer N prior to seeding | 120 | 59 |
| | Banded N at hilling | 34 | 0 |
| | Fertigated N | 58 | 11 |
| | **Total N** | **241** | **144** |
| | Soil P | (35) 0.0-0.30 m | (67) 0.0-0.30 m |
| | Fert P | 48 | 32 |
| | **Total P** | **83** | **99** |
| | **Total K** not available | | |
| 1997 | Soil N 0.0-0.60 m | 37 | 67 (52) |
| | Fert N Fall 96 | 90 | 0 |
| | Banded N at hilling | 39 | 179 |
| | Fertigated N | 88 | 41 |
| | **Total N** | **254** | **287** |

**Table 3. Farmers' soil fertility (N, P and K) before fertilization and N, P and K fertilizers applied and depth of soil samples (kg/ha).**

| | | Hays (kg/ha) | Fincastle (kg/ha) |
|---|---|---|---|
| | Soil P 0.0-0.15 m<br>0.0-0.30 m | 24 | 196 |
| | Fert P Fall 96 | 59 | 0 |
| | Fert P Spring 97 | 0 | 7 |
| | 6 fertigations | 22 | |
| | **Total P** 0.0-0.15 m | **195** | **203** |
| | Soil K 0.0-0.30 m | 685 | 1066 (1935) |
| | Fert K Fall 96 | 56 | 0 |
| | Fert K Spring 97 | 0 | 46 |
| | **Total K** | **741** | **1112** |
| 1998 | Soil N 0.0-0.60 m | 28 | 32 |
| | Fertilizer N Fall 97 | 179 | 190 |
| | N at seeding | 0 | 20 |
| | N at hilling | 47 | 35 |
| | 6 fertigations | 50 | 31 |
| | **Total N** | **304** | **308** |
| | Soil P 0.0-0.15 m | 41 | 67 |
| | Fertilizer P Fall 97 | 58 | 46 |
| | Fertilizer P at seeding | | 29 |
| | **Total P** | **99** | **142** |
| | Soil Kelowna K 0.0-0.15 m | 591 | 627 |
| | Fertilizer K Fall 97 | 74 | 74 |
| | **Total K** | **665** | **701** |
| 1999 | Soil N 0.0-0.60 m | 38 | 90 |
| | Fertilizer N Fall 98 | 157 | 112 |
| | Fertilizer N at hilling | 41 | 20 |
| | Fertigations of N | 50 | 30 |
| | **Total N** | **286** | **252** |
| | Soil P 0.0-0.15 m<br>0.0-0.30 m | 47<br>71 | 93<br>127 |
| | Fert P Fall 98 | 59 | 39 |
| | Fert P Spring | 0 | 29 |
| | **Total 0.0-0.15 Soil P** | **106** | **161** |
| | Soil K 0.0-0.30 m | 757 | 733 |
| | Fertilizer K Fall 98 | 56 | 56 |
| | Fertilizer K Spring | 0 | 0 |
| | **Total K** | **813** | **789** |

? ( ) soil nutrient values supplied by the farmer from his soil sampling

**Table 4. Soil analys is done for the site specific potato project.**

| Year | Sand (%) | Silt (%) | Clay (%) | $NO_3$ – N (ppm) | NH4-N (ppm) | Miller Axley $PO_4$-P(ppm) | Kelowna $PO_4$-P (ppm) | Ammon Acetate K (ppm) | Kelowna K (ppm) | pH | 2:1 extract E.C. (dS/m) | Zn (ppm) | Cu (ppm) | Mn (ppm) | Fe (ppm) | Na (ppm) | $CaO_3$ (ppm) | S (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1996 sampled May 26 0.0-0.90 m | † | † | † | - | - | - | - | - | - | - | - | - | | | | - | - | - |
| 1997 sampled Oct.96 0.0-0.90m | † | † | † | † | 1/6 of profiles | † | 0.0-0.15 m<br>0.15-0.30 m | | 0.0-0.15 m<br>0.15-0.30 m | † | † | 1/6 of 0.0-0.15 m samples | | | | | Hays | |
| 1998 sampled Oct. 97 0.0-0.90m | † | † | † | † | † | † | 0.0-0.15 m<br>0.15-0.30 m | | 0.0-0.15 m<br>0.15-0.30 m | † | † | 0/0-0.15 m | | | | | | |
| 1999 sampled Oct. 98 0.0-0.90 m | † | † | † | † | † | † | 0.0-0.15 m<br>0.15-0.30 m | † | 0.0-0.15 m<br>0.15-0.30 m | † | † | 0.0-0.15 m | | | | † | 0.0-.15<br>0.15-0.30 | † |

† all samples analyzed

Samples were dug from each treatment and treatment yields were determined using a yield monitor and GPS on the farmer's harvester. Disease counts of the amount (%) of tuber surfaces infected with scab and *Rhizoctonia* were determined on 160 tubers from each treatment. Occurrence of disease was not significantly different between treatments so this data is not reported.

**Table 5. Nutrients (N, P and K) in kg/ha applied on fertilizer strips in 1997.**

| | Hays | | | Fincastle | | |
|---|---|---|---|---|---|---|
| **Treatment** | **N** | **P** | **K** | **N** | **P** | **K** |
| N1 | 30 | 59 | 50 | 53 | 6 | 41 |
| N2 | 92 | 59 | 50 | 176 | 6 | 41 |
| N3 | 182 | 59 | 50 | 311 | 6 | 41 |

**Table 6. Nutrients (kg/ha) applied in 1998 on fertilizer strips in excess of farmers rate to Hays and Fincastle fields.**

| Treatment | N | P |
|---|---|---|
| N | 67 | 0 |
| P | 0 | 32 |
| NP | 67 | 32 |
| Check | 0 | 0 |

**Table 7. Fertilizer treatments at Hays in 1999.**

| | | Nutrients kg/ha | | |
|---|---|---|---|---|
| **Treatment** | **T/ha** | **N** | **P** | **K** |
| High compost | 18.1 | 199 | 84 | 174 |
| Low compost | 9.8 | 107 | 45 | 94 |
| High manure | 26.8 | 158 | 82 | 216 |
| Low manure | 12.8 | 75 | 39 | 103 |
| High phosphorus | | 90 | 58 | 0 |
| Low phosphorus | | 90 | 20 | 0 |

## Tissue Samples

Each field was tissue sampled three times at each of the grid points (early July, late July and the second or third week of August). Tissue samples consisted of 45 to 70 petioles taken from the fourth leaf of plants within 5 m of the grid sampling points. All the tissue samples were analyzed to determine $NO_3$ N, total N, P, Ca and moisture. In 1996 and 1997, 24% of the samples, and in 1998 and 1999, all the samples, were analyzed to determine K, S, Zn, B, Mn, Fe, Mg, Al, Cu, Na (Table 8). These tissue levels were compared to sufficiency limits (Table 9) based on limits used by various Alberta and USA soils laboratories.

## Pest Monitoring

Diseases were monitored by walking the fields. Some areas of the Hays fields received excess water and developed water-induced rot of tubers. These areas were not harvested. In 1999 fertilizer, compost and manure treatments were set out as strips on the Hays field. Disease counts were made on two rows from the three 50 meter long strips from each of the two replicates of the treatments. The 1999 Vauxhall and Fincastle fields had very little disease on all fertilizer treatments so no disease counts were made in these fields.

In 1996 to 1998 weeds in all fields were widely dispersed and not clustered so they were not mapped with GPS or remote sensing techniques. In 1999 dense areas of Canada Thistle (*Cirsium arvense*) occurred on the Hays field. The perimeters of some of these GPS areas were mapped with differential GPS, by walking with a backpack unit obtaining correction data from a base station at the edge of the field. These areas were then located on the CASI images of the field.

## Remote Sensing

In July 1996, Itres, a commercial remote sensing firm, collected airborne compact spectographic imager (CASI) data on the Hays potato field. Alberta Environment took color infrared photos at a scale of 1:5,000 and 1:10,000 on July 14, 1997, at Hays and Fincastle; July 23, 1998 at Hays and Fincastle and July 23, 1999 at Hays, Fincastle and 1:15,000 photos at Vauxhall. On July 28, 1999, CASI data were taken of the Hays, Fincastle and Vauxhall potato fields by Itres. GPS positions of ground control points were taken and used to prepare georeferenced images.

## Tuber Samples

In 1997, 1998 and 1999, two samples were hand dug near each grid point prior to harvest. Each hand sample consisted of four uniformly spaced plants in 1.22 m of row. The farmer at Fincastle used 0.91 m row spacing between rows and the farmer at Hays used 0.84 m spacing between rows. In addition, in 1999, four samples were hand dug from each replicate of each fertilizer treatment.

The potato samples were washed, graded into size categories and weighed to determine yield. Scab and *Rhizoctonia* scores were made on 20 tubers from each sample from Hays in 1998 and both Hays and Fincastle in 1999. Samples were chipped and chipping quality color scores were done on the Hays tuber samples in 1997, 1998 and 1999. Samples were French fried and French fry quality, color and texture scores were done on the Fincastle tuber samples in 1997, 1998 and 1999.

## Global Positioning Systems and Yield Monitoring

Global positioning techniques were used to locate points on the grid for sampling tubers (Table 10). At harvest, the potato fields were mapped using a NovAtel GPS and a Harvestmaster yield monitor mounted on the farmer's potato harvester (Campbell, 1999). The NovAtel RT-20 DGPS delivered accuracies of 0.20 m horizontal and 0.30 m vertical. A topographic map was prepared at the same time as the yield map. In 1997, wheat and barley fields were yield mapped using an Ag Leader yield monitor coupled to an Omnistar receiver, with real-time differential corrections from a geostationary satellite service. This system provided accuracies of 0.5 to 1.0 m horizontal and 1.0 to 2.0 m vertical. The Omnistar information was not suitable to use to prepare topographic maps because of the lack of accuracy in the vertical axis.

## Soil Salinity

The site at Vauxhall was chosen in 1999 because it contained a range of soil salinity. Potatoes are considered to be moderately sensitive to salinity. In April, prior to seeding the potatoes, the soil salinity in the field was mapped by towing an EM38 salinity meter behind an all-terrain vehicle and positioning it with GPS technology (Cannon et. al., 1994). On July 28 and September 1, 1999, Itres flew over the field and collected CASI data. In late September, 58 points were selected to represent different levels of soil salinity. At each of these sample points, salinity was determined with an EM38 according to McKenzie et. al. (1989). Tuber samples consisting of two 1.22 m lengths of row each with four uniformly spaced plants, were dug at these sampling points. A regression analysis was developed between tuber yields, tuber specific gravity and soil salinity. The CASI imagery was compared to the salinity map.

**Table 8. Petiole analysis volume and parameters.**

| | | Sampling date | | | Analysis | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **Location** | **1st** | **2nd** | **3rd** | **Moisture** | **N** | **Ca** | **P** | **$NO_3$ N** | **K** | **S** | **Zn** | **B** | **Fe** | **Mg** | **Al** | **Ca** | **Na** |
| 1996 | Hays | July 3 | July 30 | Aug. 20 | † | † | † | † | † | | ? | ? | ? | ? | ? | ? | ? | ? |
| | Fincastle | July 4 | July 30 | Aug. 20 | † | † | † | † | † | | ? | ? | ? | ? | ? | ? | ? | ? |
| 1997 | Hays | July 3 | July 23 | Aug. 12 | † | † | † | † | † | † | ? | ? | ? | ? | ? | ? | ? | ? |
| | Fincastle | July 7 | July 24 | Aug. 13 | † | † | † | † | † | † | ? | ? | ? | ? | ? | ? | ? | ? |
| 1998 | Hays | July 6 | July 22 | Aug. 10 | † | † | † | † | † | † | † | † | † | † | † | † | † | † |
| | Fincastle | July 7 | July 23 | Aug. 11 | † | † | † | † | † | † | † | † | † | † | † | † | † | † |
| 1999 | Hays | July 7 | July 30 | Aug. 17 | † | † | † | † | † | † | † | † | † | † | † | † | † | † |
| | Fincastle | July 9 | July 28 | Aug. 13 | † | † | † | † | † | † | † | † | † | † | † | † | † | † |
| | Vauxhall | July 6 | July 27 | Aug. 11 | † | † | † | † | † | † | † | † | † | † | † | † | † | † |

† all samples analyzed

? 1/5 of samples were analyzed

**Table 9. Potato petiole nutrient sufficiency levels from three soil/plant analysis labs and levels found in this project.**

| | **Stage/or time after emergence** | **N0$_3$-N (%)** | **P (%)** | **K (%)** |
|---|---|---|---|---|
| Lab A | | | | |
| | Vegetative | 1.2-1.5 | 03.0-04.0 | 7.0-8.0 |
| | Tuber initiation | 1.2-1.5 | 0.25-0.35 | 7.0-8.0 |
| | Tuber bulking | 1.2-1.5 | 0.25-0.30 | 6.5-7.5 |
| | Tuber half grown | 1.0-1.5 | 0.20-0.25 | 6.0-7.0 |
| | Tuber maturing | 0.5-1.0 | 0.15-0.20 | 3.0-5.0 |
| Lab B | | | | |
| | +3 weeks | 2.5-3.0 | 0.24-0.44 | 11.8-13.8 |
| | +9 weeks | 1.8-2.3 | 0.20-0.40 | 9.8-11.8 |
| | +15 weeks | 1.2-1.7 | 0.16-0.36 | 7.8-9.8 |
| | Pre-vine kill | 0.5-1.0 | 0.14-0.34 | 5.8-7.8 |
| Lab C | | | | |
| | Early season | 0.8-1.2 | 0.12-0.2 | 9-11 |
| | Mid season | 0.6-0.9 | 0.08-0.16 | 7-9 |
| | Late season | 0.3-0.5 | 0.05-0.1 | 4-6 |
| Hays and Fincastle for FL 1625, Russet Burbank or Snowden | | | | |
| | early July (3rd-7th) | 1.4-2.2 | 0.22-0.62 | 7-9 |
| | late July (23rd-30th) | 1.2-1.8 | 0.20-0.50 | 5-7 |
| | mid August (12th-17th) | 1.0-1.6 | 0.16-0.36 | 3.5-5.5 |

**Table 10. GPS Applications 1996-1999.**

| Year/Crop | Site | GPS differential source | Monitor |
|---|---|---|---|
| **1996** | | | |
| Russet Burbank Potatoes | Fincastle | Novatel RT-20 + local base corrections | Harvestmaster |
| Snowden Potatoes | Hays | Novatel RT-20 + local base corrections | Harvestmaster |
| **1997** | | | |
| Russet Burbank Potatoes | Fincastle | Omnistar + geostationary corrections | Harvestmaster |
| Snowden Potatoes | Hays | Novatel RT-20 + local base corrections | Harvestmaster |
| Wheat | Hays | Omnistar + geostationary corrections | Ag Leader |
| Barley | Fincastle | Omnistar + geostationary corrections | Ag Leader |
| **1998** | | | |
| Russet Burbank Potatoes | Fincastle | Novatel RT-20 + local base corrections | Harvestmaster |
| Snowden Potatoes | Hays | Novatel RT-20 + local base corrections | Harvestmaster |
| **1999** | | | |
| FL1625 Potatoes | Fincastle | Novatel RT-20 + local base corrections | Harvestmaster |
| Snowden Potatoes | Hays | Novatel RT-20 + local base corrections | Harvestmaster |
| Russet Burbank Potatoes (salinity only) | Vauxhall | Novatel RT-20 + local base corrections | EM38 salinity meter |

# RESULTS AND DISCUSSION

## Soil Moisture, Water Tables and Yields

In 1996, at Hays, potatoes were grown on the east half of a high-pressure pivot (Fig. 3b), which was operated at less than the optimum pressure. This resulted in an uneven distribution of water with excess water applied near the centre and insufficient water applied on the outer parts of the circle. On the same pivot, in the following year, 1997 (Fig. 3a), potatoes were grown on the western half. Meanwhile, the farmer had redesigned his system, converting the high pressure pivot to a low pressure pivot. This new pivot had uneven calibration causing a high application of water on the outer part of the circle and less in the centre. The contrasting distribution patterns from the two years are shown in Fig. 3.

Prior to redesign of the pivot system, excess irrigation near the centre of the pivot caused accumulation of water below the root zone in Hays (1996) (Fig. 4b) while the surface layers (Fig. 4b) had deficient available water, especially in the outer parts of the pivot (30% to 55% of field capacity). These conditions create the possibility for leaching of nutrients below the root zone, waterlogging and increased disease in low areas of the fields. The excess irrigation occurred because the pivot was operating near the center at less than the designed pressure.

In three years, 1997-1999 and six fields, uniformity of irrigation application was a significant factor, influencing yield in four of the six fields. In three fields, Hays 1998 (Fig. 5a), Hays 1999 and Fincastle 1999 (Fig. 5b), total yield significantly increased with increasing irrigation.

Mean tuber weights were increased with increasing irrigation at Hays 1998 (Fig. 6a) and slightly, but not significantly, decreased with increasing irrigation at Hays in 1997 (Fig. 6b).

Irrigation management is one of the critical factors influencing both yield and tuber size. Areas of the field, which received more than average irrigation plus precipitation had increased tuber numbers, reduced mean tuber weights and greater numbers of small tubers, as compared with areas which received less than average irrigation plus precipitation.

At Fincastle in 1996 and in 1999 and on the two halves of a field in 1997 and 1998, corner pivots were used. These pivots did not provide as much water to the corners as the rest of the field. When the corner arm was extended and operating, the remainder of the pivot appeared to have reduced output.

Piezometer measurements of groundwater depth movement and soil $NO_3$-N content at the Hays site in 1997 (Fig. 7) and Fincastle 1997 (Fig. 8) and 1998 are reported by Rodvang (1998 and 1999). Hays had less than half the $NO_3$ N than Fincastle. The Hays site was irrigated more than the Fincastle site. Nitrate levels were low at depth but this may be due to reducing conditions, causing denitrification. Once all nitrate is reduced, denitrifying bacteria tend to reduce sulphate to $H_2S$. The odor of $H_2S$ was present at two of the well sites at Hays in 1997 indicating some sulphate was being reduced (Rodvang, 1998). At some of the wells, the texture was coarse permitting downward movement of water. At Hays, the flow of groundwater occurred from the irrigated field outward to the unirrigated rangeland. Irrigation has caused water table mounding below the sites. Water tables rose during the summer at Hays and reached a peak of 1.2 m below the ground at one site in 1997 and 1.65 m in 1998.

At Fincastle, the irrigation applications generally were less than at Hays. The water table followed the surface topography. In 1997 water table depths ranged from 1.7 to 3.5 m. In 1998 at Fincastle, water table depths varied from 1.5 to 2.5 m below ground level and were over 5 m deep at one of the six sites. Water levels rose during the summer in both years and declined after late August. Vertical hydraulic gradients indicated slight downward flow at most piezometer nests.

In 1997, nitrate was present in soil water at the piezometer sites at levels from 1 to 20 mg/kg at Fincastle. Nitrate levels at Hays were lower, from 1 to 6 mg/kg. Site 6 (R6 in Fig. 7) was located on native range adjacent to the potato field and had almost no nitrate to a depth of 1.5 m. The difference between the nutrient level at this site and the other 5 sites shows the effect of irrigated agriculture for 19 years.

Soil water phosphorus (P) was from 4 to 10 mg/kg at the cultivated Hays replicates (Fig. 9). This was compareble to the Fincastle site, where P ranged from 20 to 40 mg/kg in the 0-0.15 m layer (Fig. 10). The higher levels of P at Fincastle than at Hays was because Fincastle received hog manure applications for a number of years. It is interesting that the P had not move below 0.60 m at the time of sampling.

## Soil Fertility

### Nitrogen

Nitrogen (N) is the fertilizer used in largest quantities by potato growers and application of 160 to 240 kg of N/ha cost from $100-$150/ha. Site specific applications of N offers possibilities for reduction of costs. Soil nutrient variability was more evident at Fincastle than at Hays. Soil nitrogen was variable on the previous fall samples for the 1997 Fincastle field and to a lesser extent on the 1997 Hays field. The 1997 Fincastle field, for the 0.0-0.60 m depth, had 40% of the sample sites considered to be very deficient, 51% deficient to marginal and 10% adequate to high (Table 11). The farmer applied 179 kg/ha N at hilling and another 41 kg/ha N by fertigation during the growing season. These applications would be anticipated to be in excess of what could be used by the crop in areas of the field that already had 73 and 173 kg/ha soil N and would be expected to reduce potato tuber specific gravity. However, there was no relationship between soil N and specific gravity at the grid sites on the field. The 1997 Fincastle site had 89% of the 0.0-0.60 m soil samples with less than 15% clay, which means excess N could easily move downward. In 1997, Hays had 73% of the sample sites with 31 kg/ha N for 0.0-0.60 m and 26% of the sites with 63 kg/ha N so the whole field was low in nitrogen.

In 1998 at Fincastle in the 0.0-0.60 m layer, 92% of the soil sample sites had less than 5 ppm N (very deficient) with an average of 14 kg/ha N. The remaining 8% (deficient to marginal) had an average of 65 kg/ha N. In 1998 at Hays, 68% of the soil sample sites had less than 5 ppm N and the remaining 32% of the sample sites had between 5 and 7.5 ppm N. The variability at these two fields in 1998 was not sufficient to justify the costs of site specific fertilization of nitrogen.

All the soil sample sites for 0.0-0.60 m at Hays in 1999 were less than 5 ppm N (Table 11). In 1999 at Fincastle the 0.0-0.60 m layer, 90% of the sample sites were very deficient (<5 ppm N), 6% were deficient to marginal (5-15 ppm N) and 4% were high (>20 ppm N). This site would offer possibilities for precision application of N with detailed mapping of soil N. This site had 27% of the 0.60-0.90 m samples with greater than average (165 kg/ha) soil N. The nitrogen at depth is evidence of leaching of nitrogen during previous cropping.

Soil N data collected from grid sampling for two fields for three years indicates only two of the six fields had sufficient variability in soil nitrogen to justify variable rate fertilization. Soil N for 6 fields (Fig. 11b) was not significantly related to petiole $NO_3$-N on July 3-7. This also indicates that when these fields were grouped together, variable rate application based on soil $NO_3$-N the previous fall does not offer possibilities for improved nitrogen management. Fincastle in 1997, and perhaps in 1999, had sufficient variability to justify the cost of sampling and analysis to determine soil nitrogen and then to apply variable rates of nitrogen fertilizer. The spatial soil fertility data must be collected before a decision can be made on the feasibility of variable rate fertilization.

**Phosphorus**

At Fincastle in 1997, soil phosphorus (P) for 0.0-0.15 m was high by Alberta Standards and exceeded 100 kg/ha P for 96% of the grid sample sites and exceeded 168 kg/ha P (20 ppm) for 58% of the sample sites (Table 12). This same field had 88% of the 0.0-0.30 m samples exceeding 200 kg/ha P and 46% of the samples exceeding 320 kg/ha P. The father of the current owners raised hogs from 1964 to about 1975 directly south of the 1997 site and used the 1997 field for spreading hog manure. It is not known how much hog manure was applied or what level the soil phosphorus reached but the subsequent 22 years cropping with little or no phosphorus fertilizer added has not yet reduced the soil P to levels which are environmentally safe. The adjacent field at Fincastle used in 1998 had only 6% of the samples for 0.0-0.15 m with soil P greater than 100 kg/ha.

In October 1998 before fertilizer was applied, the 1999 Fincastle site had high soil P in the 0.0-0.15 m layer (average 117 kg/ha) on the southern 67% of the field and adequate or marginal (average 50 kg/ha P) on the remainder of the field (Fig. 12a). The farmer had spread liquid hog manure on a portion of the field in the fall of 1997. This farmer applied 39 kg/ha P to the entire field in October 1998 and 29 kg/ha P in the spring of 1999. If phosphorus fertilizer costs $1.25/ kg P, then $1765 could have been saved from not applying P to the part of the field that received hog manure. The farmer's soil sample analysis results were not available from the fertilizer dealer for the fall of 1998 on the 1999 Fincastle field. It is not known if the fertilizer rates were estimated or were based on samples taken on the north end of the field where manure was not applied.

In 1999 at Hays (Table 12) in the 0.0-0.15 m layer, soil P was deficient to marginal on 62% of the field and adequate on 38% of the field (Miller-Axely method of analysis). The Hays fields did not have a history of receiving manure so they were generally lower in soil P than the Fincastle fields, which had received manure.

**Potassium**

Soil potassium (K) levels in samples from the Fincastle fields (Table 13) were usually adequate and, in a few cases, high. The 1997 field also had 13% of its grid sample sites with high levels of potassium (greater than 300 ppm in the 0.0-0.15 m depth). This appears to be a relic from the hog manure applications made between 1965 and 1974. Tissue potassium was adequate or high on the part of the field that received hog manure. If potassium fertilizer costs $0.55/kg K then $784 could have been saved in 1997 by not applying K to the field. The 1999 Fincastle field also had some sample sites with high levels of K. The sites in 1999 were not related to the portion of the field that received one application of hog manure in 1997. Fincastle sites have received manure applications and have been irrigated since 1956. This is longer than the Hays sites, which have been irrigated since 1978 and have not received manure applications.

The Hays sites in 1997 and 1998 (Table 13) were marginal to adequate in soil K. In 1999, the Hays sites were marginal to high but there was no easily identifiable pattern and the high areas were parts of the outer edge of the field. It does not seem economical to apply site specific applications of K to the Hays fields.

**Table 11. Soil nitrogen levels in ppm N (0.0-0.60 m depth) in October of the previous year for grid sample sites grouped by % according to Alberta Agriculture Standards.**

| Location | Year | Very deficient | Deficient | Marginal | Adequate | High |
|---|---|---|---|---|---|---|
| ppm | | **<5** | **5-7.5** | **7.5-15** | **15-20** | **>20** |
| Hays | 97 | 73 | 19 | 8 | 0 | 0 |
| | 98 | 68 | 32 | 0 | 0 | 0 |
| | 99 | 100 | 0 | 0 | 0 | 0 |
| Fincastle | 97 | 40 | 25 | 26 | 6 | 4 |
| | 98 | 92 | 6 | 2 | 0 | 0 |
| | 99 | 90 | 2 | 4 | 0 | 4 |

**Table 12. Soil phosphorus levels in ppm P (0.0-0.15 m depth) in October of the previous year for grid sample sites grouped by % according to Alberta Agriculture standards.**

| Location | Year | Deficient | Marginal | Adequate | High | Very high |
|---|---|---|---|---|---|---|
| ppm | | **<13** | **13-25** | **25-45** | **45-75** | **>75** |
| Hays | 97🗳 | 34 | 66 | 0 | 0 | 0 |
| | 98🗳 | 8 | 60 | 31 | 0 | 0 |
| | 🗳 | 12 | 79 | 8 | 0 | 0 |
| | 99🗳 | 2 | 60 | 38 | 0 | 0 |
| | 🗳 | 6 | 74 | 21 | 0 | 0 |
| Fincastle | 97🗳 | 0 | 0 | 4 | 38 | 58 |
| | 98🗳 | 20 | 35 | 39 | 6 | 0 |
| | 🗳 | 6 | 30 | 57 | 8 | 0 |
| | 99🗳 | 6 | 16 | 12 | 64 | 0 |
| | 🗳 | 2 | 24 | 22 | 53 | 0 |

🗳 Miller Axley method
🗳 Kelowna method

**Table 13. Soil potassium levels in ppm K (0.0-0.15 m depth) in October of the previous year for grid sample sites grouped by % according to Alberta Agriculture standards.**

| Location | Year | Deficient | Marginal | Adequate - | Adequate + | High |
|---|---|---|---|---|---|---|
| ppm | | **0-75** | **75-150** | **150-225** | **225-300** | **>300** |
| Hays | 97† 🗳 | 0 | 67 | 23 | 9 | 2 |
| | 98🗳 | 0 | 38 | 52 | 10 | 0 |
| | 99🗳 | 0 | 26 | 39 | 14 | 21 |
| Fincastle | 97† 🗳 | 0 | 0 | 38 | 49 | 13 |
| | 98🗳 | 4 | 40 | 36 | 15 | 6 |
| | 99🗳 | 0 | 4 | 71 | 16 | 10 |

† 0.0-0.30 m depth
🗳 Kelowna method
🗳 Ammonium acetate method

**Table 14. Petiole analysis of N, P and K for 1996-99 for 3 dates for potatoes at Hays and Fincastle showing % of samples at adequate level.**

| | $NO_3$-N % | | | P % | | | K% | | |
|---|---|---|---|---|---|---|---|---|---|
| **Table 14 a. 1996** | **July 3-4** | **July 30** | **Aug. 20**[?] | **July 3-4** | **July 30** | **Aug. 20**[?] | | | |
| Adequate level | 1.6-2.4 | 1.2-1.8 | 0.08-1.4 | 0.22-0.62 | 0.20-0.50 | 0.10-0.30 | | | |
| **Hays** % High | 2 | 0 | 0 | 0 | 0 | 0 | | | |
| % Adequate | 88 | 26 | 0 | 100 | 20 | 0 | | | |
| % Deficient | 10 | 74 | 100 | 0 | 80 | 100 | | | |
| Adequate level | 1.6-2.4 | 1.2-1.8 | 0.10-0.16 | 0.22-0.62 | 0.20-0.50 | 0.16-0.36 | | | |
| **Fincastle** % High | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| % Adequate | 88 | 0 | 0 | 100 | 63 | 88 | | | |
| % Deficient | 12 | 100 | 100 | 0 | 37 | 12 | | | |
| **Table 14 b. 1997** | **July 3-7** | **July 23-24** | **Aug. 12-13** | **July 3-7** | **July 23-24** | **Aug. 12-13** | **July 3-7** | **July 23-24** | **Aug. 12-13** |
| Adequate level | 0.16-.24 | 0.12-0.18 | 0.10-0.16 | 0.22-0.62 | 0.20-0.50 | 0.16-0.36 | 7-9 | 5-7 | 3.5-5.5 |
| **Hays** % High | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 67 |
| % Adequate | 45 | 0 | 0 | 94 | 2 | 0 | 0 | 60 | 33 |
| % Deficient | 55 | 100 | 100 | 6 | 98 | 100 | 100 | 0 | 0 |
| **Fincastle** % High | 0 | 8 | 6 | 13 | 55 | 11 | 0 | 94 | 100 |
| % Adequate | 12 | 17 | 32 | 87 | 39 | 79 | 6 | 6 | 0 |
| % Deficient | 88 | 75 | 62 | 0 | 6 | 9 | 94 | 0 | 0 |
| **Table 14 c. 1998** | **July 6-7** | **July 22-23** | **Aug. 10-11** | **July 6-7** | **July 22-23** | **Aug. 10-11** | **July 6-7** | **July 22-23** | **Aug. 10-11** |
| Adequate level | 0.16-0.24 | 0.12-0.18 | 0.10-0.16 | 0.22-0.62 | 0.20-0.50 | 0.16-0.36 | 7-9 | 5-7 | 3.5-5.5 |
| **Hays** % High | 0 | 0 | 4 | 17 | 0 | 0 | 0 | 67 | 100 |
| % Adequate | 4 | 12 | 50 | 77 | 21 | 54 | 73 | 33 | 0 |
| % Deficient | 96 | 88 | 46 | 6 | 79 | 46 | 27 | 0 | 0 |
| **Fincastle** % High | 3 | 24 | 22 | 0 | 0 | 0 | 0 | 19 | 57 |
| % Adequate | 21 | 59 | 57 | 76 | 30 | 6 | 33 | 73 | 41 |
| % Deficient | 76 | 17 | 21 | 24 | 69 | 94 | 67 | 8 | 2 |
| **Table 14 d. 1999** | **July 7** | **July 30** | **Aug. 17** | **July 7** | **July 30** | **Aug. 17** | **July 7** | **July 30** | **Aug. 17** |
| Adequate level | 0.16-0.24 | 0.10-0.18[?] | 0.08-0.14[?] | 0.22-0.62 | 0.18-0.45[?] | 0.14-0.34[?] | 7-9 | 5-7 | 3.4-5.4[?] |
| **Hays** % High | 9 | 6 | 2 | 0 | 0 | 0 | 80 | 0 | 0 |
| % Adequate | 46 | 28 | 32 | 85 | 22 | 43 | 20 | 96 | 100 |
| % Deficient | 44 | 66 | 66 | 15 | 88 | 57 | 0 | 4 | 0 |
| | **July 9** | **July 28** | **Aug. 13** | **July 9** | **July 28** | **Aug. 13** | **July 9** | **July 28** | **Aug. 13** |
| Adequate level | 1.6-2.4 | 1.2-1.8 | 1.0-1.6 | 0.22-0.62 | 0.20-0.50 | 0.16-0.36 | 7-9 | 5-7 | 3.5-5.5 |
| **Fincastle** % High | 0 | 0 | 6 | 51 | 22 | 55 | 76 | 98 | 2 |
| % Adequate | 14 | 20 | 29 | 45 | 65 | 41 | 24 | 2 | 92 |
| % Deficient | 86 | 80 | 65 | 4 | 14 | 4 | 0 | 0 | 6 |

[?] Standards were adjusted downward because of the late sampling date and Snowden, a mid-season variety, was nearing maturity.

## Petiole Analysis

Potato producers routinely take petiole samples from late June through mid to late August. The samples are tested for nitrate nitrogen ($NO_3$-N) to help producers maintain consistent nitrogen health or to make corrections for insufficient N by fertigating the entire field. Historically, potato producers did not test for phosphorous or potassium status nor did they make adjustments for insufficient P and K. In the last 3 or 4 years, many have also been analyzing for P, K in addition to $NO_3$-N.

### Nitrate Nitrogen

In 1996, petiole $NO_3$–N (Table 14) was adequate at most of the sites at the time of the first sampling but, despite fertigation with additional N, it decreased and became deficient at the time of the second and third sampling.

In 1997, petiole N at Hays (Table 14b) was adequate on 45% and deficient on 55% of the sites at the time of the first sampling and deficient on 100% of the sites at the time of the second or third samplings. Soil nitrate N was deficient on 92% of the sites (Table 11) the previous October and 77% of the field had less than 15% clay in the 0.0-0.60 m. The field received from 0.37-0.45 m of rainfall and irrigation from June 23 to September 9 (Fig. 3a). The coarse textured soils permitted leaching of nitrogen below the root zone, which meant there was excess moisture.

In 1997, the Fincastle site was deficient in petiole N (Table 14) on 88% of the field in early July to 62% by August 12. Fincastle received about the same amount of irrigation and rainfall as Hays but over a period one week longer than the Hays site (June 24 to September 18). The Russet Burbank potatoes at Fincastle used more water in the latter part of the season than the earlier maturing Snowden potatoes at Hays.

In 1998, petiole analysis on both Hays and Fincastle indicated that the percent of samples that were deficient decreased from highs of 96 and 76 early in July to 46 and 21 by August 10 or 11 (Table 14c). Total soil nitrogen plus fertilizer nitrogen (Table 3) was higher in 1998 than in 1997 and 1996. This may be the reason that the tissue nitrogen did not decline like it did in 1996 and

1997. In 1999 at the time of the third petiole sampling (Table 14d), both Hays and Fincastle had about 66% of the samples deficient in petiole N.

Petiole analysis for nitrogen in the first week of July was significantly correlated with soil N the previous October in three of the six fields monitored, such as Hays in 1999 (Fig. 11a). This was before uniform applications of nitrogen fertilizer. However, petiole nitrate for all fields was not significantly correlated to soil nitrogen (Fig. 11b) and had an r of 0.95. Petiole nitrate was significantly positively correlated to soil clay per cent (Fig. 11c) with an r of 0.45. This means it would be more useful to base a variable nitrogen fertilizer application on soil clay content than on soil nitrogen. The fields chosen for this project had most of the samples with a clay content between 6% and 32% (Fig. 2). This is a lower range clay content than is typical for agricultural soils but it is typical for potato soils. The variability of texture of the soils used in this project may be higher than is typical of soils used for potato production.

Petiole nitrate N was significantly negatively correlated to tuber yield in early July (r = 0.25) (Fig. 11d) and in late July there was no significant relationship between petiole nitrate N and yield (Fig. 11e). In August (Fig. 11f) petiole nitrate N was significantly positively correlated (r = 0.155) to yield. This suggests nitrogen supply may be excessive early in the growing season and deficient later in the season. The areas with higher clay content could be expected to retain nitrogen late in the season, while those areas lower in clay content are subject to loss of nitrogen by leaching. These same areas with a higher clay content, and therefore a higher exchange capacity could be expected to have less soluble nitrogen early in the season, thus lower petiole N content than areas with a lower clay content.

### Phosphorus

Tissue P at Hays in 1996 and 1997 (Fig. 13) was adequate in the first week of July and declined rapidly to become 100% deficient in the August samples (Tables 14a and 14b). This same decline did not occur at the Fincastle site, which had a higher level of available soil P (36% of soil sample sites tested marginal or higher) in 1997 as compared to Hays, which had 8% of soil P marginal or higher (Table 12).

In 1998, both fields were mostly marginal in soil P (Table 12) but received high applications of fertilizer P (119 kg/ha Hays and 153 kg/ha at Fincastle, Table 3). Despite these high applications of fertilizer, available tissue P declined by Aug. 10-11 to become 46% deficient at Hays and 94% deficient at Fincastle (Table 14c).

In 1999, in early July, the tissue P levels in the Hays field were mostly marginal (85 %) with some areas (15%) high (Table 14d). The Fincastle field was 51% high and 45% marginal and 4% low. Petiole P levels were high or adequate in the part of the field that had received hog manure. In the remainder of the field, petiole P levels were adequate on July 9 and declined to become deficient or adequate on July 28 and August 13.

Petiole phosphorus on six fields for July 3-7 was highly significantly positively correlated to soil P (Fig. 14a) (r = 0.57**). On the same six fields, petiole phosphorus content was highly significantly negatively correlated to soil clay content (Fig. 14b) (r = 0.32**). This occurs because soil P is tied up in unavailable forms on clay. However, there was no significant correlation between soil P and clay content. In contrast to soil nitrogen, soil phosphorus content can be used as a basis for variable rate application of phosphorus fertilizers. Petiole P was highly significantly positively correlated to yield at all three sampling times (Fig.14c, 14d and 14e). This indicates petiole P was low for optimum yields on these fields.

### Potassium

Tissue K analysis was not done in 1996. In 1997, at both Hays and Fincastle, almost all sites were deficient in the first week of July (Table 14). By July 23 and 24 tissue levels increased and by August 12-13 the Hays field had 67% high levels of K and the Fincastle field had 100% high levels of K (Table 14 and Fig. 15). A similar pattern occurred in 1998. In 1997 mean tissue K at Hays was 6.2% July 3, 6.9% July 23 and 6.0% August 12. In 1997 at Fincastle, mean tissue K was 6.5% July 7, 7.5% July 24 and 6.4% August 13. However, in 1999 both Hays and Fincastle showed most of the field with excess levels of tissue K on July 7 and 9 (Fig. 16a) and this decreased to 0% with excess at Hays and 2% with excess at Fincastle by the 13th of August (Fig.16b).

It is not known why these tissue levels in 1997 and 1998 changed so much, in contrast to the standards, which indicate tissue K levels normally decline during the season. Potassium uptake is reduced by low soil temperature. The standards have been developed in parts of the USA where soil temperatures would usually be higher than in southern Alberta. In southern Alberta, June nights are often quite cool.

Tissue K levels at both sites for three years were not significantly related to yield. Apparently these K levels were not appreciably deficient. In another experiment, in 2000 and 2001, field tests with phosphorus fertilizer and compost at a total of 5 locations showed declining tissue potassium levels throughout the season. This problem of petiole K levels deficiencies needs more study in western Canada where soil K levels are usually high but some of the growing season temperatures are lower than required for maximum growth of potatoes.

## Fertilizer Treatments

The $N_3$ treatment (Table 15) at Hays in 1997 gave the highest yield and the potato crop was worth $116/ha more than the $N_2$ treatment but required $60/ha more nitrogen fertilizer (N fertilizer cost = $0.66/kg) than the $N_2$ treatment. This increase in yield and value does not account for changes in quality such as low specific gravity, which may occur on the high N treatment. At Fincastle, the $N_2$ treatment, which was the farmer’s rate, showed the highest yield. This N2 treatment also showed losses in nitrogen below the root zone (Rodvang, 1998). In 1998 the nutrients applied (Table 6) were in addition to the farmer’s rate (Table 3).

**Table 15. 1997 potato yields (t/ha) and gross value on fertilizer strips.**

| Treatment | Hays | | Fincastle | |
|---|---|---|---|---|
| | **Yield** | **Gross value ($/ha)**[†] | **Yield** | **Gross value ($/ha)**[†] |
| $N_1$ | 39.2 | 4140 | 39.4 | 4161 |
| $N_2$ | 42.5 | 4488 | 42.7 | 4509 |
| $N_3$ | 43.6 | 4604 | 42.0 | 4435 |

[†] Value is based on 80% marketable at $132/tonne.

At both sites in 1998 (Table 16), the N treatment yielded less than the check or farmer’s rate (-4.4% Hays and –7.7% Fincastle). At both sites the NP treatment yielded similar to the check (-0.3% Hays and +1.1% Fincastle). The P treatment at both sites yielded more than the check

(+2.7% Hays and +5.3% Fincastle). These results indicate the farmers are at an optimum rate with respect to nitrogen. Phosphorus rates on these two fields may be low. Both of these fields had high phosphorus fertilizer applications (Table 3) and petiole P levels declined during the season (Table 12).

**Table 16. 1998 potato yields (t/ha) and gross value on fertilizer strips.**

| Treatment | Hays | | Fincastle | |
|---|---|---|---|---|
| | Yield | Gross value ($/ha)† | Yield | Gross value ($/ha)† |
| N | 34.9 | 3685 | 33.2 | 3506 |
| P | 38.6 | 4076 | 37.8 | 3992 |
| NP | 37.5 | 3961 | 36.6 | 3865 |
| Check | 37.6 | 3970 | 35.9 | 3791 |

† Value is based on 80% marketable at $132/tonne.

In 1999, six treatments were set out at Hays (Table 7) consisting of two rates of compost, manure and phosphorus fertilizer. Disease counts on the foliage of the plants (Table 17) indicated that the low phosphorus treatment had a greater amount of foliar disease than all other treatments. The three high rate treatments also had a lower incidence of foliar disease than their corresponding low rate treatments, indicating an overall benefit of high rates of P, whatever the form, in terms of foliar disease. Because this field has been used a number of times for growing potatoes in the last 10 years, the level of foliar diseases was quite high. *Rhizoctonia* and scab counts were also made on the tuber surfaces. Variability on tuber disease counts was high and disease occurrence on tubers was low so no conclusions can be made regarding the influence of these treatments on tuber disease.

The 1999 Hays field has a history of developing low P levels in petioles in late July and August despite high rates of P fertilizer being applied. The treatments had no significant effect on tuber yields (Table 17) although compost and manure treatments yielded slightly more than the P treatments. Tuber numbers were also recorded for each treatment.

**Table 17. Effect of P, compost and manure on tuber yield and size and disease incidence of potatoes – Hays, 1999.**

| | | | | % surface infected on 160 tubers | | % plants affected |
|---|---|---|---|---|---|---|
| **Treatments** | **Total tuber Wt (t/ha)** | **Medium Tubers (t/ha)** | **Tubers[†] /1.2 m** | ***Rhizoctonia*** | **Scab** | **Disease[†] on 600 m row** |
| Low P | 34.6 | 30.2 | 65 | 0.68 | 0.75 | 9.0 |
| High P | 36.5 | 32.5 | 70 | 0.32 | 0.88 | 7.1 |
| Low compost | 40.0 | 33.3 | 95 | 0.82 | 1.20 | 6.6 |
| High compost | 38.7 | 35.2 | 82 | 0.36 | 0.57 | 5.9 |
| Low manure | 37.2 | 34.0 | 81 | 0.68 | 0.57 | 7.6 |
| High manure | 39.8 | 36.2 | 75 | 0.86 | 0.73 | 6.1 |

[†] significant at 5% level

## Pest Monitoring

### Weeds

In most fields, the weeds did not occur in large numbers in any one area so they were not suitable for site specific management. In 1999 on the Hays field, there were patches from 10 m to 50 m in diameter, which were heavily infested with Canada Thistle. In late August prior to harvest, the perimeters of some of these patches were mapped with GPS. It was not possible to identify these patches on remote sensed imagery taken on July 28. If accurately identified, these patches of Canada Thistle could be controlled with spot applications of chemicals such as Lontrel (clopyralid) or Roundup (glyphosate). These chemicals are toxic to potatoes so this is an extreme treatment and the herbicides need to be applied precisely. The potential exists for developing an irrigation system, which will provide site specific applications of herbicides, as well as water (Eberlein, 1999).

### Disease

Diseases were monitored each year on all fields. Disease incidence was low and diseased plants were scattered. No attempt was made to map disease. Late blight did occur in varying degrees on the fields prior to harvest and it would have been possible to map this disease but it is difficult to distinguish from vine senescence. Disease surveys were done in the middle of August when the incidence of late blight was low.

### Insects

Colorado potato beetles were the only insect pest present at sufficient levels to require insecticide application by the farmers. Colorado potato beetles are native to southern Alberta so the problem of resistance to insecticides is not as important as in areas where it only occurs on potatoes. It is not necessary to retain non resistant populations for reproduction in portions of the fields as described by Weisz et. al.(1996). Flescher et. al.(1999) describes how Colorado potato beetle are most dense near the edge of fields thus making them suitable for site specific management. However, due to farmer vigilance and spray programs, the Colorado potato beetles never became a serious problem in any areas of the fields tested, so were not suitable for site specific management.

## Remote Sensing

Potato fields are closely monitored during the growing season for the onset of nutrient deficiencies, disease and pests. With respect to nutrients, typically test areas are established in a field and 40 to 50 petioles from representative plants are collected at each sampling date for determination of primarily N but also P and K content (Schaupmeyer, 1992). This method of petiole sampling provides only limited information regarding spatial variability across the whole field and does not provide information suitable for use with variable rate equipment. Remote sensing data offers one source of spatial information suitable for use in site-specific management systems. Digital imaging systems provide the potential to delineate management zones within a field based upon soil characteristics and the detection of crop stresses both in the short and long term (Brisco et al., 1998, Moran et al., 1997). A number of algorithms have been proposed to measure chlorophyll or N content of plants using remote sensing (Table 18). The close correlation between leaf chlorophyll and N availability suggests that chlorophyll content can be use to characterize N status and vice versa (Filella and Peñuelas, 1994). The majority of the algorithms or indices are based upon reflectance in the green (530-600 nm), red (670-680 nm) or so-called 'red-edge' (690-710 nm) normalized to reflectance in the near-infrared (750-900 nm) range of the electromagnetic spectrum. Reflectance at wavelengths above 735 nm is relatively insensitive to chlorophyll or N levels while reflectance at 550 and 690-710 nm is most sensitive. Sensitivity to N stress at 670-680 nm is variable due to the signal being saturated and reflectance reaching a minimum at relatively low chlorophyll levels (Gitelson et al., 1999). The objective within this study was to test, using airborne remote sensing imagery, the suitability of the reported algorithms to estimate petiole-N content in potatoes and examine the spatial information regarding N status across the field.

**Table 18. Published algorithms for chlorophyll/N estimation using remote sensing data.**

| Index | Formula | Citation | CASI bands |
|---|---|---|---|
| **Simple ratio** | | | |
| $SR_{800\_670}$ | $(R_{800nm}/R_{670nm})$ | | 17, 25 |
| $SR_{695\_430}$ | $(R_{695nm}R_{430nm})$ | Carter 1994 | 1, 18 |
| $SR_{605\_760}$ | $(R_{605nm}/R_{760nm})$ | Carter 1994 | 12, 23 |
| $SR_{695\_760}$ | $(R_{695nm}/R_{760nm})$ | Carter 1994 | 18, 23 |
| $SR_{695\_670}$ | $(R_{695nm}/R_{670nm})$ | Carter 1994 | 17, 18 |
| $SR_{750\_705}$ | $(R_{750nm}/R_{705nm})$ | Gitelson and Merzlyak 1996, Sims and Gamon 2002 | 19, 22 |
| $SR_{750\_550}$ | $(R_{750nm}/R_{550nm})$ | Gitelson and Merzlyak 1996, Lichtenthaler et al. 1996 | 9, 22 |
| $SR_{667\_717}$ | $(R_{667nm}/R_{717nm})$ | Leblon et al. 2001 | 17, 20 |
| $SR_{550\_850}$ | $(R_{550nm}/R_{850nm})$ | Schepers et al. 1996 | 9, 28 |
| $SR_{710\_850}$ | $(R_{710nm}/R_{850nm})$ | Schepers et al. 1996 | 19, 28 |
| $SR_{800\_680}$ | $(R_{800nm}/R_{680nm})$ | Sims and Gamon 2002 | 17, 25 |
| $SR_{735\_700}$ | $(R_{735nm}/R_{700nm})$ | Gitelson and Merzlyak. 1999 | 19, 21 |
| Pigment specific simple ratio (PSSR) | $(R_{810nm}/R_{676nm})$ | Blackburn 1998 | 17, 26 |
| **Normalized difference index** | | | |
| Normalized green difference vegetation index (NGVDI) | $(R_{750nm} - R_{550nm})/(R_{750nm} + R_{550nm})$ | Gitelson et al. 1996 | 9, 22 |
| Photochemical reflectance index (PRI) | $(R_{531nm} - R_{570nm})/(R_{531nm} + R_{570nm})$ | Gamon et al. 1992 | 8, 10 |
| Pigment specific normalized difference (PSND) | $(R_{810nm} - R_{676nm})/(R_{810nm} + R_{676nm})$ | Blackburn 1998 | 17, 26 |
| Normalized difference index ($NDI_{750\_700}$) | $(R_{750nm} - R_{700nm})/(R_{750nm} + R_{700nm})$ | Gitelson and Merzlyak 1994, Sims and Gamon 2002 | 19, 22 |
| Normalized difference index ($NDI_{800\_680}$) | $(R_{800nm} - R_{680nm})/(R_{800nm} + R_{680nm})$ | Sims and Gamon 2002 | 17, 25 |
| Normalized pigments chlorophyll ratio index (NPCI) | $(R_{680nm} - R_{430nm})/(R_{680nm} + R_{430nm})$ | Peñuelas et al. 1994 | 1, 17 |
| Structure-insensitive pigment index (SIPI) | $(R_{800nm} - R_{445nm})/(R_{800nm} + R_{680nm})$ | Peñuelas et al. 1995 | 2, 17, 25 |
| **Others** | | | |
| Modified simple ratio ($mSR_{750\_445}$) | $(R_{750nm} - R_{445nm})/(R_{705nm} - R_{445nm})$ | Sims and Gamon 2002 | 2, 19, 22 |
| Modified normalized ratio ($mNR_{750\_445}$) | $(R_{750nm} - R_{705nm})/(R_{750nm} + R_{705nm} - 2*R_{445nm})$ | Sims and Gamon 2002 | 2, 19, 22 |
| Optimized soil adjusted vegetation index (OSAVI) | $(1 + 0.16)*(R_{800nm} - R_{670nm})/(R_{800nm} + R_{670nm} + 0.16)$ | Rondeaux et al. 199 | 17, 25 |
| Modified chlorophyll absorption in reflectance index (MCARI) | $[(R_{700nm} - R_{670nm}) - (0.2*(R_{700nm} - R_{550nm}))*(R_{700nm}/R_{670nm})]$ | Daughtry et al. 2000 | 9, 17, 19 |
| Transformed chlorophyll absorption in reflectance index (TCARI) | $3*[(R_{700nm} - R_{670nm}) - (0.2*(R_{700nm} - R_{550nm}))*(R_{700nm}/R_{670nm})]$ | Haboudane et al. 2002 | 9, 17, 19 |
| Plant senescence reflectance index (PSRI) | $(R_{680nm} - R_{500nm})/(R_{750nm})$ | Merzlyak et al. 1999 | 6, 17, 22 |
| Carotenoids | $[4.145*(S_{760nm/}\ S_{500nm})*(R_{500nm}/R_{760nm})]-1.171$ | Chapelle et al. 1992 | 5, 23 |
| Chlorophyll b | $2.94*[((S_{675nm/}\ R_{650nm}*S_{700nm})*(R_{650nm}*R_{700nm}/R_{675nm}))]+0.378$ | Chapelle et al. 1992 | 15, 17, 18 |
| Chlorophyll a | $22.735[=(S_{675nm}/S700_{nm})*(R_{700nm}/R_{675nm})]-10.407$ | Chapelle et al. 1992 | 17, 18 |

**Nitrogen**

On July 28, 1999, Itres acquired digital images over the Hays and Fincastle test fields. The image data were acquired over the spectral range 420-965 nm using a Compact Airborne Spectrographic Imager (CASI) at 2 and 3 m resolution. The spectral bands in which data were acquired varied with the resolution from 36 to 48 nm respectively. The image data were radiometrically corrected and geocoded by Itres.

The data were imported into the ENVI? image analysis software package (Research Systems Inc. Colorado, USA) and converted from spectral radiance units (µW cm$^{-2}$ sr$^{-1}$ nm$^{-1}$) to surface reflectance (%) using the FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes) atmospheric correction model (Anon., 2001). The input parameters used in the model are shown in Table 19.

**Table 19. Input parameters for the FLAASH atmospheric correction model.**

| **Parameter** | **Input** |
|---|---|
| Latitude/Longitude | 49.9867N, 111.8523W |
| Sensor altitude | 2.286 km |
| Ground elevation | 0.786 km |
| Atmospheric model | Sub-Artic Summer |
| Aerosol model | Rural |
| Visibility | 40 km |

Images of the various chlorophyll/N indices outlined in Table 18 were created using the band math function in the image analysis software. The spatial patterns of the indices across the sites were visually examined and compared to those in the kriged maps derived from the ground based petiole nitrate N samples. The grid sampling points were overlaid on the imagery and the reflectance values under a 3 x 3-pixel window centered over each grid point were extracted for each band and each chlorophyll/N index. The relationship between the various chlorophyll/N indices and the petiole nitrate N values was assessed using correlation and regression analyses.

True colour images derived from the 2 m resolution airborne imagery for both the Fincastle and Hays sites are shown in Fig. 17. Both the 2 and 3 m resolution images were processed but due to the similarity in the information content only the 2 m data will be discussed. The images show differential “greeness” across the fields, particularly in the Hays field. The spatial patterns tend to correspond to soil texture, particularly in the northern end of the field at Hays and likely results from poorer growth on the coarse textured soils. Consistent with the observation that many of the proposed indices involve reflectance in similar wavebands, the spatial patterns in the images derived for the various indices were similar (Table 18). Only the images showing the spatial variability in the index $SR_{550\_850}$ derived from reflectance at 550 and 850 nm are shown (Fig. 18 and 19). Visual comparison of the petiole-N maps derived in Surfer? using the grid point petiole nitrate N data and the index $SR_{550\_850}$ shows similarities in the patterns across both fields. Generally, areas of low petiole nitrate N exhibited high values for the $SR_{550\_850}$ index.

### Fincastle Site

Correlation analysis showed a strong relationship between most of the chlorophyll/N indices and petiole nitrate N for the Fincastle site (Table 20). The strongest relationships were evident with simple ratios involving either reflectance in the green band (550 nm) or the red-edge (700-710 nm) and the near infrared reflectance (750-850 nm). These observations can be attributed to the greater range of chlorophyll/N content to which reflectance at 550 and 700-710 nm responds. The absorption feature at 660-680 nm saturates at relatively low chlorophyll content and thus relative to 550 or 700-710 nm is insensitive to variation in chlorophyll/N.

### Hays Site

At the Hays site, visually there were some similarities between the spatial patterns within the image of the $SR_{550\_850}$ index and the kriged map of the ground based sampling. The extent of the N deficient areas in the remote sensing image appeared less than in the kriged map. The imagery may provide a more accurate representation of the spatial variability given that each pixel in the remote sensing image represents information from an area of 2 x 2 m on the ground while the ground data is an interpolation from grid points at greater than 100 m apart. Quantitative analysis showed only a limited number of indices were significantly related to petiole nitrate N. The strength of the relationship was poor compared to that at the Fincastle site. The lack of a strong relationship may reflect uncertainty in the georeferencing of the airborne imagery and the sampling sites and the heterogeneity of the crop reflectance in the areas selected for sampling (Deguise et al., 1998).

**Table 20. Relationship between the various proposed indices and petiole nitrate N samples.**

| Index | Fincastle | Hays |
|---|---|---|
| **Simple ratio** | | |
| SR800_680 | 0.751 | NS |
| SR695_430 | -0.734 | -0.356 |
| SR605_760 | -0.781 | NS |
| SR695_760 | -0.748 | NS |
| SR695_670 | 0.449 | -0.318 |
| SR750_705 | 0.820 | NS |
| SR750_550 | 0.821 | NS |
| SR677_717 | -0.639 | NS |
| SR550_850 | -0.832 | NS |
| SR710_850 | -0.832 | NS |
| SR735_700 | 0.821 | NS |
| PSSR | 0.764 | NS |
| **Normalized difference index** | | |
| NGVDI | 0.809 | NS |
| PRI | 0.770 | NS |
| PSND | 0.706 | NS |
| NDI750_700 | 0.809 | NS |
| NDI750_705 | 0.696 | NS |
| NDI800_680 | 0.707 | NS |
| SIPI | -0.660 | NS |
| **Other** | | |
| mSR750_705 | 0.821 | 0.326 |
| mNR750_705 | 0.813 | 0.308 |
| OSAVI | 0.722 | NS |
| MCARI | 0.445 | -0.298 |
| TCARI | -0.800 | -0.317 |
| PSRI | -0.597 | |
| Carotenoids | 0.746 | NS |
| Chlorophyll a | -0.448 | 0.313 |
| Chlorophyll b | -0.674 | NS |
| PSRI | -0.597 | NS |
| NPCI | -0.702 | NS |
| **# of Observations** | **N=51** | **N=54** |

## Summary

The results of the study indicated that potato petiole nitrate N could be estimated from remote sensing imagery at one test site but not the other. At the Fincastle site, visually the spatial patterns in the remote sensing derived maps for N levels and those derived from ground based plant sampling were similar. Errors in the overlay of petiole sampling points on the remote sensing imagery may account for the lack of a significant quantitative relationship at the Hays site. Further studies are being conducted to determine the ability to estimate plant N content using remote sensing techniques.

## Soil Salinity

A soil salinity map was made of the additional Vauxhall potato field in 1999 (Fig. 20). This permitted identifying those areas of the field where problem levels of salinity occurred. Tuber samples in these areas were compared to measurements of electrical conductivity (E.C.) calculated from EM38 readings and a tolerance of potatoes to salinity was developed for this field (Fig. 21a). A 50% yield reduction of potatoes occurred at an E.C. of about 6 dS/m. This method is suitable for precision applications to potato production. A salinity tolerance limit and a salinity map means it is then possible to identify those areas where it is not feasible to grow potatoes. Specific gravity of tubers was found to be higher in saline soils than non-saline soils (Fig. 21b).

## CONCLUSIONS

A yield monitor was successfully adapted to two farmers' potato harvesters. Maps of tuber yields were developed based on data collected from the harvester. Difficulties were encountered on parts of fields where soil lumps occurred. These lumps usually occurred on areas with a high clay content and resulted in false high yield readings from the mass-based yield sensor. This will be a major restriction to yield mapping of potatoes unless technology can be developed to separate tubers from soil lumps on the harvester belt.

Yield maps were also developed from grid sampling. These grid samples were used to determine tuber yield, average tuber size and tuber quality as measured by specific gravity, chipping score and French fry score. Uniformity of tuber quality is a major concern of processors. Uniformity of irrigation affected tuber size. No relationship was found between chipping and French fry score and the measured factors of soil or water in the field.

Grid sampling was used to develop numerous maps of irrigation and precipitation, consumptive water use, soil texture and nutrient contents, plant petiole (tissue) nutrient contents and the tuber characteristics just described.

Grid sampling of the fields showed variability in soil texture. Most of the fields contained about 6 to 30% clay with a few sites with as much as 40% clay. The texture was correlated to various soil and plant chemical properties.

When yield mapping with differential GPS using a base station in the corner of the field, accurate topographic maps could be developed. When differential corrections were obtained from a geostationary satellite service, the vertical accuracy was no longer suitable for confident topographical mapping.

Soil levels and fertilizer applications of nitrogen by the farmers were in most cases equal to what a crop of potatoes yielding 50 t/ha would be anticipated to take up. No allowance was made for release of nitrogen from soil organic matter. Tissue nitrate levels were frequently deficient according to standards used by Alberta potato growers. Two of six fields had sufficient variability of soil nitrogen to justify the cost of soil sampling and variable rate application. However, petiole $NO_3$-N in the first week of July was significantly negatively related to clay content (0.0-0.60 m) and was not significantly related to soil $NO_3$-N. This means it would be more useful for farmers on these fields to base a site specific nitrogen application on soil clay content than on soil $NO_3$-N content.

Soil P was significantly positively correlated to petiole P content. Soil P was not significantly correlated to clay content or other easily-measured soil characteristics. Opportunities exist for precision applications of phosphorus particularly on two of the fields that had a history of receiving non-uniform applications of manure. Thus, in the absence of any easily-measured factors that are correlated to P, a strategy of phosphorus fertilizer applications based on grid sampling of soil phosphorus should provide some improvement in efficiency of uptake of phosphorus.

Potassium levels in the soil from 1997 to 1999 were marginal to adequate on most grid sample sites. In 1997 and 1998 petiole K levels were deficient in the first week of July but became adequate to high in two later samplings. The reason for this is not known. It may be due to lower soil temperatures in early July restricting uptake, rather than the higher soil temperatures in the USA where the standards were developed. There is a need for research that will develop local standards for petiole K levels.

Diseases and insect pests were examined but their occurrence was very infrequent and highly variable, thus not predictable or manageable with site specific technologies. Weeds were carefully managed by farmers thus fields were too weed-free to allow for examination of the usefulness of site specific management for weed control. The sites used in the trials, like most potato fields, were extremely flat, which eliminated the opportunity for relating landscape position to potato yield.

Economic analysis indicated that grid sampling and site specific applications of P and K, on a field that received uneven manure applications, would have realized significant savings.

Remote sensing imagery was successful correlated to plant petiole NO3-N at one test site but not the other. Errors in the overlay of petiole sampling points on the remote sensing imagery may account for the lack of a significant quantitative relationship at the Hays site.

Piezometers were used to measure groundwater depth movement and soil $NO_3$-N content at the Hays (1997) and Fincastle (1997, 1998) sites. Overall, nitrate levels were low at depth but this may have been due to reducing conditions, causing denitrification. At the Hays site, flow of groundwater occurred from the irrigated field outward to an unirrigated rangeland. Irrigation has caused water table mounding below the sites and water tables rose during the summer at the Hays site.

# FIGURES

Snowden Potatoes: Hays 1997 Sample Sites

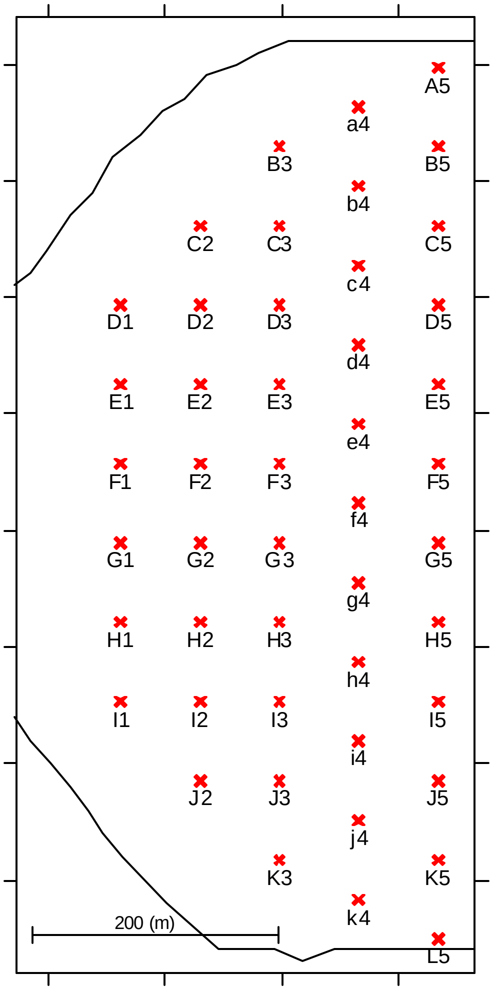


**Figure 1. Sampling grid for yield, petioles, water and soil samples for Snowden potatoes grown at Hays in 1997.**

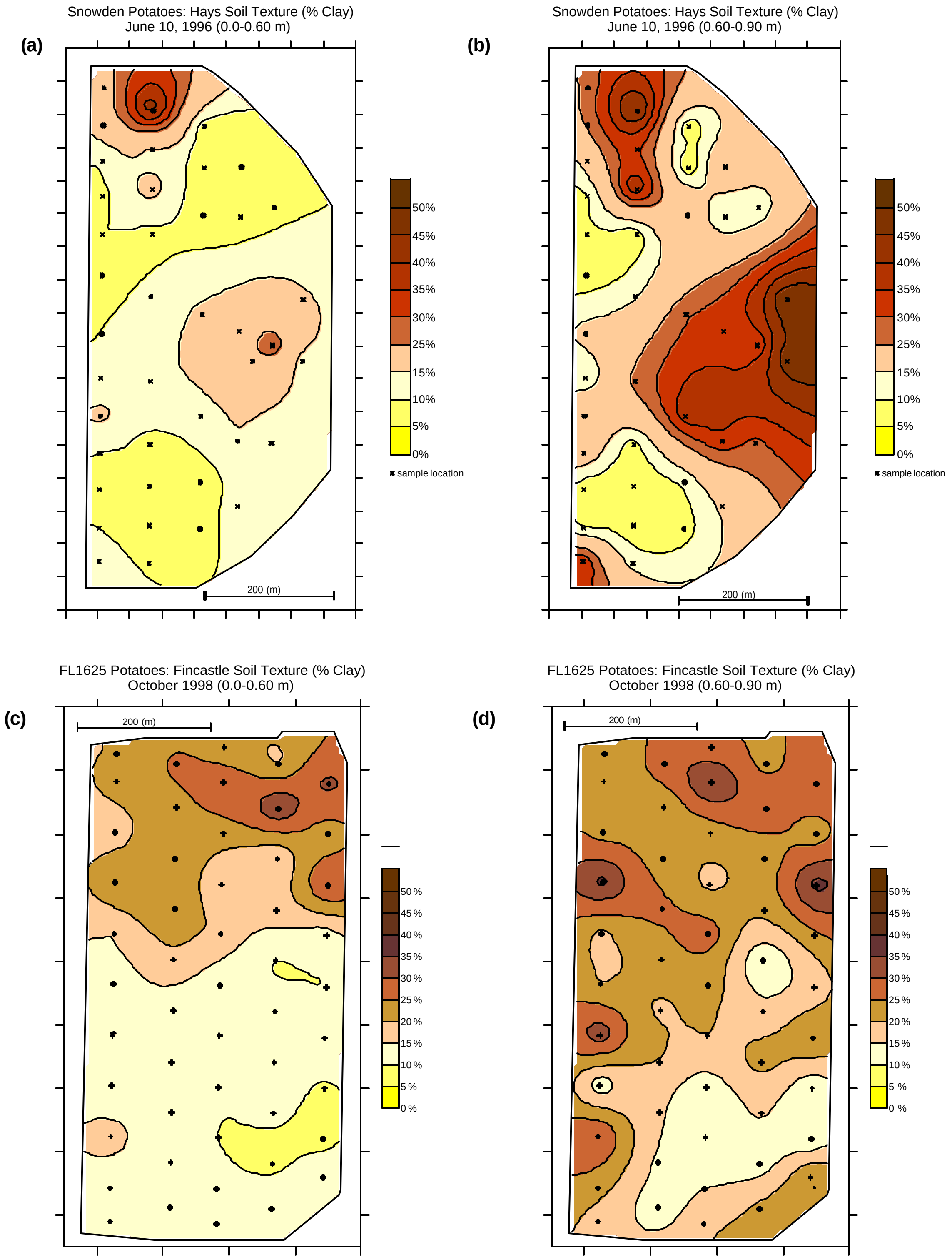


**Figure 2. Soil texture maps of Hays 1996 (a and b) and Fincastle 1999 (c and d) fields for two soil depths 0.0-0.60 m and 0.60-0.90 m.**

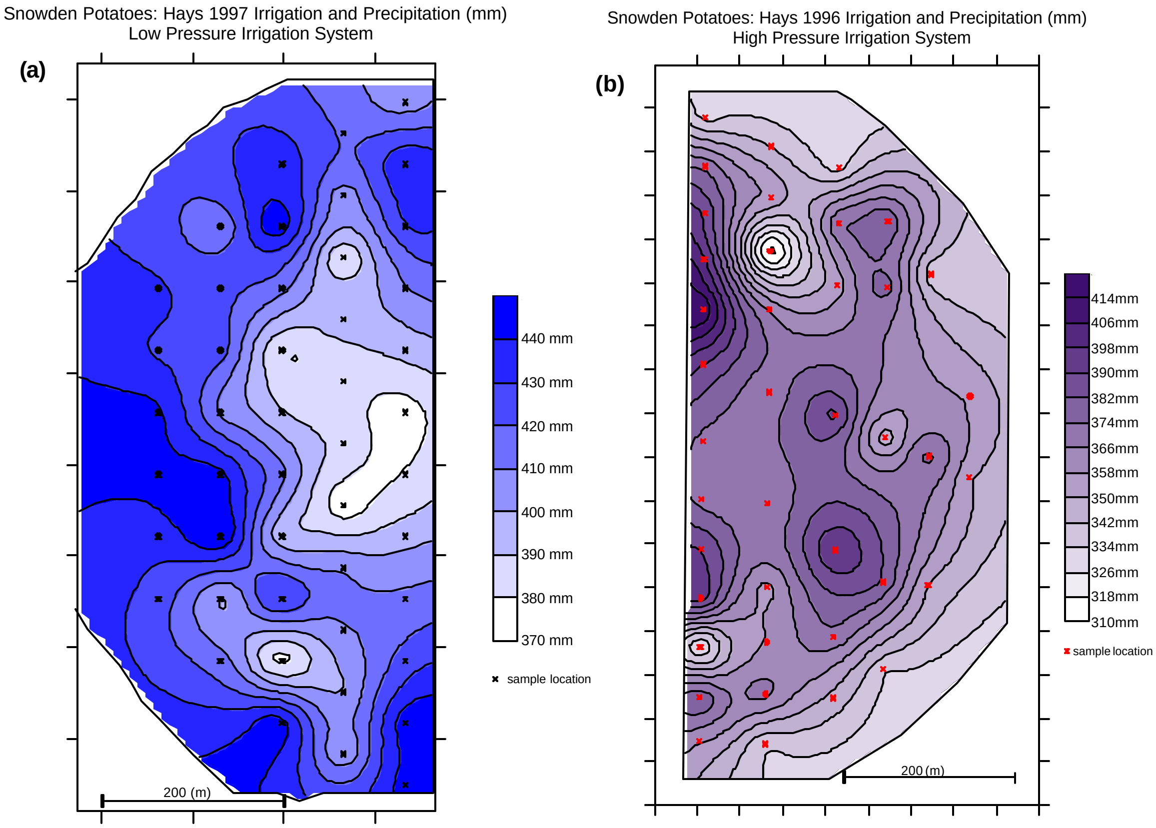


Figure 3. Change of sprinkler design causing contrasting distribution of irrigation and preciptation at Hays in 1997 west (a) and 1996 east (b).

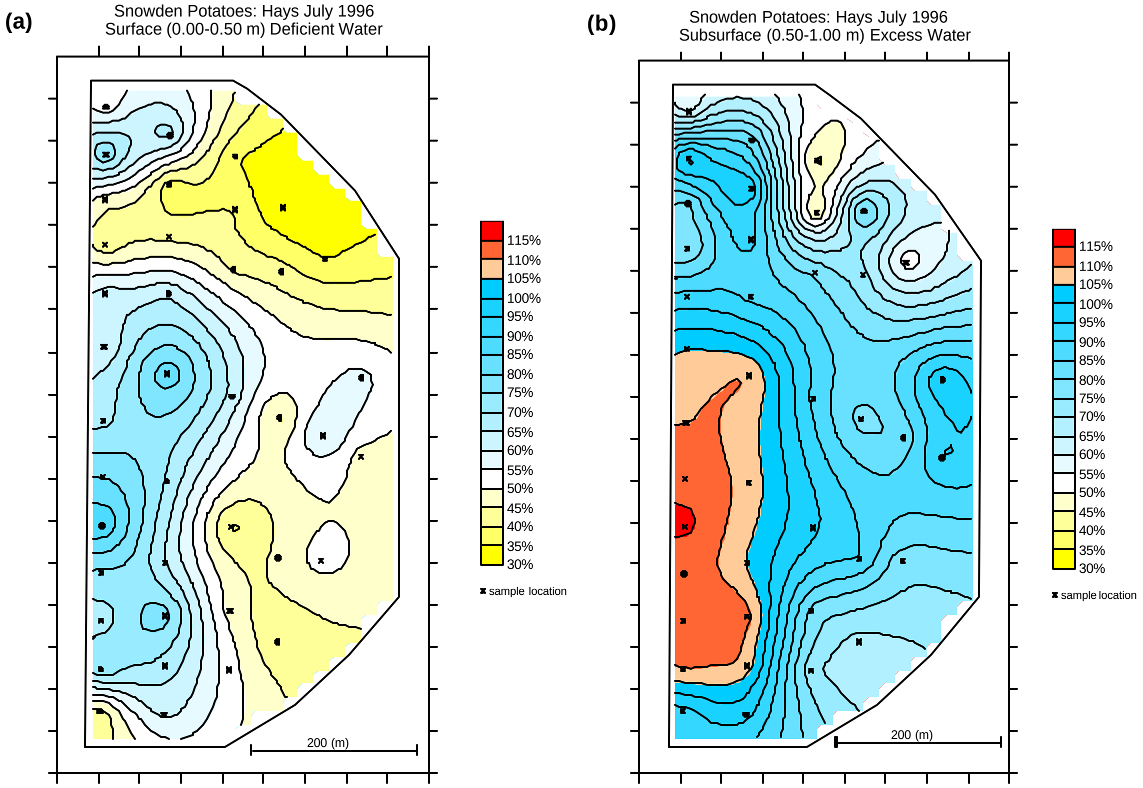
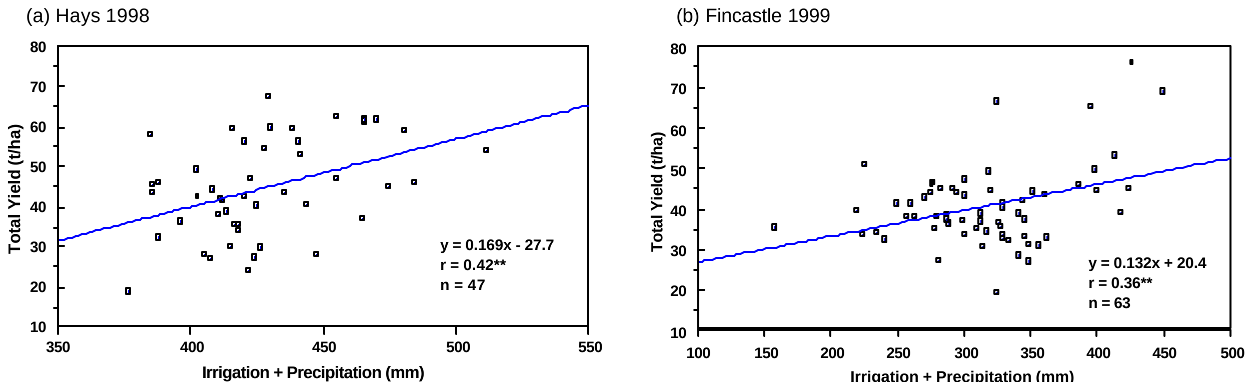
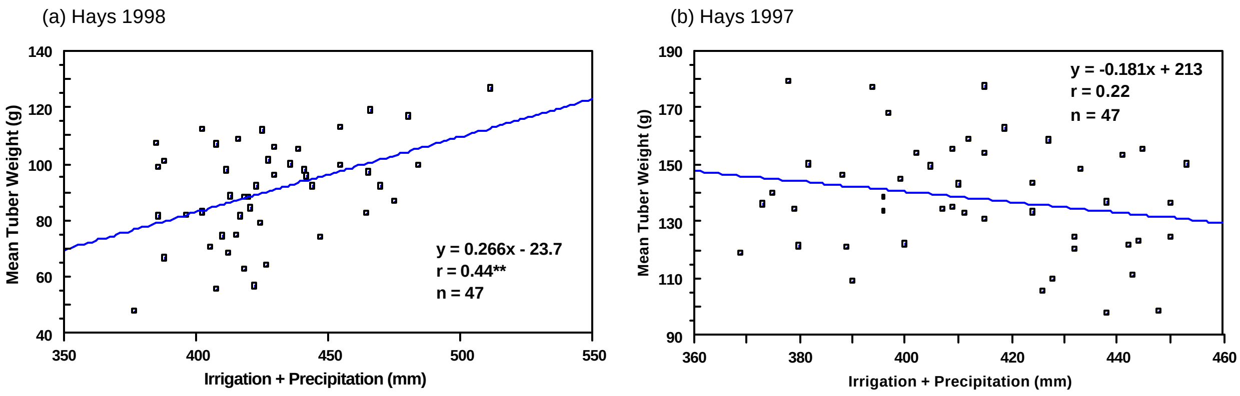


**Figure 4. Percent of available moisture (100% = field capacity) in 1996 at Hays for (a) 0.0-0.50 m and (b) 0.50-1.00 m.**



** = r significant at the 0.01 level

**Figure 5. Correlation between total potato yield and total added water (irrigation + precipitation) at (a)Hays 1998 and (b)Fincastle 1999.**



** = r significant at the 0.01 level

**Figure 6. Correlation between mean tuber weight and total added water (irrigation + precipitation) at (a)Hays 1998 and (b)Hays 1997.**

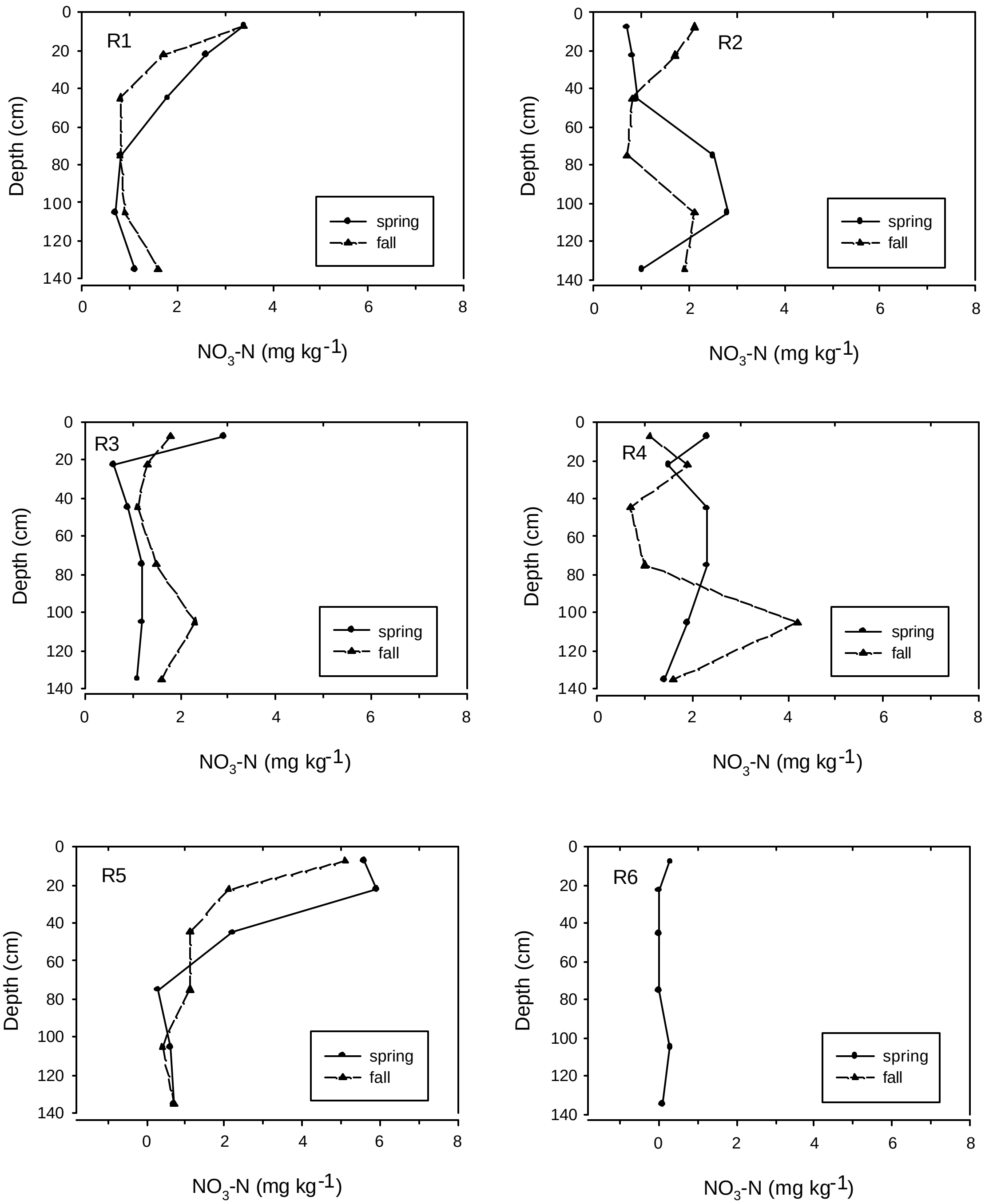


**Figure 7. Soil NO$_3$-N at piezometer sites from 1997 at Hays.**

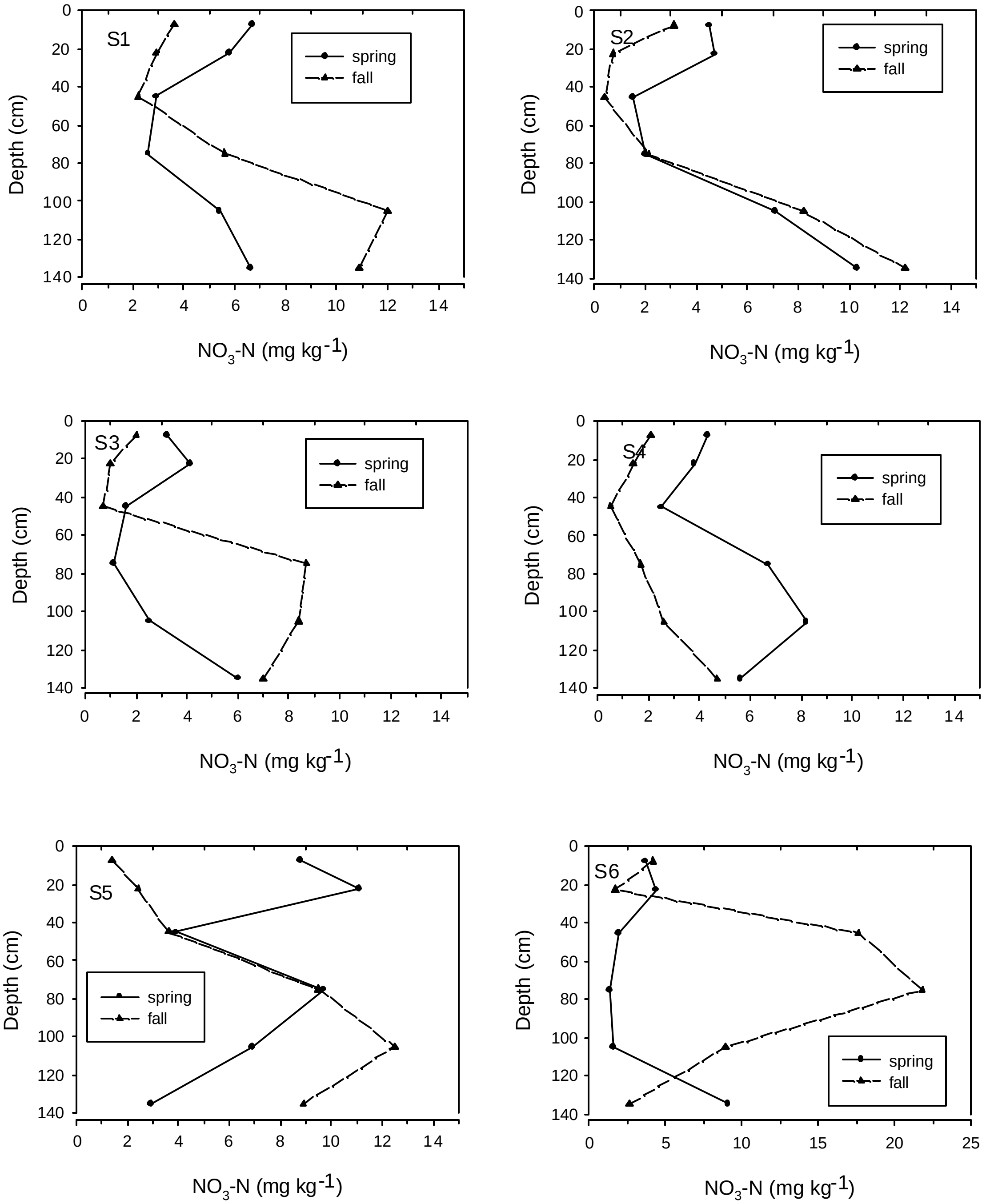


Figure 8. Soil NO$_3$-N levels at piezometer sites from 1997 at Fincastle.

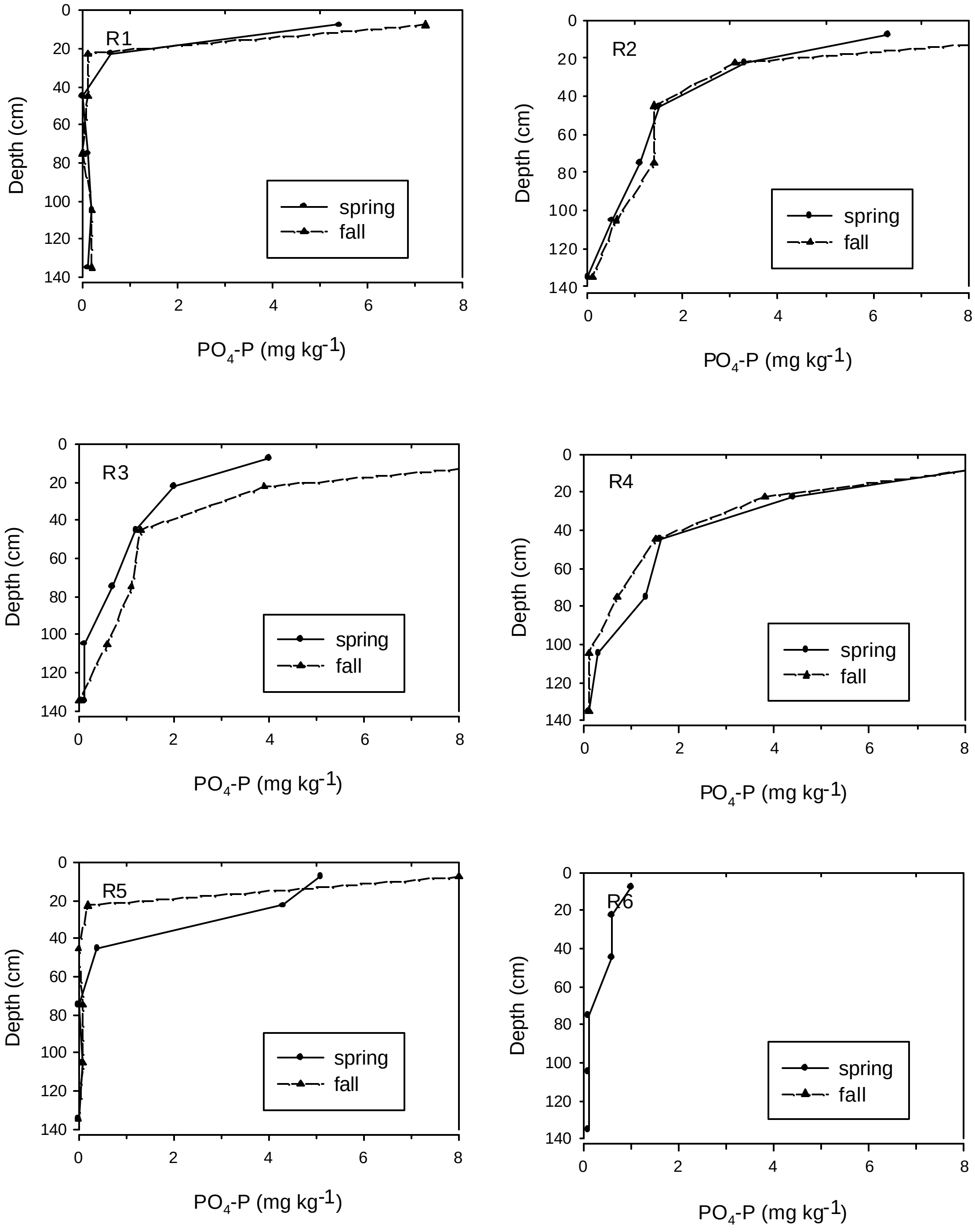


**Figure 9. Soil $PO_4$-P at piezometer sites from 1997 at Hays.**

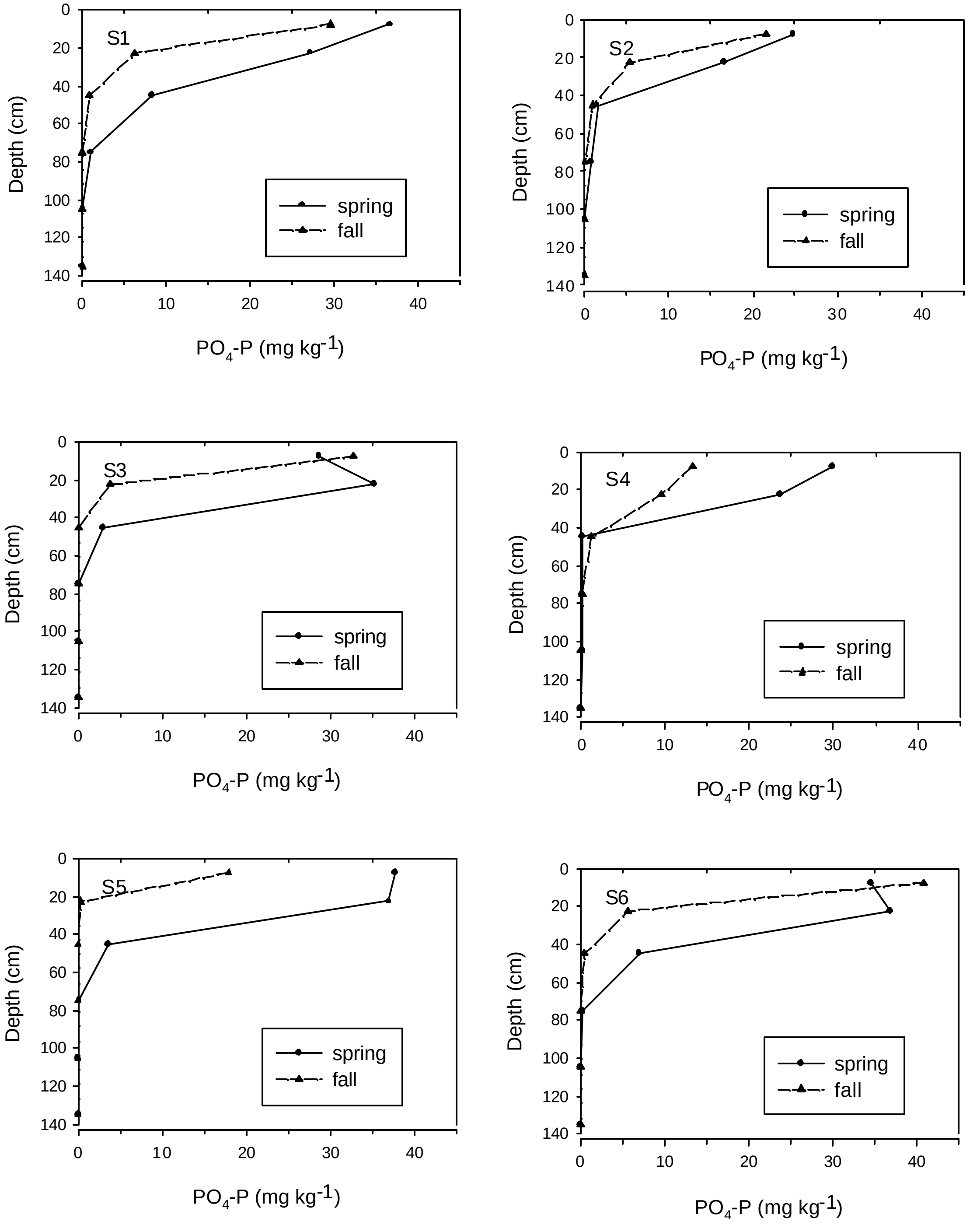
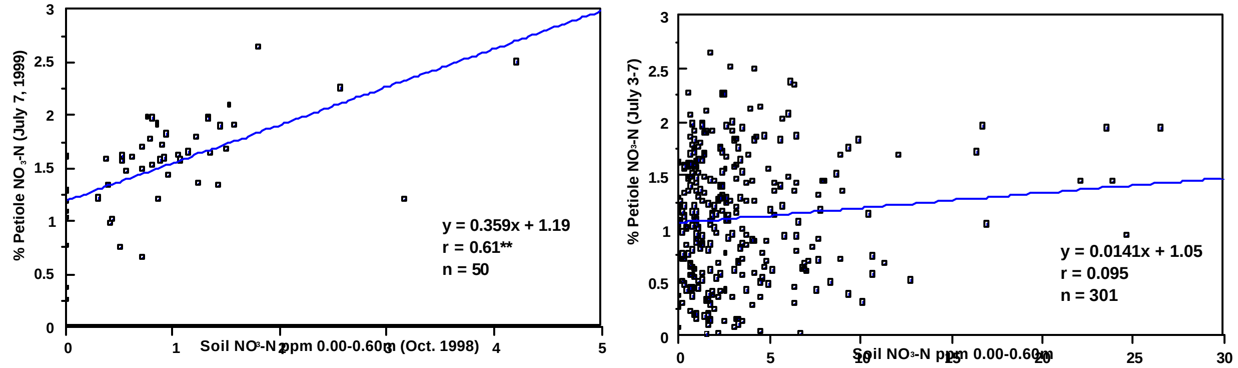


**Figure 10. Soil PO$_4$-P at piezometer sites from 1997 at Fincastle.**

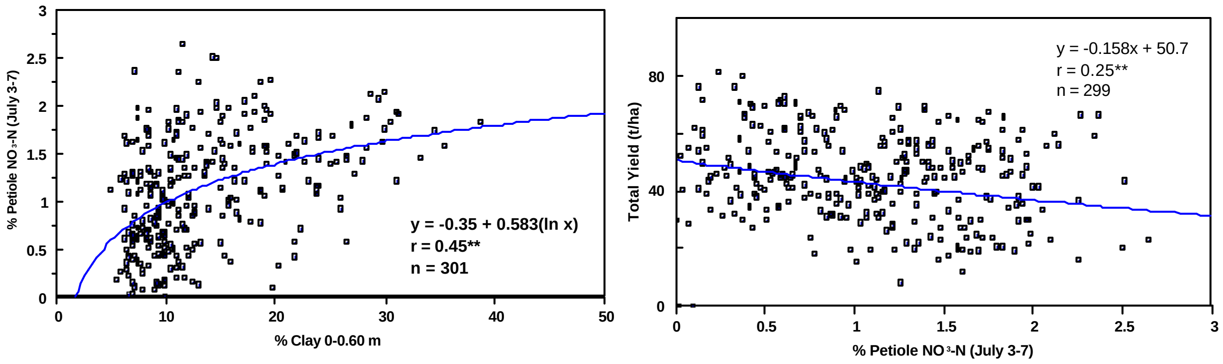
(a) Hays 1999: Soil $NO_3$-N ppm and Petiole $NO_3$-N % (July 7)

(b) 1997-99: Soil $NO_3$-N ppm and Petiole $NO_3$-N % (July3- 7)



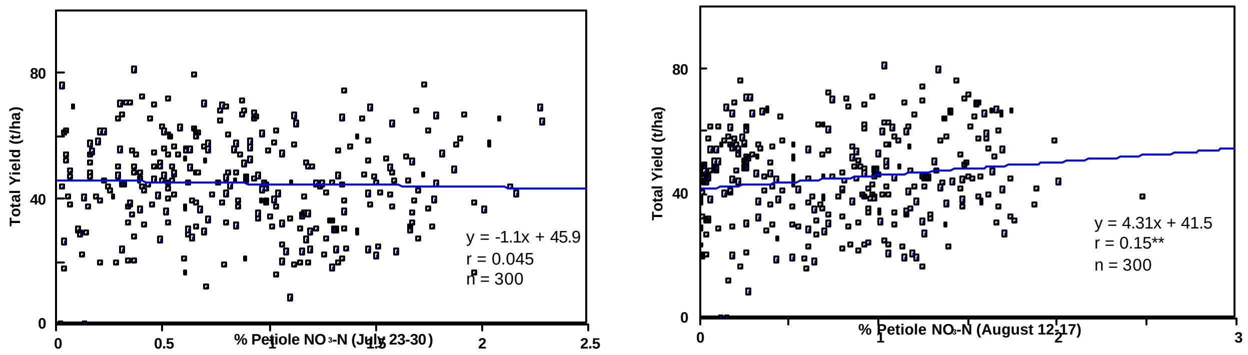
(c) 1997-99: % Clay (0.0-0.60 m) and Petiole $NO_3$-N % (July 3-7)

(d) 1997-99: Petiole $NO_3$-N % (July 3-7) and Total yield (t/ha)



(e) 1997-99: Petiole $NO_3$-N % (July 22-30) and Total yield (t/ha)

(f) 1997-99: Petiole $NO_3$-N % (August 12-17) and Total yield (t/ha)



* = r significant at the 0.05 level, ** = r significant at the 0.01 level

**Figure 11. Correlation between potato petiole $NO_3$-N and (a) soil $NO_3$-N for Hays 1999 and (b) soil $NO_3$-N, (c) soil clay and (d, e and f) total yield for Fincastle and Hays potatoes 1997-1999.**

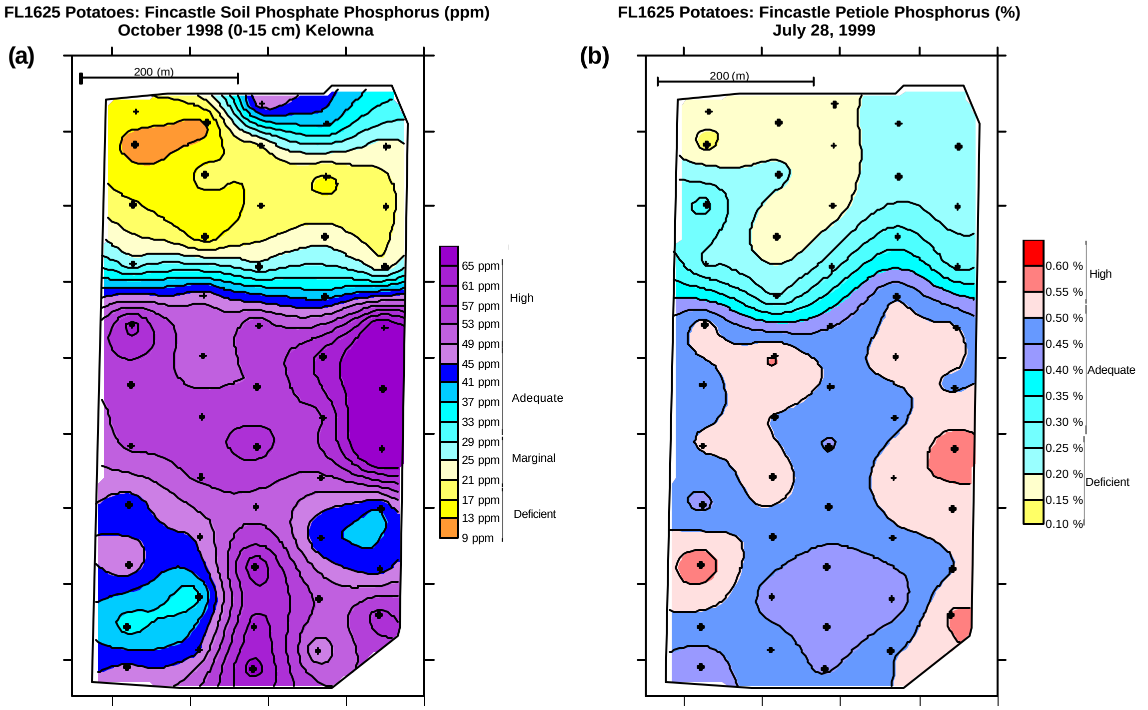


**Figure 12. Fincastle (a) soil PO$_4$-P (October 1998, 0.00-0.15 m) and (b) petiole P (July 28, 1999) for a field which was partially fertilized with hog manure October 1997.**

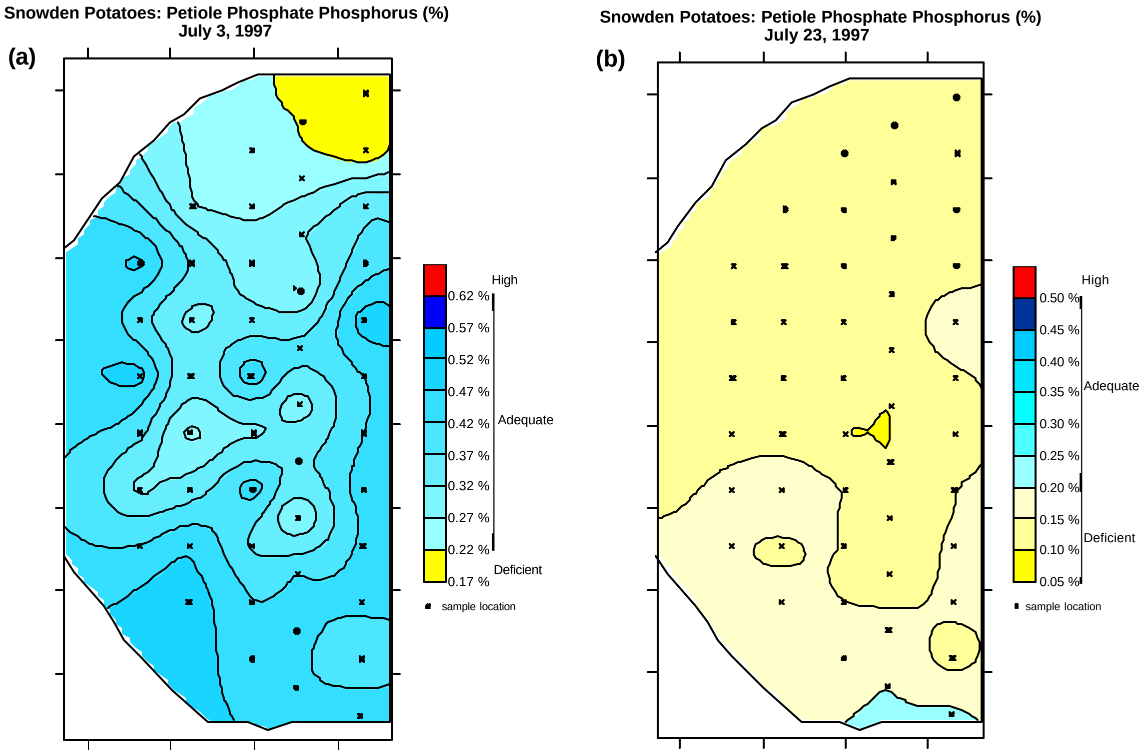
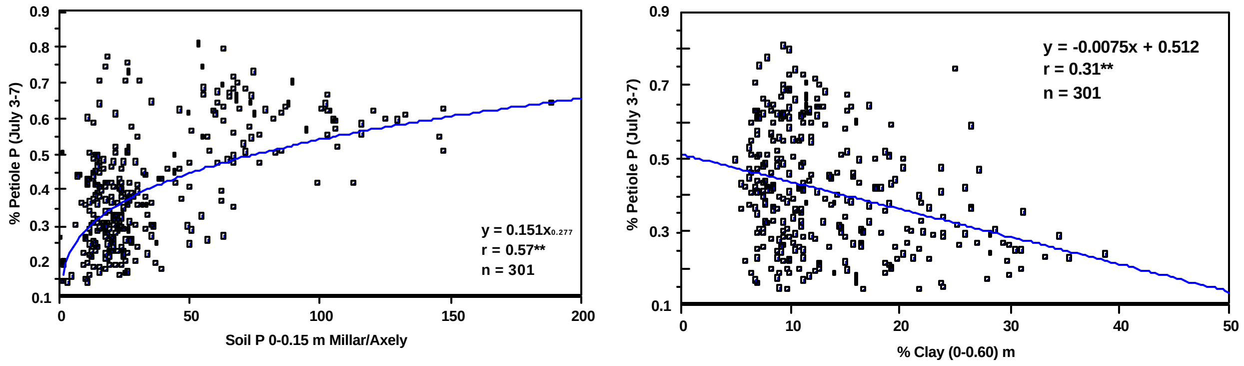
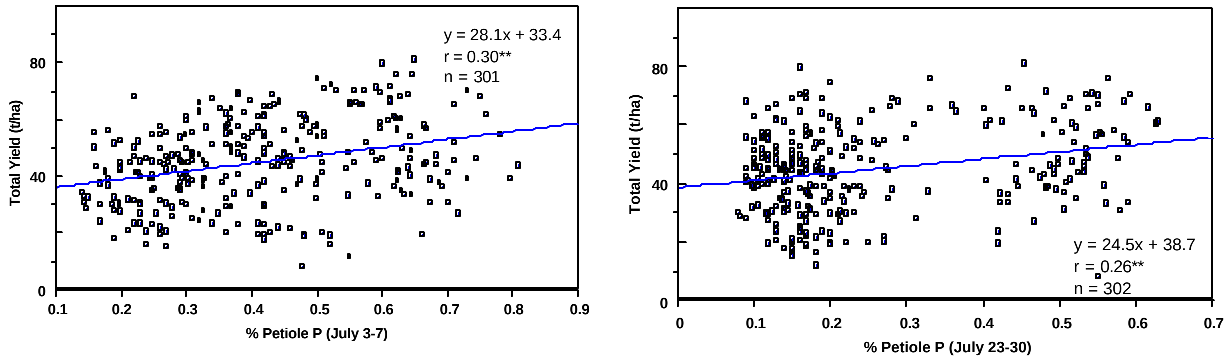


**Figure 13. Petiole P levels at Hays (July 1998) showing rapid decline of petiole P from (a) July 3 to (b) July 23, 1997.**



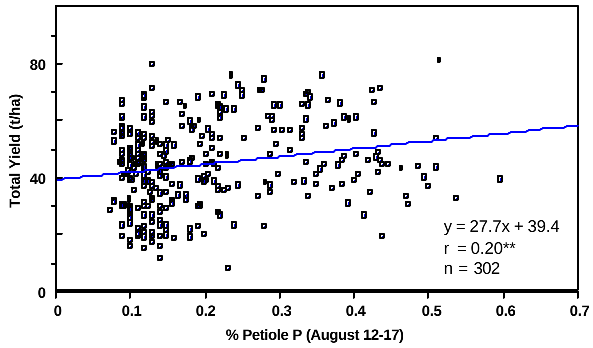
(a) 1997-99: Soil P ppm (0.0-0.15 m) and Petiole P % (July 3-7)

(b) 1997-99: Soil % Clay (0-0.60 m) and Petiole P % (July 3-7)



(c) 1997-99: Petiole P % (July 3-7) and Total Yield (t/ha)

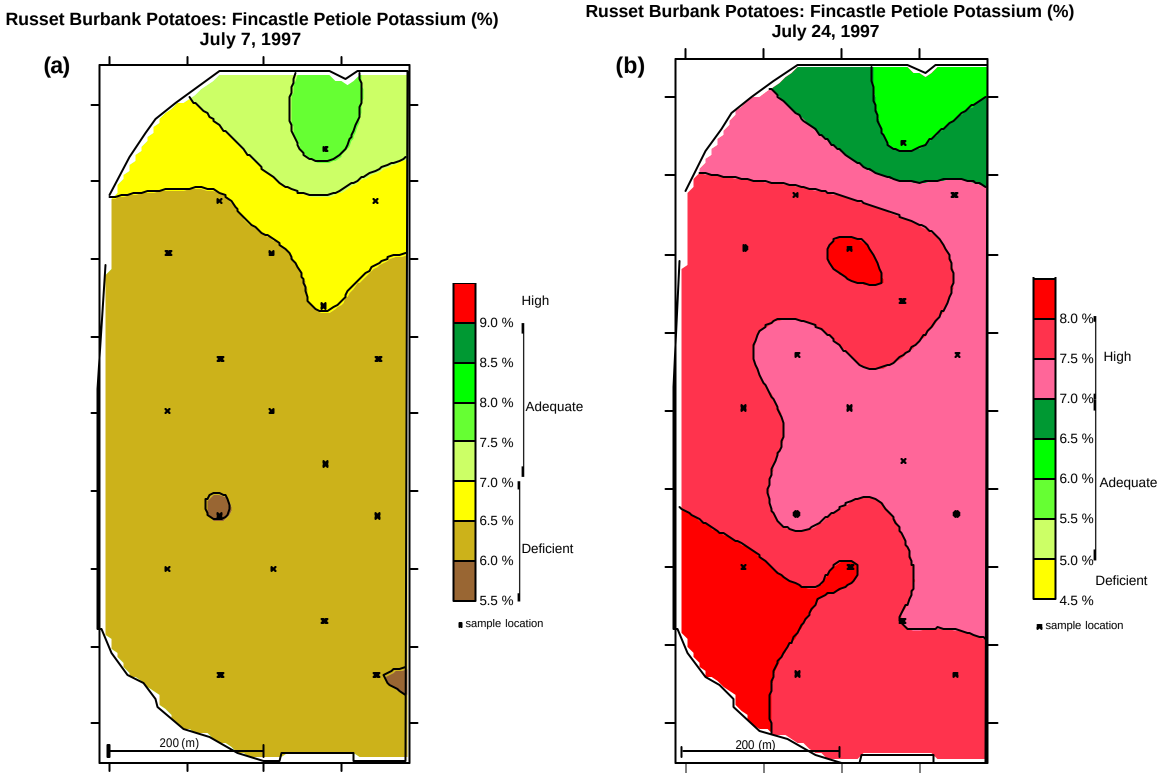
(d) 1997-99: Petiole P % (July 23-30) and Total Yield (t/ha)



(e) 1997-99: Petiole P % (August 12-17) and Total Yield (t/ha)

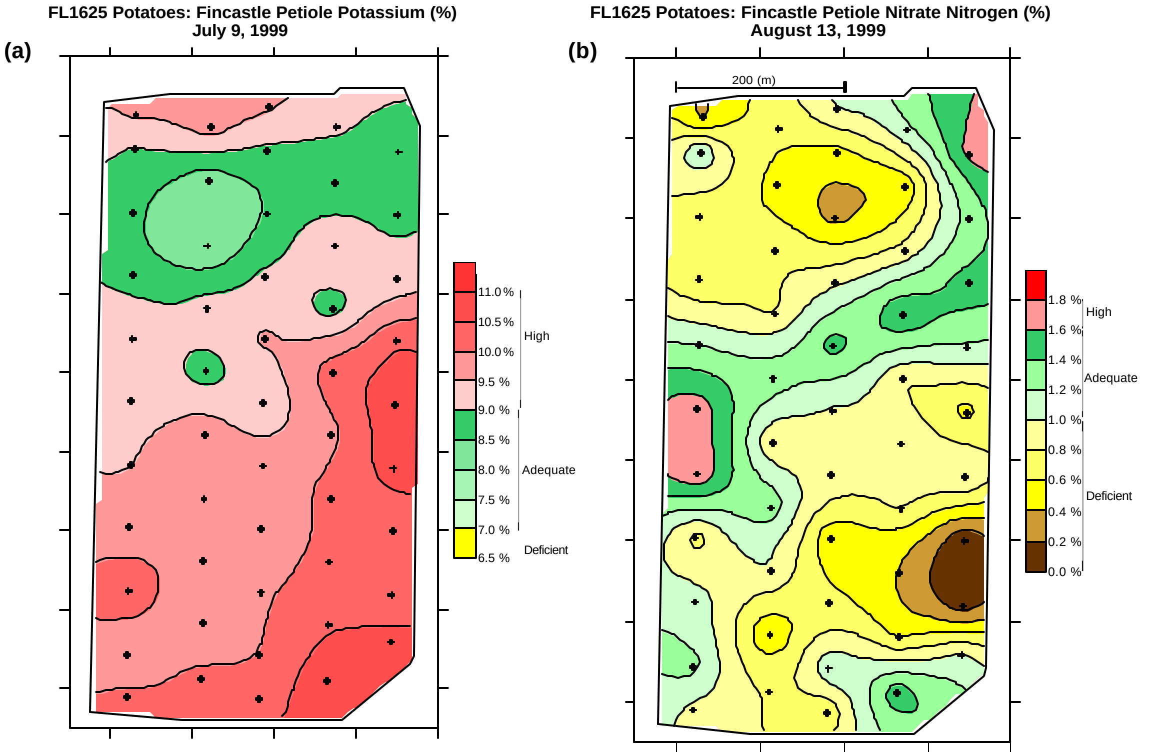
* = r significant at the 0.05 level, ** = r significant at the 0.01 level

**Figure 14. Correlation between potato petiole P and (a) soil $PO_4$-P, (b) soil clay and (c, d and e) total yield for 3 sampling dates at Hays and Fincastle for 1997-1999.**


Russet Burbank Potatoes: Fincastle Petiole Potassium (%)
July 7, 1997

Russet Burbank Potatoes: Fincastle Petiole Potassium (%)
July 24, 1997

**Figure 15. Petiole potassium showing an increase of percent K from (a) July 7, 1997 to (b) July 24, 1997 at Fincastle.**


FL1625 Potatoes: Fincastle Petiole Potassium (%)
July 9, 1999

FL1625 Potatoes: Fincastle Petiole Nitrate Nitrogen (%)
August 13, 1999

**Figure 16. Petiole potassium showing a slight decrease of percent K from (a) July 9, 1999 to (b) August 13, 1999 at Fincastle.**

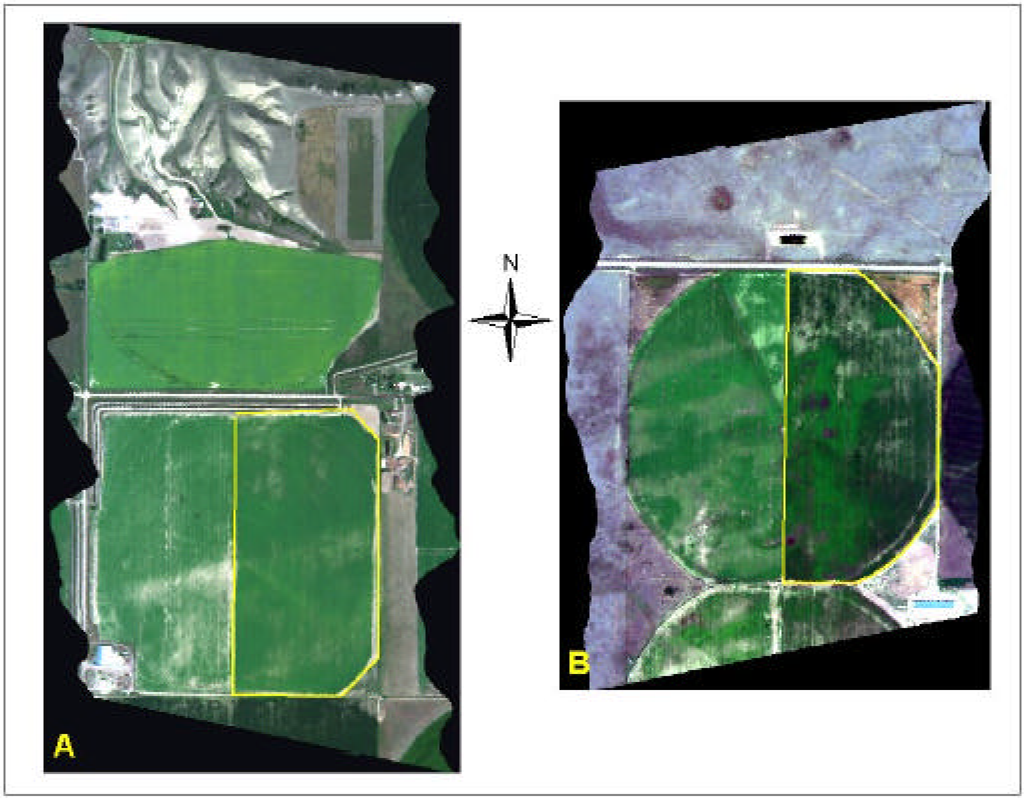


**Figure 17. True colour composite images acquired July 28, 1999 at the (a) Fincastle and (b) Hays sites.**

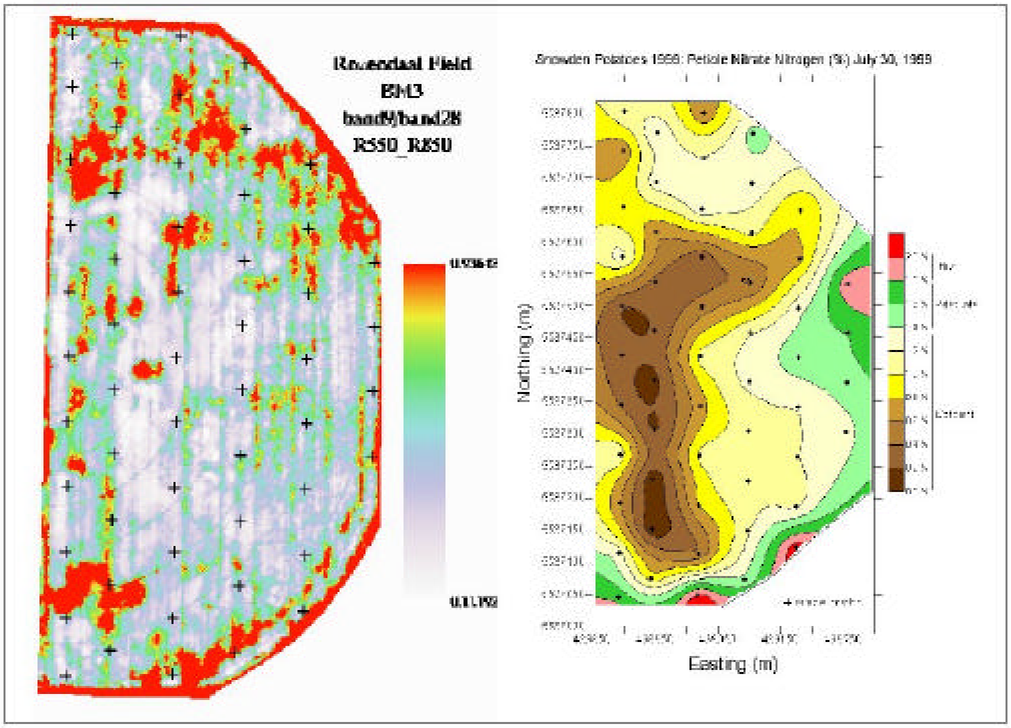


Figure 18. Fincastle site $SR_{550\_850}$ index image and petiole N map (July 28, 1999) derived from ground-based sampling.

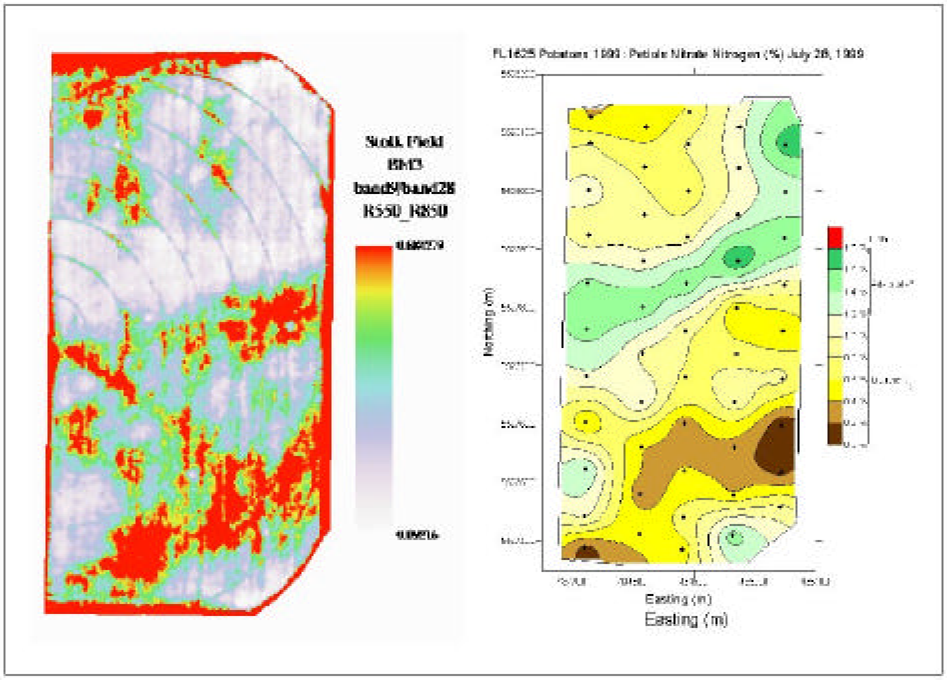


Figure 19. Hays site $SR_{550\_850}$ index image and petiole N map (July 30, 1999) derived from ground-based sampling.

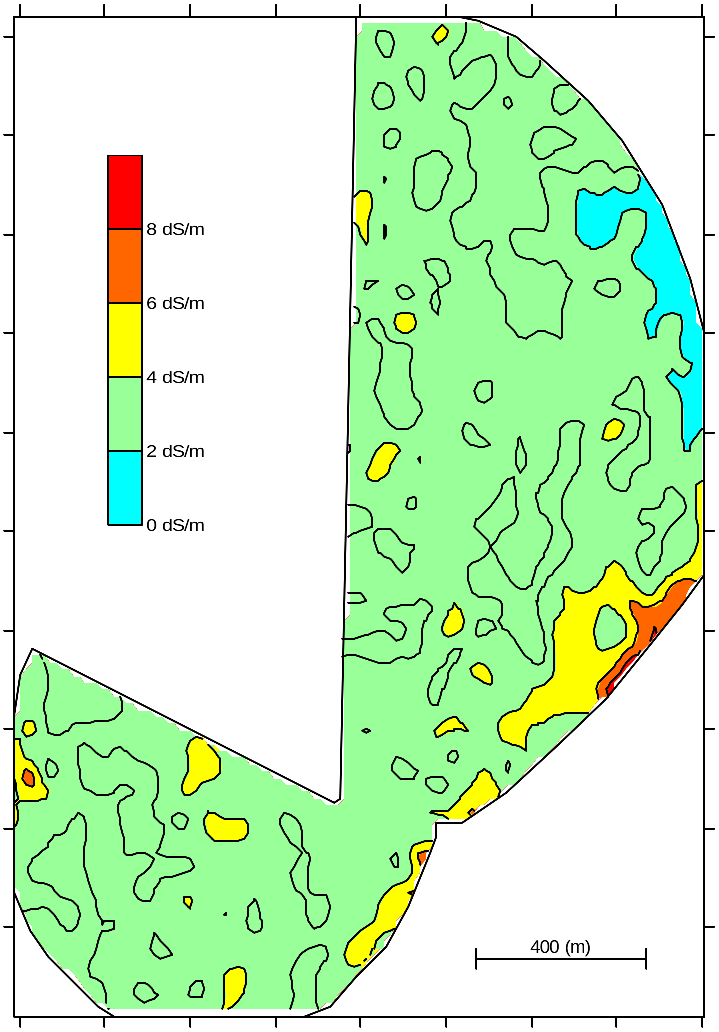
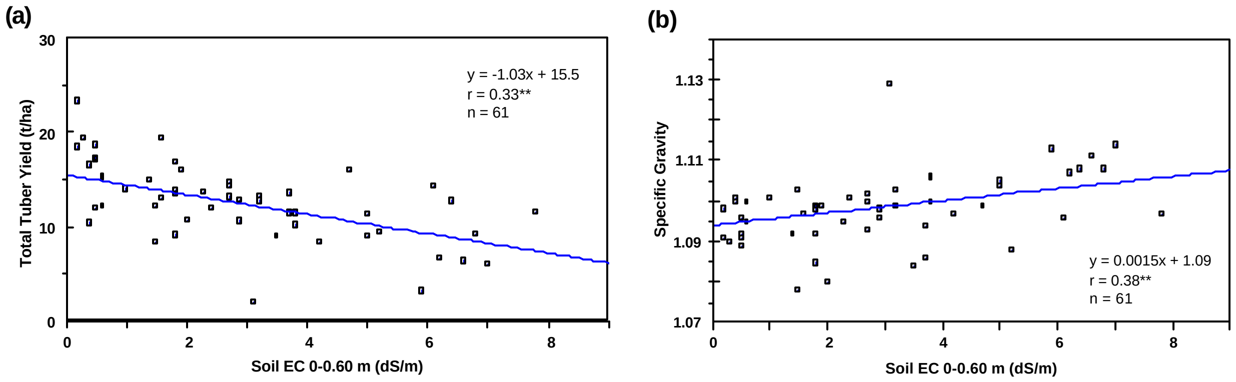


**Figure 20. Soil salinity map (E.C. dS/m) for Vauxhall potatoes, April 1999.**



** = r significant at the 0.01 level

**Figure 21. The effect of soil salinity on (a) tuber yield and (b) tuber specific gravity for Vauxhall potatoes 1999.**

# IMPLICATIONS OF THE STUDY WITH REGARD TO THE IMPROVEMENT OF ALBERTA'S AGRICULTURAL AND FOOD INDUSTRY AND ADVANCEMENT OF AGRICULTURAL KNOWLEDGE

This project showed the difficulties using current yield monitoring equipment on many commercial fields. When soil variability is present, there are areas, which contain a high percentage of clay and form lumps on the harvester. The yield monitor weighs the material on the harvester belt and does not distinguish between potatoes and other material. Yield monitors usually work satisfactorily on fields, which do not contain medium or fine textured areas. Upper limits of currently used potato petiole nutrient sufficiency standards for phosphorus were found to be high. Subsequent experiments with rates of phosphorus on potatoes have confirmed this.

Petiole nutrient contents of potassium were shown to be unreliable as an indication of potassium deficiency. Research needs to be done to determine what are critical levels for yield or quality and what factors influence the potassium of petioles when grown under conditions with cold night temperatures like those of southern Alberta.

Field variability and lack of uniformity of output of irrigation water were found to be factors, which influence the growth and quality of potatoes. Farmers would do well to measure the output and uniformity of their irrigation systems.

Soil salinity was shown to be a measurable characteristic, which can be used to select portions of potential fields, which are not suitable for growing potatoes.

Site specific monitoring and yield mapping of a potato field, which is sampled by grid is a useful research technique to identify factors, which may be influencing yield and quality of potatoes.

# ACKNOWLEDGEMENTS

Support for this project was received from the Alberta Agriculture Research Institute, Potato Growers of Alberta, Cargill, Potash and Phosphate Institute of Canada, Southern Agri Services, Westco and The Snack Food Association of Canada. Laboratory analysis was provided by the AAFRD Soil and Crop Diagnostic Centre, Edmonton. Two farm operations – one at Hays, the other Fincastle – allowed access to their fields and their potato and grain harvesters.

J. Rodvang monitored ground water at a series of piezometer nests in 1997 and 1998 and prepared the related portion of this document, including the text and Figures 7-10.

A. Smith of Agriculture and Agri-Food Canada, Lethbridge interpreted the 1999 CASI data and prepared the related portion of this document, including the text, Tables.18-20 and Figure 17-19. A. Smith's full report also appears as an appendix in this document.

L. Hingley, technologist for the Soil and Water Agronomy Program, conducted yield monitoring, sample collection and data organization and he prepared the figures and appendices for this document.

The Precision Agriculture Project with Potatoes was operated by an Alberta Agriculture, Food and Rural Development (AAFRD) team. Soil moisture budgets were determined by R. Hohm and T. Harms. D. McKenzie, R. Skretting, B. winter, T. Dell, A. Harms, H. Harms and L. Wenger collected and processed samples. J. Panford organized measurement of tuber chipping and French fry scores. M. Eliason and D. McKay assisted with setting up yield monitoring equipment. C. Murray proofread the manuscript. Word processing of the manuscript was done by S. Day and M. Bunney.

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# APPENDICES

Appendices I to VIII list the raw data collected from the grid sample sites, including soil characteristics, plant tissue nutrients, rain gauge readings and hand-dug tuber sample attributes. Appendix IX provides the data from the 1999 Vauxhall soil salinity site. Appendix X is the remote sensing document provided by A. Smith.

## I. 1996 Fincastle Grid Sample Data

| **1996 Fincastle Site (FL1625)** | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Position Data** | | **Moisture** | | **Soil Characteristics** | | | **Petiole Nutrient Contents** | | | | | | | | |
| Site | Easting (m) | Northing (m) | Irrigation + Precipitation (mm) | Consumptive Use (mm) | Clay (%) | | pH | $NO_3$-N (%) | | | P (%) | | | Ca (%) | | |
| Info✍ | | | DR | | | | | DT[1] | DT[2] | DT[3] | DT[1] | DT[2] | DT[3] | DT[1] | DT[2] | DT[3] |
| Depth (cm) | | | | (0-50) | (0-60) | (60-90) | (0-90) | | | | | | | | | |
| 1 | 434777.637 | 5527480.426 | 298 | 350 | 11 | 14 | 7.4 | 0.96 | 0.20 | 0.18 | 0.48 | 0.16 | 0.11 | 1.36 | 1.49 | 1.78 |
| 2 | 434781.031 | 5527683.803 | 321 | 352 | 13 | 18 | 7.6 | 0.08 | 0.03 | 0.06 | 0.54 | 0.34 | 0.18 | 0.87 | 1.08 | 1.55 |
| 3 | 434783.654 | 5527839.738 | 328 | 379 | 17.5 | 25 | 7.7 | 0.53 | 0.25 | 0.00 | 0.53 | 0.31 | 0.11 | 1.03 | 1.10 | 1.21 |
| 4 | 434786.785 | 5528039.644 | 306 | 379 | 23 | 23 | 8.2 | 1.29 | 0.34 | 0.01 | 0.27 | 0.12 | 0.06 | 1.43 | 1.22 | 1.27 |
| 5 | 434973.944 | 5528031.152 | 295 | 333 | 23 | 28 | 7.7 | 1.48 | 0.38 | 0.12 | 0.56 | 0.22 | 0.12 | 1.16 | 1.02 | 1.21 |
| 6 | 434971.236 | 5527835.103 | 307 | 389 | 12.5 | 19 | 7.4 | 1.15 | 0.59 | 0.14 | 0.51 | 0.23 | 0.13 | 1.23 | 1.59 | 1.59 |
| 7 | 434969.571 | 5527672.749 | 289 | 344 | 11 | 17 | 7.3 | 0.98 | 0.31 | 0.07 | 0.49 | 0.15 | 0.13 | 1.34 | 1.71 | 1.73 |
| 8 | 434965.784 | 5527471.701 | 315 | 379 | 9 | 10 | 7.3 | 0.90 | 0.01 | 0.02 | 0.52 | 0.22 | 0.18 | 1.09 | 1.22 | 1.49 |
| **Means** | | | **307** | **363** | **15** | **19** | **7.6** | **0.92** | **0.26** | **0.08** | **0.49** | **0.22** | **0.13** | **1.19** | **1.30** | **1.48** |

✍ **Additional Information, as follows.**

DR – June 28 – August 16, 1996

DT[1] – July 4, 1996
DT[2] – July 30, 1996
DT[3] – August 20, 1996

## II. 1996 Hays Grid Sample Data

| **1996 Hays Site (Snowden)** | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Position Data** | | **Moisture** | | **Soil Characteristics** | | | **Petiole Nutrient Contents** | | | | | | | | |
| Site | Easting (m) | Northing (m) | Irrigation + Precip. (mm) | Consumptive Use (mm) | Clay (%) | | PH | $NO_3$-N (%) | | | P (%) | | | Ca (%) | | |
| Info ☞ | | | DR | | | | | $DT^1$ | $DT^2$ | $DT^3$ | $DT^1$ | $DT^2$ | $DT^3$ | $DT^1$ | $DT^2$ | $DT^3$ |
| Depth (cm) | | | | (0-100) | (0-60) | (60-90) | (0-30) | | | | | | | | | |
| 1 | 438902.045 | 5537073.788 | 359 | 356 | 12 | 35 | 5.6 | | 1.19 | 0.34 | 0.38 | 0.19 | 0.07 | 0.9 | 1.0 | 1.2 |
| 2 | 438902.672 | 5537123.641 | 384 | 392 | 10 | 9 | 6.6 | 2.00 | 0.59 | 0.06 | 0.41 | 0.17 | 0.07 | 0.9 | 1.1 | 1.8 |
| 3 | 438903.484 | 5537181.997 | 321 | 331 | 8 | 7 | 6.6 | 2.09 | 0.37 | 0.05 | 0.44 | 0.18 | 0.06 | 0.9 | 1.2 | 2.0 |
| 4 | 438904.003 | 5537237.907 | 398 | 384 | 10 | 21 | 6.2 | 2.38 | 1.47 | 0.35 | 0.46 | 0.23 | 0.07 | 1.0 | 1.1 | 1.4 |
| 5 | 438904.662 | 5537293.805 | 391 | 383 | 17 | 23 | 6.5 | 2.32 | 1.75 | 0.71 | 0.42 | 0.22 | 0.07 | 0.8 | 0.9 | 1.4 |
| 6 | 438905.223 | 5537351.503 | 371 | 375 | 11 | 10 | 7.2 | 2.48 | 1.56 | 0.43 | 0.50 | 0.21 | 0.07 | 0.8 | 0.9 | 1.5 |
| 7 | 438906.604 | 5537417.929 | 372 | 383 | 10 | 17 | 6.3 | 1.86 | 0.95 | 0.33 | 0.44 | 0.13 | 0.07 | 1.0 | 1.2 | 1.7 |
| 8 | 438907.019 | 5537506.409 | 390 | 406 | 9 | 7 | 7.1 | 1.48 | 0.71 | 0.08 | 0.44 | 0.10 | 0.07 | 1.0 | 1.4 | 1.7 |
| 9 | 438907.631 | 5537568.681 | 423 | 446 | 10 | 9 | 6.4 | 1.55 | 0.67 | 0.14 | 0.39 | 0.11 | 0.07 | 0.9 | 1.3 | 1.7 |
| 10 | 438908.385 | 5537626.645 | 401 | 390 | 9 | 9 | 6.3 | 1.59 | 0.66 | 0.12 | 0.44 | 0.12 | 0.07 | 1.0 | 1.3 | 1.6 |
| 11 | 438908.782 | 5537679.863 | 390 | 398 | 11 | 17 | 6.6 | 1.96 | 1.04 | 0.40 | 0.43 | 0.12 | 0.08 | 1.0 | 1.2 | 1.5 |
| 12 | 438909.163 | 5537733.54 | 373 | 386 | 36 | 48 | 7.5 | 2.35 | 1.25 | | 0.30 | 0.16 | | 1.1 | 1.1 | |
| 13 | 438909.557 | 5537789.555 | 331 | 373 | 20 | 26 | 7.6 | 2.07 | 1.08 | 0.32 | 0.25 | 0.13 | 0.06 | 1.1 | 1.5 | 1.8 |
| 14 | 438986.812 | 5537755.953 | 342 | 352 | 44 | 47 | 7.8 | 2.13 | 1.24 | 0.84 | 0.35 | 0.14 | 0.07 | 1.0 | 1.3 | 1.8 |
| 15 | 438986.256 | 5537697.291 | 358 | 383 | 14 | 31 | 7.2 | 2.02 | 0.88 | 0.38 | 0.48 | 0.16 | 0.08 | 1.0 | 1.2 | 1.5 |
| 16 | 438985.613 | 5537636.566 | 302 | 344 | 18 | 40 | 7.2 | 2.26 | 1.35 | 0.47 | 0.49 | 0.19 | 0.07 | 0.9 | 1.1 | 1.6 |
| 17 | 438984.958 | 5537568.789 | 366 | 363 | 9 | 7 | 7.2 | 1.70 | 0.97 | 0.37 | 0.50 | 0.16 | 0.08 | 0.8 | 1.1 | 1.7 |
| 18 | 438983.743 | 5537474.191 | 368 | 354 | 11 | 14 | 7.1 | 1.76 | 0.69 | 0.16 | 0.47 | 0.12 | 0.08 | 0.7 | 1.1 | 1.5 |
| 19 | 438982.247 | 5537346.354 | 365 | 374 | 14 | 26 | 7.1 | 2.07 | 0.00 | 0.41 | 0.50 | 0.00 | 0.08 | 0.9 | 0.0 | 1.5 |
| 20 | 438981.503 | 5537250.395 | 354 | 381 | 9 | 8 | 7.3 | 2.02 | 0.64 | 0.35 | 0.49 | 0.19 | 0.07 | 0.9 | 1.1 | 1.5 |
| 21 | 438980.989 | 5537187.362 | 358 | 363 | 9 | 7 | 7.8 | 1.53 | 0.23 | 0.03 | 0.34 | 0.13 | 0.07 | 0.9 | 1.2 | 1.6 |
| 22 | 438980.163 | 5537128.009 | 370 | 384 | 8 | 6 | 8 | 1.62 | 0.49 | 0.19 | 0.35 | 0.13 | 0.06 | 0.9 | 1.0 | 1.6 |
| 23 | 438979.531 | 5537070.395 | 334 | 355 | 10 | 13 | 6.2 | 1.80 | 1.30 | 0.40 | 0.39 | 0.20 | 0.07 | 1.0 | 0.8 | 1.5 |
| 24 | 439058.761 | 5537122.957 | 348 | 387 | 9 | 8 | 6.1 | 2.01 | 0.75 | 0.27 | 0.38 | 0.11 | 0.06 | 0.9 | 1.2 | 1.7 |
| 25 | 439059.473 | 5537193.538 | 373 | 376 | 7 | 11 | 5.9 | 2.33 | 0.75 | 0.11 | 0.45 | 0.15 | 0.07 | 1.2 | 1.4 | 1.7 |
| 26 | 439060.845 | 5537292.797 | 399 | 404 | 13 | 38 | 5.9 | 2.08 | 0.84 | 0.29 | 0.44 | 0.13 | 0.06 | 0.9 | 1.3 | 1.7 |
| 27 | 439061.772 | 5537447.533 | 393 | 402 | 16 | 29 | 6.7 | 2.16 | 1.19 | 0.71 | 0.48 | 0.14 | 0.08 | 1.0 | 1.0 | 1.5 |
| 28 | 439063.901 | 5537597.375 | 353 | 379 | 8 | 23 | 7 | 2.09 | 1.24 | 0.30 | 0.41 | 0.12 | 0.07 | 0.9 | 1.3 | 1.6 |
| 29 | 439065.186 | 5537668.442 | 373 | 415 | 7 | 6 | 6.9 | 2.09 | 0.84 | 0.22 | 0.41 | 0.10 | 0.08 | 1.0 | 1.2 | 1.7 |
| 30 | 439066.187 | 5537731.877 | 330 | 362 | 8 | 7 | 6.4 | 2.34 | 1.51 | 0.29 | 0.49 | 0.15 | 0.07 | 1.0 | 1.3 | 1.7 |
| 31 | 439123.012 | 5537670.624 | 382 | 400 | 5 | 25 | 6.7 | 1.82 | 0.70 | 0.10 | 0.45 | 0.12 | 0.07 | 1.0 | 1.2 | 1.6 |
| 32 | 439121.895 | 5537594.491 | 378 | 410 | 7 | 10 | 6.5 | 1.92 | 0.69 | 0.17 | 0.42 | 0.09 | 0.07 | 1.0 | 1.3 | 1.5 |
| 33 | 439119.689 | 5537422.167 | 344 | 410 | 19 | 34 | 6.4 | 2.20 | 1.07 | 0.52 | 0.43 | 0.10 | 0.07 | 0.9 | 1.2 | 1.7 |
| 34 | 439117.792 | 5537256.015 | 382 | 438 | 15 | 34 | 6.6 | 1.92 | 0.89 | 0.31 | 0.46 | 0.13 | 0.07 | 0.9 | 1.2 | 1.6 |
| 35 | 439117.272 | 5537156.568 | 335 | 353 | 12 | 16 | 6.8 | 2.06 | 1.19 | 0.38 | 0.39 | 0.12 | 0.06 | 0.8 | 1.1 | 1.7 |
| 36 | 439169.852 | 5537252.858 | 350 | 378 | 12 | 29 | 6.3 | 2.31 | 1.02 | 0.48 | 0.38 | 0.10 | 0.06 | 0.8 | 1.4 | 1.6 |
| 37 | 439171.477 | 5537400.514 | 378 | 395 | 29 | 30 | 7.6 | 2.09 | 0.99 | 0.53 | 0.31 | 0.17 | 0.07 | 1.0 | 1.1 | 1.5 |
| 38 | 439174.2 | 5537609.394 | 336 | 373 | 9 | 10 | 6.8 | 2.32 | 1.30 | 0.45 | 0.45 | 0.11 | 0.06 | 1.0 | 1.4 | 1.9 |
| 39 | 439218.719 | 5537469.349 | 357 | 385 | 16 | 50 | 6.1 | 2.21 | 1.23 | 0.75 | 0.35 | 0.12 | 0.07 | 1.0 | 1.2 | 1.5 |
| 40 | 439218.169 | 5537376.241 | 351 | 391 | 13 | 48 | 6.7 | 2.42 | 1.04 | 0.70 | 0.42 | 0.14 | 0.07 | 1.0 | 1.2 | 1.5 |
| **Means** | | | **365** | **383** | **13** | **21** | **6.8** | **2.04** | **0.96** | **0.35** | **0.42** | **0.14** | **0.07** | **0.9** | **1.2** | **1.6** |

☞ **Additional Information, as follows.**

DR – June 17 – September 09, 1996
$DT^1$ – July 3, 1996
$DT^2$ – July 30, 1996
$DT^3$ – August 20, 1996

# III. 1997 Fincastle Grid Sample Data

| 1997 Fincastle Site (Russet Burbank) | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Position Data** | | **Moisture** | | **Soil Characteristics** | | | | | | | **Petiole Nutrient Contents** | | | | | | | | | **Hand-Sampled Tuber Data** | | | | |
| Site | Easting (m) | Northing (m) | Irrigation + Precipitation (mm) | Consumptive Use (mm) | Clay (%) | | $CaCO_3$ (%) | $NO_3$-N (ppm) | | $PO_4$-P (ppm) | K (ppm) | $NO_3$-N (%) | | | P (%) | | | K (%) | | | Total Yield (t/ha) | Medium Tuber Yield (t/ha) | Mean Tuber Weight (g) | Specific Gravity | Chipping Score |
| Info✤ | | | DR | | | | | | | Kel | Kel | DT[1] | DT[2] | DT[3] | DT[1] | DT[2] | DT[3] | DT[1] | DT[2] | DT[3] | | | | | |
| Depth (cm) | | | | (0-100) | (0-60) | (60-90) | (0-30) | (0-60) | (60-90) | (0-15) | (0-30) | | | | | | | | | | | | | | |
| B1 | 430474.374 | 5523475.42 | 388 | 457.8 | 10 | | | 3.5 | | | 164.0 | 1.00 | 0.90 | 0.21 | 0.27 | 0.15 | 0.10 | | | | 47 | 40 | 153.9 | 1.084 | 6.5 |
| C1 | 430474.374 | 5523407.42 | 511 | 616.2 | 17 | | 1.85 | 4.9 | | | 330.5 | 0.87 | 0.41 | 0.06 | 0.26 | 0.18 | 0.08 | 6.3 | 7.7 | 6.6 | 32 | 28 | 122.2 | 1.080 | 6.0 |
| D1 | 430474.374 | 5523339.42 | 429 | 609 | 24 | | | 22.1 | | 99 | 250.0 | 1.43 | 1.73 | 0.98 | 0.29 | 0.25 | 0.15 | | | | 48 | 43 | 124.4 | 1.087 | 7.5 |
| E1 | 430474.374 | 5523271.42 | 346 | 467.5 | 9 | | | 3.3 | | | 144.0 | 0.70 | 0.53 | 0.26 | 0.37 | 0.31 | 0.19 | | | | 60 | 40 | 140.6 | 1.086 | 6.5 |
| F1 | 430474.374 | 5523203.42 | 421 | 530.2 | 10 | | | 7.7 | | | 167.0 | 0.89 | 0.93 | 1.69 | 0.55 | 0.46 | 0.29 | 6.2 | 7.7 | 6.9 | 66 | 57 | 194.8 | 1.089 | 7.5 |
| G1 | 430474.374 | 5523135.42 | 463 | 578.1 | 9 | | | 12.8 | | | 239.0 | 0.51 | 0.69 | 1.11 | 0.60 | 0.48 | 0.29 | | | | 57 | 50 | 127.7 | 1.086 | 6.0 |
| H1 | 430474.374 | 5523067.42 | 449 | 548.4 | 8 | | | 2.2 | | | 186.0 | 0.36 | 0.20 | 0.17 | 0.66 | 0.57 | 0.36 | | | | 58 | 36 | 109.7 | 1.087 | 6.5 |
| I1 | 430474.374 | 5522999.42 | 374 | 456 | 8 | | | 5.7 | | | 243.5 | 1.21 | 0.81 | 0.72 | 0.62 | 0.52 | 0.34 | 6.4 | 8.1 | 7.3 | 61 | 47 | 198.7 | 1.083 | 8.0 |
| J1 | 430474.374 | 5522931.42 | 372 | 432.5 | 9 | | | 16.8 | | 152 | 257.5 | 1.95 | 1.58 | 0.87 | 0.55 | 0.50 | 0.29 | | | | 49 | 30 | 157.1 | 1.077 | 7.5 |
| A2 | 430542.374 | 5523543.42 | 408 | 496.1 | 7 | 7 | | 2.9 | 2.6 | | 186.0 | 1.26 | 1.12 | 0.15 | 0.41 | 0.17 | 0.18 | | | | 57 | 35 | 221.3 | 1.086 | 7.5 |
| B2 | 430542.374 | 5523475.42 | 435 | 573.5 | 8 | | | 4.8 | | 101 | 290.0 | 0.69 | 0.45 | 0.30 | 0.57 | 0.45 | 0.30 | 6.4 | 7.6 | 6.5 | 66 | 46 | 144.3 | 1.088 | 7.5 |
| C2 | 430542.374 | 5523407.42 | 518 | 602.2 | 20 | | | 4.2 | | | 329.5 | 1.26 | 1.10 | 0.28 | 0.48 | 0.55 | 0.23 | | | | 8 | 4 | 40.4 | 1.021 | 6.0 |
| D2 | 430542.374 | 5523339.42 | 420 | 572 | 12 | | | 7.2 | | | 227.0 | 0.69 | 1.35 | 1.40 | 0.56 | 0.54 | 0.33 | | | | 66 | 41 | 124.9 | 1.081 | 5.0 |
| E2 | 430542.374 | 5523271.42 | 354 | 485 | 10 | | | 7.4 | | | 181.5 | 0.83 | 0.66 | 1.67 | 0.48 | 0.40 | 0.29 | 6.3 | 7.1 | 6.2 | 60 | 48 | 120.1 | 1.078 | 5.5 |
| F2 | 430542.374 | 5523203.42 | 441 | 538.5 | 8 | | | 8.9 | | 66 | 185.5 | 0.71 | 0.85 | 1.61 | 0.48 | 0.55 | 0.33 | | | | 58 | 32 | 118.7 | 1.084 | 6.5 |
| G2 | 430542.374 | 5523135.42 | 446 | 595.1 | 9 | | | 10.7 | | | 188.5 | 0.75 | 0.88 | 1.66 | 0.61 | 0.55 | 0.37 | | | | 67 | 44 | 135.4 | 1.085 | 6.5 |
| H2 | 430542.374 | 5523067.42 | 428 | 525.9 | 7 | | | 9.4 | | 57 | 150.5 | 0.37 | 0.29 | 0.19 | 0.57 | 0.40 | 0.22 | 6.0 | 7.2 | 6.5 | 66 | 41 | 143.5 | 1.086 | 7.0 |
| I2 | 430542.374 | 5522999.42 | 420 | 554.8 | 8 | | | 24.7 | | | 330.5 | 0.94 | 0.89 | 0.83 | 0.63 | 0.59 | 0.34 | | | | 68 | 45 | 105.6 | 1.084 | 6.5 |
| J2 | 430542.374 | 5522931.42 | 375 | 460.1 | 9 | | | 7.8 | | | 199.5 | 1.30 | 1.38 | 1.34 | 0.62 | 0.55 | 0.30 | | | | 57 | 47 | 140.4 | 1.081 | 8.0 |
| K2 | 430542.374 | 5522863.42 | 402 | 492.6 | 7 | | | 6.2 | | | 204.0 | 2.36 | 1.78 | 1.74 | 0.61 | 0.5 | 0.43 | 6.5 | 7.8 | 7.3 | 66 | 47 | 169.2 | 1.074 | 6.0 |
| A3 | 430610.374 | 5523543.42 | 367 | 496.9 | 9 | 20 | | 12.2 | 20.6 | 107 | 429.0 | 1.69 | 2.28 | 1.53 | 0.42 | 0.36 | 0.22 | | | | 65 | 44 | 228.8 | 1.081 | 8.0 |
| B3 | 430610.374 | 5523475.42 | 417 | 563.3 | 8 | 8 | | 3.5 | 4.3 | | 210.5 | 0.72 | 0.57 | 0.10 | 0.51 | 0.52 | 0.25 | | | | 54 | 29 | 129.7 | 1.083 | 6.5 |
| C3 | 430610.374 | 5523407.42 | 461 | 608.8 | 19 | 34 | | 6.6 | 3.3 | | 356.5 | 1.07 | 1.45 | 1.00 | 0.50 | 0.52 | 0.39 | 6.4 | 8.1 | 7.0 | 48 | 33 | 115.2 | 1.078 | 7.0 |
| D3 | 430610.374 | 5523339.42 | 470 | 620.9 | 18 | 24 | | 6.6 | 3.6 | | 304.5 | 0.78 | 1.75 | 1.17 | 0.42 | 0.41 | 0.29 | | | | 62 | 43 | 158.3 | 1.082 | 6.0 |
| E3 | 430610.374 | 5523271.42 | 382 | 475.4 | 7 | 9 | | 3.1 | 1.8 | 78 | 171.5 | 0.61 | 1.03 | 0.67 | 0.47 | 0.49 | 0.28 | | | | 62 | 45 | 153.7 | 1.087 | 6.5 |
| F3 | 430610.374 | 5523203.42 | 453 | 561.3 | 8 | 10 | | 1.7 | 1.7 | | 182.5 | 0.39 | 0.31 | 0.39 | 0.40 | 0.36 | 0.15 | 6.1 | 7.4 | 5.8 | 67 | 49 | 171.5 | 1.090 | 6.5 |
| G3 | 430610.374 | 5523135.42 | 452 | 536.7 | 9 | 8 | | 7.7 | 3.2 | | 255.0 | 0.43 | 0.47 | 0.74 | 0.56 | 0.55 | 0.34 | | | | 70 | 46 | 120.9 | 1.087 | 7.0 |
| H3 | 430610.374 | 5523067.42 | 453 | 542.4 | 7 | 8 | | 8.3 | 5.1 | | 238.5 | 0.50 | 0.08 | 0.20 | 0.60 | 0.51 | 0.34 | | | | 69 | 55 | 133.2 | 1.093 | 7.0 |
| I3 | 430610.374 | 5522999.42 | 402 | 503.8 | 9 | 10 | | 7.9 | 7.8 | | 258.5 | 1.16 | 0.56 | 0.47 | 0.67 | 0.56 | 0.31 | 6.4 | 8.0 | 6.2 | 57 | 53 | 135.6 | 1.087 | 7.5 |
| J3 | 430610.374 | 5522931.42 | 456 | 578.8 | 13 | 14 | | 26.6 | 6.9 | | 169.5 | 1.93 | 1.59 | 1.24 | 0.59 | 0.53 | 0.34 | | | | 46 | 27 | 149.6 | 1.075 | 6.5 |
| K3 | 430610.374 | 5522863.42 | 453 | 530.3 | 11 | 11 | | 6.4 | 9.0 | 152 | 244.0 | 2.35 | 1.90 | 1.61 | 0.60 | 0.52 | 0.37 | | | | 59 | 37 | 120.4 | 1.077 | 5.5 |
| A4 | 430678.374 | 5523543.42 | 431 | 535.3 | 7 | 8 | | 3.5 | 3.3 | | 205.5 | 0.86 | 0.71 | 0.53 | 0.51 | 0.59 | 0.43 | | 7.1 | 6.3 | 56 | 41 | 122.3 | 1.090 | 7.5 |
| B4 | 430678.374 | 5523475.42 | 434 | 539.5 | 6 | 6 | | 3.1 | 2.8 | | 196.0 | 0.62 | 0.35 | 0.27 | 0.53 | 0.59 | 0.42 | | | | 71 | 54 | 129.8 | 1.090 | 8.5 |
| C4 | 430678.374 | 5523407.42 | 441 | 556.8 | 11 | 10 | | 16.4 | 13.3 | 98 | 267.0 | 1.70 | 1.58 | 1.37 | 0.35 | 0.47 | 0.23 | | | | 64 | 47 | 145.2 | 1.081 | 7.0 |
| D4 | 430678.374 | 5523339.42 | 424 | 553.2 | 10 | 17 | | 4.6 | 4.6 | | 269.5 | 0.76 | 1.12 | 1.41 | 0.55 | 0.62 | 0.38 | 6.5 | 8.0 | 6.5 | 66 | 58 | 143.3 | 1.087 | 6.0 |
| E4 | 430678.374 | 5523271.42 | 384 | 490.5 | 7 | 7 | | 3.0 | 2.8 | | 271.5 | 0.37 | 0.33 | 0.29 | 0.51 | 0.54 | 0.27 | | | | 71 | 55 | 138.7 | 1.086 | 5.5 |
| F4 | 430678.374 | 5523203.42 | 412 | 530.2 | 7 | 7 | | 4.6 | 3.6 | | 246.0 | 0.54 | 0.97 | 0.92 | 0.63 | 0.62 | 0.39 | | | | 61 | 44 | 95.7 | 1.085 | 6.0 |
| G4 | 430678.374 | 5523135.42 | 414 | 515.6 | 8 | 9 | | 11.3 | 13.6 | | 367.0 | 0.67 | 0.70 | 0.83 | 0.57 | 0.53 | 0.28 | 6.4 | 7.4 | 6.1 | 70 | 60 | 114.6 | 1.091 | 7.0 |
| H4 | 430678.374 | 5523067.42 | 458 | 558.2 | 9 | 10 | | 5.2 | 6.1 | | 259.5 | 0.60 | 0.40 | 0.73 | 0.52 | 0.43 | 0.25 | | | | 73 | 52 | 100.7 | 1.087 | 7.0 |
| I4 | 430678.374 | 5522999.42 | 468 | 570.1 | 7 | 7 | 0.2 | 6.9 | 5.1 | 78 | 256.0 | 0.63 | 0.70 | 0.69 | 0.58 | 0.53 | 0.30 | | | | 52 | 39 | 87.1 | 1.080 | 5.5 |
| J4 | 430678.374 | 5522931.42 | 438 | 555.6 | 11 | 10 | | 6.4 | 2.7 | | 156.5 | 1.34 | 0.85 | 1.06 | 0.29 | 0.23 | 0.12 | 6.4 | 7.4 | 6.4 | 39 | 33 | 128.1 | 1.087 | 6.5 |
| K4 | 430678.374 | 5522863.42 | 448 | 562.1 | 16 | 42 | | 9.1 | 22.1 | | 193.0 | 1.34 | 2.03 | 1.56 | 0.50 | 0.50 | 0.27 | | | | 58 | 45 | 112.8 | 1.087 | 8.5 |
| A5 | 430746.374 | 5523543.42 | 369 | 464.4 | 7 | 6 | | 3.4 | 3.8 | 94 | 208.5 | 0.67 | 0.49 | 0.11 | 0.63 | 0.54 | 0.32 | | | | 50 | 33 | 75.0 | 1.081 | 7.5 |
| B5 | 430746.374 | 5523475.42 | 425 | 527.6 | 10 | 16 | 0 | 4.3 | 18.0 | | 229.5 | 0.87 | 0.66 | 1.51 | 0.62 | 0.42 | 0.39 | 6.6 | 6.8 | 6.3 | 61 | 46 | 109.2 | 1.092 | 6.5 |
| C5 | 430746.374 | 5523407.42 | 429 | 559.4 | 14 | 11 | | 6.5 | 8.8 | | 261.5 | 1.41 | 1.32 | 1.05 | 0.40 | 0.30 | 0.21 | | | | 56 | 39 | 132.8 | 1.088 | 7.5 |
| D5 | 430746.374 | 5523339.42 | 429 | 573.6 | 10 | 28 | | 3.2 | 7.4 | | 168.0 | 0.15 | 0.52 | 1.50 | 0.61 | 0.48 | 0.44 | | | | 72 | 60 | 116.0 | 1.090 | 7.0 |
| E5 | 430746.374 | 5523271.42 | 424 | 552.3 | 8 | 21 | | 2.0 | 4.5 | | 173.5 | 0.24 | 0.36 | 1.03 | 0.65 | 0.45 | 0.51 | 6.3 | 6.7 | 7.0 | 81 | 65 | 100.7 | 1.089 | 6.5 |
| F5 | 430746.374 | 5523203.42 | 481 | 647.8 | 12 | 30 | | 10.1 | 12.2 | 205 | 454.5 | 0.32 | 0.07 | 0.03 | 0.64 | 0.54 | 0.43 | | | | 49 | 21 | 65.6 | 1.084 | 6.5 |
| G5 | 430746.374 | 5523135.42 | 429 | 568.7 | 26 | 36 | | 17.0 | 30.7 | | 145.5 | 1.04 | 0.85 | 1.12 | 0.42 | 0.24 | 0.20 | | | | 48 | 35 | 116.4 | 1.082 | 6.5 |
| H5 | 430746.374 | 5523067.42 | 469 | 557.7 | 13 | 16 | | 3.6 | 2.3 | | 250.5 | 0.13 | 0.05 | 0.07 | 0.64 | 0.59 | 0.51 | 6.0 | 7.1 | 6.3 | 54 | 32 | 81.5 | 1.090 | 6.5 |
| I5 | 430746.374 | 5522999.42 | 462 | 553.3 | 13 | 15 | | 3.3 | 2.6 | | 188.0 | 0.15 | 0.04 | 0.18 | 0.62 | 0.63 | 0.40 | | | | 61 | 42 | 91.3 | 1.084 | 7.0 |
| J5 | 430746.374 | 5522931.42 | 437 | 553.1 | 10 | 15 | | 1.7 | 2.3 | 115 | 172.5 | 0.13 | 0.03 | 0.23 | 0.62 | 0.56 | 0.36 | | | | 76 | 60 | 133.0 | 1.087 | 5.5 |
| K5 | 430746.374 | 5522863.42 | 382 | 546.1 | 10 | 22 | 0.1 | 2.2 | 2.6 | | 300.5 | 0.67 | 0.67 | 0.90 | 0.59 | 0.58 | 0.40 | 6.0 | 7.2 | | 48 | 35 | 109.1 | 1.087 | 7.0 |
| **Means** | | | **427** | **541.2** | **11** | **15** | **0.54** | **7.5** | **7.2** | **108** | **236.1** | **0.89** | **0.85** | **0.82** | **0.53** | **0.47** | **0.31** | **6** | **7.5** | **6** | **59** | **43** | **129.4** | **1.084** | **6.7** |

✤ **Additional Information, as follows.**

DR – June 24 – September 18, 1997

Kel – Kelowna method

DT[1] – July 7, 1997

DT[2] – July 24, 1997

DT[3] – August 13, 1997

# IV. 1997 Hays Grid Sample Data

| **1998 Hays Site (Snowden)** | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Position Data** | | **Moisture** | | **Soil Characteristics** | | | | | | | | **Petiole Nutrient Contents** | | | | | | | | | **Hand-Sampled Tuber Data** | | | | |
| Site | Easting (m) | Northing (m) | Irrigation + Precipitation (mm) | Consumptive Use (mm) | Clay (%) | | $CaCO_3$ (%) | $NO_3$-N (ppm) | | $PO_4$-P (ppm) | K (ppm) | | $NO_3$-N (%) | | | P (%) | | | K (%) | | | Total Yield (t/ha) | Medium Tuber Yield (t/ha) | Mean Tuber Weight (g) | Specific Gravity | Chipping Score |
| Info | | | DR | | | | | | | Kel | AA | Kel | DT$^1$ | DT$^2$ | DT$^3$ | DT$^1$ | DT$^2$ | DT$^3$ | DT$^1$ | DT$^2$ | DT$^3$ | | | | | |
| Depth (cm) | | | | (0-100) | (0-60) | (60-90) | (0-30) | (0-60) | (60-90) | (0-15) | (0-30) | (0-30) | | | | | | | | | | | | | | |
| D1 | 438562.2 | 5537593.3 | 432 | 525 | 8 | 5 | | 3.8 | 2.5 | 17 | 176.9 | 119 | 1.25 | 0.21 | 0.06 | 0.48 | 0.13 | 0.09 | 6.2 | 7.3 | | 61 | 61 | 120.4 | 1.085 | 50.5 |
| E1 | 438562.2 | 5537525.3 | 428 | 599 | 22 | 42 | | 3.9 | 1.7 | 20 | 243.8 | 155 | 1.69 | 0.81 | 0.26 | 0.38 | 0.12 | 0.09 | | | 6.6 | 48 | 47 | 109.8 | 1.084 | 44.5 |
| F1 | 438562.2 | 5537457.3 | 443 | 562 | 11 | 28 | | 4.1 | 2.9 | 13 | 123.6 | 74 | 1.45 | 0.83 | 0.13 | 0.49 | 0.12 | 0.10 | | | | 56 | 55 | 111.2 | 1.088 | 44.5 |
| G1 | 438562.2 | 5537389.3 | 442 | 577 | 13 | 35 | | 5.0 | 1.7 | 15 | 136.1 | 87 | 1.56 | 0.29 | 0.25 | 0.39 | 0.13 | 0.10 | | | | 51 | 50 | 121.8 | 1.084 | 44 |
| H1 | 438562.2 | 5537321.3 | 433 | 574 | 17 | 30 | | 2.5 | 2.3 | 17 | 127.5 | 81 | 1.70 | 0.51 | 0.10 | 0.31 | 0.15 | 0.10 | 6.1 | 6.9 | 5.8 | 48 | 47 | 148.3 | 1.085 | 52 |
| I1 | 438562.2 | 5537253.3 | 426 | 525 | 8 | 25 | | 3.6 | 2.2 | 15 | 127.5 | 76 | 1.52 | 0.87 | 0.22 | 0.42 | 0.15 | 0.11 | | | | 54 | 53 | 105.8 | 1.084 | 48 |
| C2 | 438630.2 | 5537661.3 | 411 | 559 | 30 | 29 | | 6.1 | 1.4 | 10 | 163.5 | 91 | 2.07 | 0.63 | 0.34 | 0.27 | 0.11 | 0.09 | | | | 56 | 55 | 132.7 | 1.090 | 50.5 |
| D2 | 438630.2 | 5537593.3 | 424 | 545 | 6 | 14 | 0.05 | 8.9 | 3.9 | 13 | 172.5 | 111 | 1.70 | 0.99 | 0.18 | 0.37 | 0.12 | 0.10 | | | | 56 | 52 | 143.7 | 1.082 | 51.5 |
| E2 | 438630.2 | 5537525.3 | 427 | 569 | 18 | 38 | | 3.5 | 1.5 | 16 | 335.4 | 206 | 1.94 | 0.51 | 0.27 | 0.30 | 0.14 | 0.09 | 6.5 | 8.4 | 7.4 | 61 | 59 | 158.6 | 1.083 | 52 |
| F2 | 438630.2 | 5537457.3 | 407 | 528 | 22 | 41 | 0 | 8.7 | 1.5 | 13 | 151.9 | 99 | 1.50 | 0.98 | 0.19 | 0.33 | 0.12 | 0.10 | | | | 44 | 44 | 134.2 | 1.089 | 54.5 |
| G2 | 438630.2 | 5537389.3 | 444 | 596 | 31 | 43 | | 4.2 | 1.5 | 12 | 136.6 | 85 | 1.83 | 0.76 | 0.37 | 0.25 | 0.12 | 0.09 | | | | 45 | 45 | 123.1 | 1.088 | 43.5 |
| H2 | 438630.2 | 5537321.3 | 453 | 583 | 15 | 36 | | 3.1 | 1.1 | 12 | 123.5 | 69 | 1.82 | 1.17 | 0.27 | 0.34 | 0.20 | 0.11 | 6.4 | 7.5 | 5.1 | 52 | 51 | 150.1 | 1.085 | 46 |
| I2 | 438630.2 | 5537253.3 | 396 | 480 | 6 | 4 | 0 | 6.5 | 4.7 | 16 | 105.4 | 60 | 0.92 | 0.15 | 0.02 | 0.47 | 0.14 | 0.12 | | | | 37 | 36 | 133.7 | 1.083 | 43.5 |
| J2 | 438630.2 | 5537185.3 | 415 | 498 | 5 | 4 | 0 | 5.4 | 1.3 | 15 | 102.6 | 64 | 1.12 | 0.21 | 0.01 | 0.50 | 0.18 | 0.12 | | | | 39 | 39 | 130.6 | 1.083 | 39.5 |
| B3 | 438698.2 | 5537729.3 | 438 | 574 | 33 | 40 | 1.35 | 3.3 | 1.8 | 14 | 178.0 | 90 | 1.47 | 0.52 | 0.14 | 0.23 | 0.11 | 0.10 | | | | 40 | 38 | 97.8 | 1.091 | 51.5 |
| C3 | 438698.2 | 5537661.3 | 450 | 547 | 11 | 37 | | 5.3 | 2.2 | 14 | 137.5 | 76 | 1.36 | 0.46 | 0.19 | 0.25 | 0.10 | 0.09 | 6.3 | 7.0 | 6.1 | 55 | 54 | 124.5 | 1.088 | 46 |
| D3 | 438698.2 | 5537593.3 | 415 | 559 | 21 | 45 | | 3.2 | 1.5 | 13 | 132.4 | 72 | 1.15 | 0.61 | 0.21 | 0.31 | 0.11 | 0.09 | | | | 56 | 52 | 177.5 | 1.085 | 50 |
| E3 | 438698.2 | 5537525.3 | 378 | 497 | 10 | 20 | 0 | 9.4 | 1.6 | 18 | 298.6 | 176 | 1.75 | 0.93 | 0.15 | 0.34 | 0.13 | 0.09 | | | | 68 | 61 | 179.5 | 1.082 | 44 |
| F3 | 438698.2 | 5537457.3 | 390 | 485 | 7 | 5 | | 4.6 | 2.2 | 20 | 109.9 | 65 | 0.35 | 0.06 | 0.01 | 0.46 | 0.14 | 0.10 | 6.2 | 6.6 | 6.3 | 47 | 46 | 109.2 | 1.087 | 45.5 |
| G3 | 438698.2 | 5537389.3 | 415 | 501 | 8 | 8 | | 2.7 | 0.5 | 15 | 111.8 | 75 | 1.07 | 0.16 | 0.03 | 0.31 | 0.10 | 0.11 | | | | 49 | 48 | 154 | 1.087 | 45.5 |
| H3 | 438698.2 | 5537321.3 | 389 | 506 | 6 | 7 | | 3.4 | 7.1 | 16 | 130.5 | 93 | 1.29 | 0.29 | 0.06 | 0.45 | 0.15 | 0.10 | | | | 47 | 45 | 121.2 | 1.084 | 41.5 |
| I3 | 438698.2 | 5537253.3 | 438 | 564 | 27 | 32 | | 2.1 | 1.4 | 9 | 130.6 | 78 | 1.45 | 0.71 | 0.20 | 0.36 | 0.15 | 0.10 | 6.3 | 5.8 | 4.2 | 58 | 57 | 136.6 | 1.088 | 47 |
| J3 | 438698.2 | 5537185.3 | 369 | 504 | 6 | 6 | 0.85 | 2.7 | 1.9 | 24 | 131.4 | 83 | 1.23 | 0.36 | 0.09 | 0.42 | 0.15 | 0.11 | | | | 50 | 50 | 118.8 | 1.080 | 49.5 |
| K3 | 438698.2 | 5537117.3 | 450 | 587 | 14 | 43 | | 5.4 | 3.8 | 13 | 86.5 | 59 | 1.41 | 0.51 | 0.26 | 0.45 | 0.17 | 0.11 | | | | 56 | 55 | 136.3 | 1.088 | 50 |
| a4 | 438766.2 | 5537763.3 | 419 | 551 | 15 | 31 | 1.2 | 3.4 | 1.4 | 12 | 159.6 | 97 | 1.64 | 0.55 | 0.27 | 0.22 | 0.11 | 0.10 | | | | 50 | 47 | 162.7 | 1.091 | 47 |
| b4 | 438766.2 | 5537695.3 | 405 | 548 | 28 | 29 | | 4.8 | 1.2 | 15 | 210.4 | 111 | 1.87 | 0.90 | 0.32 | 0.24 | 0.10 | 0.09 | 6.1 | 6.8 | 7.0 | 46 | 40 | 149.7 | 1.085 | 45 |
| c4 | 438766.2 | 5537627.3 | 379 | 522 | 15 | 44 | | 2.4 | 1.5 | 15 | 110.1 | 72 | 1.53 | 0.94 | 0.35 | 0.32 | 0.12 | 0.09 | | | | 66 | 65 | 134.2 | 1.090 | 47.5 |
| d4 | 438766.2 | 5537559.3 | 397 | 541 | 20 | 40 | | 3.0 | 1.5 | 13 | 191.1 | 107 | 1.92 | 1.02 | 0.25 | 0.26 | 0.11 | 0.09 | | | | 58 | 52 | 168 | 1.087 | 47 |
| e4 | 438766.2 | 5537491.3 | 382 | 467 | 8 | 18 | | 2.4 | 1.6 | 13 | 125.1 | 85 | 1.31 | 0.16 | 0.05 | 0.38 | 0.12 | 0.09 | 6.1 | 7.3 | 6.9 | 58 | 57 | 150.2 | 1.085 | 42 |
| f4 | 438766.2 | 5537423.3 | 388 | 479 | 11 | 24 | | 4.3 | 1.0 | 15 | 292.5 | 155 | 1.85 | 0.89 | 0.01 | 0.29 | 0.10 | 0.11 | | | | 46 | 43 | 146.4 | 1.086 | 46.5 |
| g4 | 438766.2 | 5537355.3 | 373 | 529 | 23 | 39 | | 3.8 | 1.7 | 12 | 100.9 | 67 | 1.42 | 0.56 | 0.09 | 0.37 | 0.11 | 0.10 | | | | 49 | 48 | 136.1 | 1.086 | 39.5 |
| h4 | 438766.2 | 5537287.3 | 409 | 597 | 30 | 43 | | 2.3 | 1.5 | 10 | 132.8 | 77 | 1.75 | 1.06 | 0.35 | 0.26 | 0.10 | 0.09 | 6.1 | 7.1 | 5.5 | 55 | 53 | 135.2 | 1.090 | 50.5 |
| i4 | 438766.2 | 5537219.3 | 409 | 524 | 8 | 18 | | 3.3 | 1.5 | 11 | 133.9 | 88 | 1.76 | 0.61 | 0.42 | 0.42 | 0.12 | 0.12 | | | | 55 | 55 | 155.2 | 1.085 | 44.5 |
| j4 | 438766.2 | 5537151.3 | 399 | 513 | 7 | 11 | | 2.4 | 0.7 | 8 | 81.8 | 52 | 1.29 | 0.46 | 0.04 | 0.44 | 0.17 | 0.12 | | | | 46 | 44 | 145.1 | 1.084 | 44 |
| k4 | 438766.2 | 5537083.3 | 400 | 510 | 8 | 7 | | 6.6 | 2.1 | 12 | 94.5 | 57 | 1.86 | 0.89 | 0.28 | 0.43 | 0.20 | 0.13 | 6.2 | 6.2 | 4.6 | 51 | 50 | 122 | 1.083 | 47 |
| A5 | 438834.2 | 5537797.3 | 402 | 516 | 19 | 27 | | 2.7 | 2.4 | 11 | 232.2 | 127 | 1.97 | 0.61 | 0.22 | 0.20 | 0.13 | 0.08 | | | | 53 | 53 | 154.1 | 1.086 | 46 |
| B5 | 438834.2 | 5537729.3 | 441 | 568 | 30 | 37 | | 4.5 | 1.8 | 16 | 216.7 | 122 | 2.13 | 0.92 | 0.25 | 0.18 | 0.11 | 0.08 | | | | 56 | 55 | 153.3 | 1.089 | 48 |
| C5 | 438834.2 | 5537661.3 | 432 | 555 | 9 | 12 | | 5.1 | 1.7 | 15 | 136.2 | 87 | 1.17 | 0.14 | 0.02 | 0.36 | 0.12 | 0.09 | 6.3 | 7.2 | 7.0 | 40 | 40 | 124.5 | 1.082 | 48 |
| D5 | 438834.2 | 5537593.3 | 410 | 539 | 15 | 45 | 0.7 | 3.2 | 2.8 | 14 | 154.9 | 92 | 1.60 | 0.16 | 0.03 | 0.39 | 0.13 | 0.11 | | | | 47 | 46 | 143.1 | 1.084 | 48 |
| E5 | 438834.2 | 5537525.3 | 394 | 478 | 10 | 12 | | 5.6 | 3.0 | 12 | 106.4 | 64 | 1.83 | 0.16 | 0.07 | 0.5 | 0.19 | 0.12 | | | | 54 | 54 | 177.1 | 1.086 | 46.5 |
| F5 | 438834.2 | 5537457.3 | 375 | 489 | 11 | 38 | | 9.9 | 2.8 | 14 | 112.0 | 68 | 1.83 | 0.23 | 0.11 | 0.42 | 0.14 | 0.12 | 6.2 | 6.8 | 6.3 | 61 | 55 | 140.1 | 1.087 | 38.5 |
| G5 | 438834.2 | 5537389.3 | 380 | 546 | 18 | 40 | | 2.6 | 2.8 | 11 | 121.5 | 71 | 1.55 | 0.40 | 0.10 | 0.42 | 0.13 | 0.12 | | | | 48 | 48 | 121.4 | 1.082 | 45.5 |
| H5 | 438834.2 | 5537321.3 | 396 | 516 | 12 | 36 | 0 | 6.1 | 2.7 | 14 | 134.0 | 82 | 1.49 | 0.65 | 0.27 | 0.45 | 0.15 | 0.14 | | | | 48 | 46 | 138.6 | 1.086 | 42.5 |
| I5 | 438834.2 | 5537253.3 | 412 | 573 | 19 | 38 | 0 | 3.1 | 1.9 | 11 | 103.1 | 69 | 1.58 | 0.77 | 0.45 | 0.43 | 0.16 | 0.12 | 6.2 | 7.0 | 4.9 | 65 | 59 | 159.1 | 1.085 | 39.5 |
| J5 | 438834.2 | 5537185.3 | 424 | 535 | 8 | 25 | | 2.6 | 2.1 | 13 | 113.1 | 71 | 1.13 | 0.25 | 0.05 | 0.44 | 0.16 | 0.12 | | | | 44 | 43 | 133.5 | 1.090 | 46 |
| K5 | 438834.2 | 5537117.3 | 448 | 590 | 19 | 32 | | 2.8 | 3.0 | 10 | 107.4 | 67 | 1.13 | 0.53 | 0.02 | 0.36 | 0.13 | 0.13 | | | | 32 | 31 | 98.5 | 1.086 | 47 |
| L5 | 438834.2 | 5537049.3 | 445 | 591 | 27 | 45 | | 2.7 | 1.7 | 15 | 226.0 | 120 | 1.29 | 0.91 | 0.31 | 0.47 | 0.22 | 0.13 | 6.4 | 7.6 | 6.1 | 53 | 50 | 155.5 | 1.082 | 43.5 |
| **Means** | | | **412** | **539** | **15** | **28** | **0.4** | **4.3** | **2.1** | **14** | **150** | **90** | **1.52** | **0.58** | **0.18** | **0.36** | **0.14** | **0.10** | **6.2** | **7.0** | **6.0** | **51** | **50** | **137.9** | **1.086** | **46.3** |

**Additional Information, as follows.**

DR – June 23 – September 4, 1997
Kel – Kelowna method
AA – Ammonium Acetate method
DT$^1$ – July 3, 1997
DT$^2$ – July 23, 1997
DT$^3$ – August 12, 1997

# V. 1998 Fincastle Grid Sample Data

| **1998 Fincastle Site (Russet Burbank)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Position Data** | | **Moisture** | | | | **Soil Characteristics** | | | | | | | | **Petiole Nutrient Contents** | | | | | | | | | **Hand-Sampled Tuber Data** | | | | |
| Site | Easting (m) | Northing (m) | Irrigation + Precipitation (mm) | Consumptive Use (mm) | Available Water (%) | | Clay (%) | | $CaCO_3$ (%) | $NO_3$-N (ppm) | | $PO_4$-P (ppm) | K (ppm) | | $NO_3$-N (%) | | | P (%) | | | K (%) | | | Total Yield (t/ha) | Medium Tuber Yield (t/ha) | Mean Tuber Weight (g) | Specific Gravity | French Fry Score |
| Info | | | DR | | | | | | | | | Kel | AA | Kel | DT$^1$ | DT$^2$ | DT$^3$ | DT$^1$ | DT$^2$ | DT$^3$ | DT$^1$ | DT$^2$ | DT$^3$ | | | | | |
| Depth (cm) | | | | (0-100) | (0-60) | (60-100) | (0-60) | (60-90) | (0-30) | (0-60) | (60-90) | (0-15) | (0-30) | (0-30) | | | | | | | | | | | | | | |
| A1 | 430812.375 | 5523543.126 | 361 | 363.2 | 34 | 64 | 10 | 11 | 0.20 | 1.8 | 1.1 | 32.5 | 125.5 | 148.6 | 0.86 | 1.36 | 1.57 | 0.30 | 0.19 | 0.13 | 6.5 | 6.6 | 5.3 | 39 | 27 | 141.0 | 1.066 | 9.3 |
| B1 | 430811.632 | 5523475.175 | 379 | 391.4 | 31 | 52 | 10 | 28 | | 1.4 | 5.3 | 20.8 | | 152.4 | | 1.05 | 0.95 | | 0.13 | 0.09 | | 6.4 | 4.8 | 42 | 27 | 96.1 | 1.071 | 9.3 |
| C1 | 430810.417 | 5523407.056 | 382 | 395.3 | 122 | 88 | 12 | 8 | | 2.2 | 1.0 | 40.9 | | 258.8 | 1.26 | 1.71 | 1.21 | 0.28 | 0.21 | 0.14 | 7.4 | 8.2 | 8.5 | 42 | 30 | 139.4 | 1.074 | 9.5 |
| D1 | 430809.695 | 5523339.225 | 382 | 376.7 | 68 | 177 | 6 | 7 | | 0.9 | 1.5 | 34.0 | | 129.4 | 0.19 | 0.40 | 0.22 | 0.43 | 0.19 | 0.12 | 5.7 | 5.2 | 3.4 | 44 | 33 | 105.8 | 1.075 | 8.8 |
| E1 | 430808.867 | 5523271.117 | 389 | 387.5 | 83 | 170 | 8 | 8 | | 7.1 | 3.5 | 39.8 | | 163.6 | 0.61 | 1.66 | 1.57 | 0.46 | 0.27 | 0.21 | 6.7 | 7.1 | 6.0 | 46 | 34 | 134.7 | 1.084 | 9.3 |
| F1 | 430807.816 | 5523203.228 | 573 | 531.3 | 165 | 203 | 10 | 21 | | 1.1 | 0.9 | 34.8 | | 105.4 | 0.51 | 0.62 | 0.52 | 0.19 | 0.12 | 0.10 | 6.0 | 5.1 | 4.6 | 30 | 22 | 110.4 | 1.068 | 9.0 |
| G1 | 430806.907 | 5523135.176 | 396 | 360.2 | 63 | 111 | 8 | 7 | 2.90 | 0.9 | 1.2 | 39.3 | 92.5 | 121.0 | 0.62 | 1.11 | 1.28 | 0.20 | 0.13 | 0.15 | 6.0 | 4.6 | 5.3 | 45 | 31 | 128.1 | 1.075 | 8.5 |
| H1 | 430806.02 | 5523067.21 | 421 | 425.9 | 56 | 63 | 11 | 12 | | 1.4 | 1.7 | 22.8 | | 116.8 | 0.86 | 1.04 | 1.22 | 0.17 | 0.14 | 0.17 | 6.2 | 4.7 | | 37 | 24 | 138.1 | 1.078 | 8.8 |
| I1 | 430805.056 | 5522999.311 | 432 | 436.0 | 78 | 114 | 9 | 8 | | 4.2 | 9.4 | 47.0 | | 94.6 | 0.58 | 0.36 | 0.65 | 0.25 | 0.13 | 0.13 | 5.9 | 5.3 | 5.3 | 35 | 20 | 112.5 | 1.067 | 8.3 |
| J1 | 430804.199 | 5522931.362 | 447 | 448.3 | 110 | 191 | 10 | 17 | | 1.2 | 4.3 | 57.8 | | 114.0 | 0.44 | 0.98 | 0.92 | 0.33 | 0.19 | 0.20 | 6.2 | 5.4 | 6.5 | 39 | 35 | 175.8 | 1.073 | 6.8 |
| K1 | 430803.338 | 5522863.337 | 434 | 461.5 | 95 | 108 | 24 | 27 | | 2.7 | 3.9 | 62.0 | | 157.8 | 1.67 | 1.82 | 1.63 | 0.30 | 0.26 | 0.20 | 6.5 | 7.5 | 7.1 | 55 | 47 | 171.1 | 1.083 | 7.8 |
| A2 | 430885.597 | 5523576.237 | 289 | 306.5 | -4 | 37 | 13 | 10 | | 2.4 | 3.0 | 19.7 | | 131.2 | 2.26 | 2.02 | 1.87 | 0.33 | 0.17 | 0.13 | 7.0 | 5.7 | 6.0 | 37 | 32 | 172.6 | 1.074 | 8.3 |
| B2 | 430884.757 | 5523508.167 | 400 | 463.9 | 28 | 11 | 11 | 44 | | 1.8 | 6.6 | 21.1 | | 80.0 | 1.45 | 1.97 | 2.48 | 0.33 | 0.22 | 0.20 | 6.0 | 5.2 | 4.3 | 39 | 34 | 130.7 | 1.083 | 9.0 |
| C2 | 430883.885 | 5523440.255 | 361 | 415.0 | 74 | 114 | 21 | 23 | 8.65 | 10.5 | 30.5 | 33.8 | 163.5 | 132.8 | 1.14 | 1.23 | 1.66 | 0.27 | 0.21 | 0.20 | 5.9 | 6.7 | 7.2 | 31 | 17 | 113.1 | 1.074 | 8.5 |
| D2 | 430883.145 | 5523372.328 | 364 | 393.0 | 81 | 51 | 9 | 6 | | 2.4 | 3.0 | 31.6 | | 229.4 | 1.75 | 1.88 | 1.99 | 0.33 | 0.21 | 0.21 | 7.1 | 7.9 | 8.1 | 57 | 42 | 137.0 | 1.079 | 9.3 |
| E2 | 430882.246 | 5523304.386 | 373 | 407.9 | 130 | 150 | 10 | 10 | | 1.1 | 3.0 | 32.7 | | 195.4 | 1.30 | 1.50 | 1.65 | 0.22 | 0.16 | 0.18 | 7.6 | 6.2 | 7.5 | 47 | 39 | 206.0 | 1.077 | 9.0 |
| F2 | 430881.387 | 5523236.416 | 360 | 418.0 | 95 | 168 | 10 | 9 | 6.95 | 2.7 | 4.2 | 13.3 | 87.0 | 178.6 | 1.07 | 1.67 | 1.25 | 0.14 | 0.15 | 0.19 | 6.6 | 5.0 | 6.1 | 31 | 26 | 171.1 | 1.076 | 9.5 |
| G2 | 430880.517 | 5523168.414 | 356 | 402.0 | 71 | 115 | 9 | 9 | | 2.2 | 5.6 | 26.4 | | 184.0 | 1.28 | 1.67 | 1.65 | 0.19 | 0.11 | 0.19 | 8.0 | 5.2 | 7.2 | 52 | 50 | 198.5 | 1.080 | 7.8 |
| H2 | 430879.658 | 5523100.519 | 528 | 533.6 | 74 | 114 | 9 | 8 | | 1.0 | 1.5 | 23.7 | | 101.2 | 1.16 | 1.69 | 0.92 | 0.24 | 0.17 | 0.19 | 6.9 | 6.0 | 7.4 | 40 | 34 | 156.4 | 1.074 | 9.0 |
| I2 | 430878.826 | 5523032.568 | 402 | 417.8 | 80 | 217 | 10 | 9 | | 0.8 | 1.1 | 20.4 | | 154.4 | 1.02 | 1.58 | 1.70 | 0.22 | 0.15 | 0.20 | 6.8 | 4.8 | 6.7 | 41 | 32 | 130.3 | 1.070 | 8.8 |
| J2 | 430877.991 | 5522964.592 | 373 | 391.8 | 92 | 135 | 11 | 10 | 0.40 | 0.8 | 0.8 | 32.1 | 119.0 | 166.6 | 1.16 | 1.47 | 1.39 | 0.36 | 0.17 | 0.19 | 7.0 | 5.8 | 6.0 | 58 | 43 | 163.3 | 1.077 | 7.8 |
| K2 | 430877.172 | 5522896.629 | 388 | 462.7 | 37 | 108 | 14 | 16 | | 2.6 | 4.4 | 46.2 | | 167.6 | 1.27 | 1.79 | 1.75 | 0.45 | 0.28 | 0.21 | 7.4 | 6.4 | 6.4 | 45 | 31 | 142.0 | 1.079 | 9.7 |
| L2 | 430876.273 | 5522828.614 | 313 | 351.0 | 87 | 109 | 14 | 20 | | 2.9 | 3.9 | 39.1 | | 148.8 | 2.51 | 2.15 | 2.01 | 0.46 | 0.20 | 0.22 | 7.2 | 5.3 | 6.7 | 44 | 34 | 131.8 | 1.074 | 9.0 |
| A3 | 430958.199 | 5523541.139 | 314 | 313.9 | 65 | 128 | 13 | 13 | | 1.0 | 3.2 | 27.9 | | 174.6 | 0.88 | 1.07 | 1.30 | 0.21 | 0.10 | 0.08 | 7.3 | 5.3 | 4.1 | 32 | 16 | 77.1 | 1.061 | 9.0 |
| B3 | 430957.419 | 5523473.105 | 370 | 351.4 | 60 | 100 | 8 | 8 | | 0.6 | 1.4 | 20.3 | | 102.0 | 0.66 | 0.84 | 0.99 | 0.33 | 0.11 | 0.09 | 8.5 | 6.1 | 5.0 | 46 | 26 | 92.9 | 1.074 | 8.0 |
| C3 | 430956.612 | 5523405.18 | 380 | 360.2 | 132 | 177 | 17 | 31 | 0.55 | 0.7 | 0.6 | 43.1 | 286.0 | 310.0 | 1.60 | 1.57 | 1.50 | 0.30 | 0.16 | 0.10 | 9.0 | 9.0 | 9.0 | 50 | 41 | 145.5 | 1.075 | 9.3 |
| D3 | 430955.742 | 5523337.179 | 415 | 405.3 | 73 | 117 | 12 | 14 | | 0.2 | 1.4 | 20.1 | | 138.0 | 1.26 | 1.78 | 1.62 | 0.18 | 0.10 | 0.10 | 7.1 | 5.0 | 3.7 | 40 | 28 | 105.1 | 1.076 | 8.8 |
| E3 | 430954.96 | 5523269.237 | 408 | 408.6 | 91 | 187 | 12 | 15 | | 0.3 | 0.7 | 11.8 | | 100.0 | 1.07 | 1.68 | 1.74 | 0.19 | 0.11 | 0.10 | 7.4 | 4.3 | 3.9 | 33 | 23 | 106.5 | 1.075 | 9.3 |
| F3 | 430954.204 | 5523201.266 | 414 | 407.6 | 40 | 76 | 9 | 9 | | 0.0 | 0.0 | 11.9 | | 59.6 | 0.08 | 0.12 | 0.12 | 0.15 | 0.08 | 0.07 | 6.6 | 5.2 | 5.0 | 29 | 15 | 86.6 | 1.065 | 7.5 |
| G3 | 430953.393 | 5523133.326 | 398 | 399.6 | 72 | 119 | 10 | 15 | | 0.3 | 1.7 | 9.14 | | 57.8 | 0.48 | 0.73 | 0.81 | 0.23 | 0.09 | 0.09 | 6.7 | 4.0 | 3.2 | 41 | 31 | 116.5 | 1.076 | 7.8 |
| H3 | 430952.655 | 5523065.387 | 488 | 462.0 | 139 | 137 | 15 | 13 | 8.15 | 8.1 | 13.2 | 16.3 | 91.5 | 109.0 | 1.44 | 1.36 | 0.89 | 0.20 | 0.12 | 0.09 | 7.7 | 5.6 | 5.4 | 31 | 22 | 127.4 | 1.070 | 8.5 |
| I3 | 430951.737 | 5522997.333 | 456 | 442.1 | 108 | 108 | 11 | 15 | | 2.8 | 8.1 | 21.0 | | 122.6 | 0.91 | 0.97 | 0.97 | 0.25 | 0.10 | 0.10 | 8.1 | 6.0 | 3.8 | 39 | 29 | 116.7 | 1.069 | 8.3 |
| J3 | 430951.063 | 5522929.518 | 408 | 417.2 | 74 | 99 | 14 | 12 | | 1.5 | 4.4 | 21.8 | | 92.2 | 1.71 | 1.67 | 1.38 | 0.19 | 0.12 | 0.12 | 7.5 | 5.0 | 6.5 | 30 | 22 | 137.7 | 1.075 | 8.5 |
| K3 | 430950.116 | 5522861.567 | 320 | 340.8 | 46 | 137 | 15 | 36 | | 5.8 | 23.9 | 42.4 | | 257.4 | 2.03 | 2.17 | 1.89 | 0.30 | 0.10 | 0.11 | 8.5 | 7.2 | 7.5 | 42 | 36 | 156.8 | 1.064 | 8.5 |
| B4 | 431030.577 | 5523506.315 | 285 | 324.8 | 51 | 91 | 10 | 10 | 0.25 | 1.1 | 1.3 | 24.6 | 84.0 | 168.6 | 0.91 | 1.36 | 1.48 | 0.29 | 0.17 | 0.11 | 5.0 | 5.2 | 3.9 | 36 | 29 | 111.4 | 1.070 | 8.5 |
| C4 | 431029.8 | 5523438.124 | 391 | 455.2 | 101 | 151 | 23 | 31 | | 1.4 | 2.6 | 34.7 | | 583.2 | 1.64 | 1.47 | 1.46 | 0.23 | 0.18 | 0.12 | 6.4 | 6.2 | 5.5 | 52 | 31 | 128.5 | 1.068 | 8.3 |
| D4 | 431029.115 | 5523370.278 | 395 | 442.3 | 79 | 109 | 19 | 24 | | 0.9 | 1.1 | 24.7 | | 212.2 | 1.11 | 1.30 | 1.09 | 0.22 | 0.17 | 0.11 | 6.5 | | 5.8 | 45 | 28 | 133.5 | 1.075 | 9.5 |
| E4 | 431028.422 | 5523302.245 | 418 | 435.5 | 102 | 120 | 16 | 30 | | 1.2 | 2.0 | 29.3 | | 143.8 | 1.01 | 1.35 | 1.48 | 0.27 | 0.18 | 0.14 | 6.4 | 5.3 | 4.8 | 45 | 35 | 141.2 | 1.084 | 9.8 |
| F4 | 431027.637 | 5523234.197 | 427 | 451.9 | 45 | 114 | 16 | 35 | 1.10 | 1.0 | 1.6 | 15.8 | 65.0 | 73.0 | 1.04 | 1.24 | 1.42 | 0.16 | 0.16 | 0.11 | 5.8 | | 3.6 | 44 | 35 | 117.8 | 1.076 | 7.5 |
| G4 | 431027.011 | 5523166.323 | 418 | 443.4 | 107 | 198 | 9 | 9 | | 0.8 | 1.7 | 23.9 | | 451.8 | 0.80 | 0.95 | 1.18 | 0.28 | 0.19 | 0.12 | 5.9 | 5.3 | 4.4 | 47 | 29 | 109.4 | 1.074 | 8.8 |
| H4 | 431026.258 | 5523098.333 | 422 | 422.3 | 103 | 181 | 10 | 14 | | 0.8 | 0.8 | 27.5 | | 180.4 | 0.46 | 0.25 | 0.42 | 0.20 | 0.14 | 0.10 | 6.1 | 7.5 | 6.5 | 42 | 25 | 85.3 | 1.066 | 9.0 |
| I4 | 431025.488 | 5523030.342 | 398 | 390.9 | 63 | 79 | 9 | 10 | | 1.0 | 1.0 | 38.6 | | 117.6 | 1.08 | 1.53 | 1.36 | 0.18 | 0.20 | 0.12 | 6.1 | 6.8 | 5.7 | 42 | 34 | 119.0 | 1.076 | 8.2 |
| J4 | 431024.776 | 5522962.35 | 433 | 429.6 | 63 | 98 | 17 | 14 | | 1.2 | 2.9 | 12.0 | | 260.0 | 0.82 | 1.29 | 1.17 | 0.14 | 0.14 | 0.13 | 5.4 | 4.9 | 4.0 | 33 | 25 | 107.0 | 1.070 | 8.5 |
| K4 | 431023.95 | 5522894.345 | 316 | 347.2 | -2 | 9 | 13 | 14 | 0.45 | 1.0 | 1.4 | 35.6 | 196.5 | 429.2 | 1.35 | 1.56 | 1.01 | 0.20 | 0.16 | 0.14 | 6.7 | 6.5 | 6.6 | 53 | 36 | 117.1 | 1.074 | 9.0 |
| B5 | 431100.839 | 5523472.144 | 319 | 348.5 | 21 | 9 | 9 | 7 | | 1.8 | 2.9 | 30.6 | | 94.8 | 1.07 | 1.88 | 1.49 | 0.48 | 0.21 | 0.15 | 5.8 | 5.7 | 3.8 | 49 | 32 | 80.9 | 1.080 | 8.5 |
| C5 | 431100.222 | 5523403.549 | 320 | 349.0 | 35 | 18 | 10 | 10 | | 1.0 | 1.2 | 40.8 | | 128.8 | 0.96 | 1.25 | 1.53 | 0.27 | 0.14 | 0.11 | 6.0 | 5.3 | 2.6 | 45 | 27 | 92.6 | 1.080 | 8.5 |
| D5 | 431099.213 | 5523334.033 | 400 | 424.6 | 122 | 144 | 21 | 25 | 6.15 | 2.3 | 9.6 | 25.5 | 134.0 | 240.8 | 1.41 | 1.23 | 0.88 | 0.30 | 0.20 | 0.16 | 6.6 | 6.5 | 6.4 | 45 | 37 | 191.5 | 1.083 | 8.5 |
| E5 | 431098.364 | 5523267.723 | 396 | 425.4 | 108 | 165 | 16 | 31 | | 1.9 | 6.9 | 31.1 | | 213.8 | 1.22 | 2.09 | 1.20 | 0.43 | 0.26 | 0.17 | 6.9 | 7.4 | 6.6 | 65 | 54 | 123.4 | 1.085 | 9.5 |
| F5 | 431097.599 | 5523200.61 | 413 | 416.1 | 101 | 181 | 9 | 25 | | 2.6 | 2.5 | 31.5 | | 145.6 | 0.78 | 1.65 | 0.89 | 0.39 | 0.26 | 0.15 | 6.6 | 6.4 | 4.8 | 53 | 42 | 109.7 | 1.083 | 8.5 |
| G5 | 431096.721 | 5523133.014 | 426 | 432.1 | 68 | 134 | 9 | 9 | 0.00 | 1.5 | 3.1 | 39.2 | 43.5 | 156.2 | 0.33 | 1.73 | 1.44 | 0.65 | 0.33 | 0.24 | 6.9 | 6.4 | 5.7 | 76 | 52 | 118.6 | 1.084 | 8.7 |
| H5 | 431095.435 | 5523062.111 | 399 | 427.5 | 36 | 68 | 9 | 9 | | 1.0 | 2.7 | 38.3 | | 201.8 | 0.15 | 0.63 | 0.40 | 0.26 | 0.12 | 0.09 | 7.1 | 6.7 | 7.0 | 50 | 38 | 124.7 | 1.076 | 8.6 |
| I5 | 431093.623 | 5522995.354 | 449 | 496.2 | 104 | 135 | 11 | 28 | | 1.3 | 2.1 | 31.2 | | 283.6 | 1.26 | 2.28 | 1.15 | 0.43 | 0.28 | 0.23 | 6.9 | 7.5 | 7.8 | 69 | 59 | 167.8 | 1.084 | 8.5 |
| J5 | 431092.706 | 5522928.4 | 324 | 357.5 | 52 | 113 | 20 | 28 | | 0.5 | 1.3 | 32.7 | | 222.4 | 2.27 | 1.93 | 1.64 | 0.44 | 0.28 | 0.17 | 6.8 | 7.4 | 7.4 | 67 | 55 | 147.2 | 1.082 | 9.8 |
| **Means** | | | **393** | **408.9** | **76** | **116** | **12** | **16** | **2.98** | **1.9** | **3.9** | **29.9** | **124** | **174.8** | **1.09** | **1.39** | **1.28** | **0.28** | **0.17** | **0.14** | **6.7** | **6.0** | **5.7** | **44** | **33** | **130.2** | **1.075** | **8.7** |

**Additional Information, as follows.**

DR – June 19 – September 16, 1998
Kel – Kelowna method
AA – Ammonium Acetate method
DT$^1$ – July 7, 1998
DT$^2$ – July 23, 1998
DT$^3$ – August 11, 1998

# VI. 1998 Hays Grid Sample Data

| **1998 Hays Site (Snowden)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Position Data** | | **Moisture** | | | | **Soil Characteristics** | | | | | | | | **Petiole Nutrient Contents** | | | | | | | | | **Hand-Sampled Tuber Data** | | | | | |
| Site | Easting (m) | Northing (m) | Irrigation + Precipitation (mm) | Consumptive Use (mm) | Available Water (%) | | Clay (%) | | CaCO$_3$ (%) | NO$_3$-N (ppm) | | PO$_4$-P (ppm) | K (ppm) | | NO$_3$-N (%) | | | P (%) | | | K (%) | | | Total Yield (t/ha) | Medium Tuber Yield (t/ha) | Mean Tuber Weight (g) | Specific Gravity | French Fry Score | Chipping Score |
| Info | | | DR | | | | | | | | | Kel | AA | Kel | DT$^1$ | DT$^2$ | DT$^3$ | DT$^1$ | DT$^2$ | DT$^3$ | DT$^1$ | DT$^2$ | DT$^3$ | | | | | | |
| Depth (cm) | | | | (0-100) | (0-60) | (60-100) | (0-60) | (60-90) | (0-30) | (0-60) | (60-90) | (0-15) | (0-30) | (0-30) | | | | | | | | | | | | | | | |
| D1 | 438531.588 | 5536799.196 | 421 | 475 | 76 | 100 | 26 | 29 | | 5.7 | 2.7 | 21 | | 135 | 1.42 | 0.46 | 1.05 | 0.26 | 0.11 | 0.11 | 6.6 | 6.0 | | 50 | 43 | 84 | 1.086 | | 56.5 |
| E1 | 438530.645 | 5536731.164 | 475 | 520 | 109 | 125 | 24 | 28 | | 2.5 | 0.6 | 5 | | 165 | 1.17 | 0.30 | 1.07 | 0.16 | 0.09 | 0.11 | 7.2 | 6.9 | 5.9 | 56 | 45 | 87 | 1.086 | | 59.8 |
| F1 | 438529.643 | 5536663.144 | 396 | 442 | 79 | 122 | 19 | 16 | 5.15 | 0.6 | 0.0 | 2 | 159 | 174 | 1.40 | 0.99 | 1.36 | 0.20 | 0.11 | 0.15 | 7.5 | 6.8 | 6.8 | 43 | 36 | 82 | 1.087 | | 60.3 |
| G1 | 438528.756 | 5536595.036 | 414 | 442 | 89 | 182 | 8 | 16 | | 0.7 | 5.7 | 21 | | 103 | 0.65 | 0.32 | 1.26 | 0.26 | 0.15 | 0.36 | 6.7 | 6.8 | 6.9 | 45 | 39 | 89 | 1.082 | | 59.0 |
| H1 | 438527.841 | 5536527.115 | 465 | 502 | 187 | 255 | 9 | 12 | | 3.4 | 2.0 | 22 | | 157 | 0.82 | 0.55 | 1.28 | 0.23 | 0.09 | 0.18 | 8.0 | 9.0 | 8.4 | 45 | 37 | 83 | 1.080 | | 59.0 |
| I1 | 438526.875 | 5536459.222 | 423 | 453 | 95 | 145 | 10 | 10 | 0 | 3.7 | 3.0 | 26 | 224 | 249 | 0.94 | 0.53 | 1.70 | 0.39 | 0.15 | 0.33 | 8.2 | 8.6 | 9.4 | 54 | 47 | 92 | 1.079 | | 61.0 |
| B2 | 438606.003 | 5536900.103 | 430 | 493 | 80 | 97 | 12 | 10 | | 3.2 | 0.6 | 31 | | 255 | 1.84 | 1.44 | 1.60 | 0.71 | 0.33 | 0.34 | 8.4 | 8.6 | 8.2 | 66 | 60 | 96 | 1.078 | | 62.0 |
| C2 | 438605.04 | 5536832.07 | 385 | 428 | 86 | 154 | 11 | 25 | | 7.7 | 2.7 | 32 | | 211 | 0.71 | 0.65 | 0.93 | 0.36 | 0.13 | 0.17 | 7.9 | 8.0 | 6.8 | 62 | 58 | 107 | 1.081 | | 59.0 |
| D2 | 438604.228 | 5536764.072 | 455 | 491 | 115 | 174 | 14 | 31 | 0 | 5.8 | 1.9 | 29 | 193 | 230 | 0.93 | 0.78 | 1.25 | 0.38 | 0.15 | 0.21 | 7.8 | 7.4 | 7.6 | 70 | 63 | 113 | 1.072 | | 58.8 |
| E2 | 438603.286 | 5536696.175 | 388 | 412 | 99 | 171 | 11 | 13 | | 6.4 | 1.6 | 34 | | 181 | 0.30 | 0.16 | 0.53 | 0.36 | 0.15 | 0.15 | 7.7 | 7.8 | 6.7 | 52 | 46 | 101 | 1.080 | | 53.8 |
| F2 | 438602.362 | 5536628.131 | 402 | 458 | 104 | 191 | 6 | 18 | | 1.6 | 1.9 | 22 | | 109 | 0.18 | 0.36 | 1.18 | 0.36 | 0.23 | 0.33 | 6.9 | 6.8 | 6.8 | 55 | 50 | 112 | 1.079 | | 56.0 |
| G2 | 438601.431 | 5536560.217 | 386 | 407 | 110 | 164 | 7 | 27 | | 1.8 | 8.0 | 20 | | 84 | 0.41 | 0.38 | 0.61 | 0.42 | 0.24 | 0.21 | 6.8 | 7.1 | 5.7 | 54 | 46 | 81 | 1.081 | | 60.3 |
| H2 | 438600.605 | 5536492.16 | 420 | 468 | 113 | 189 | 10 | 33 | | 5.0 | 2.8 | 28 | | 164 | 0.48 | 0.58 | 1.04 | 0.39 | 0.20 | 0.22 | 7.5 | 6.9 | 6.1 | 63 | 56 | 88 | 1.079 | | 63.8 |
| I2 | 438599.74 | 5536424.228 | 408 | 423 | 114 | 205 | 7 | 11 | 0 | 2.3 | 3.4 | 26 | 158 | 136 | 0.42 | 0.37 | 1.05 | 0.37 | 0.19 | 0.22 | 7.7 | 7.1 | 7.3 | 49 | 44 | 107 | 1.077 | | 57.3 |
| J2 | 438598.797 | 5536356.45 | 425 | 493 | 72 | 101 | 7 | 17 | | 0.7 | 1.7 | 19 | | 160 | 0.44 | 0.50 | 0.75 | 0.31 | 0.18 | 0.15 | 7.7 | 7.2 | 6.6 | 46 | 40 | 112 | 1.083 | | 61.8 |
| B3 | 438679.351 | 5536933.121 | 466 | 498 | 86 | 144 | 13 | 34 | | 4.1 | 1.0 | 24 | | 190 | 0.90 | 0.77 | 0.93 | 0.22 | 0.09 | 0.12 | 7.6 | 7.9 | 6.2 | 68 | 61 | 97 | 1.086 | | 62.0 |
| C3 | 438678.595 | 5536865.14 | 416 | 443 | 97 | 183 | 11 | 28 | | 3.7 | 1.8 | 21 | | 177 | 0.43 | 0.50 | 1.06 | 0.32 | 0.10 | 0.13 | 7.7 | 7.8 | 7.2 | 63 | 60 | 109 | 1.082 | | 55.0 |
| D3 | 438677.665 | 5536797.213 | 412 | 399 | 100 | 184 | 7 | 9 | | 1.8 | 2.3 | 23 | | 124 | 0.29 | 0.23 | 0.70 | 0.41 | 0.10 | 0.17 | 7.3 | 6.9 | 6.6 | 46 | 42 | 98 | 1.085 | | 60.0 |
| E3 | 438676.925 | 5536729.388 | 386 | 395 | 129 | 180 | 10 | 29 | | 6.9 | 10.7 | 27 | | 154 | 0.68 | 0.49 | 0.86 | 0.38 | 0.10 | 0.16 | 7.4 | 6.9 | 6.6 | 52 | 44 | 99 | 1.078 | | 61.5 |
| F3 | 438676.024 | 5536661.359 | 388 | 428 | 154 | 205 | 8 | 33 | 0 | 1.6 | 2.8 | 24 | 96 | 92 | 0.35 | 0.48 | 0.37 | 0.38 | 0.14 | 0.14 | 7.0 | 5.9 | 6.0 | 41 | 32 | 67 | 1.077 | | 61.3 |
| G3 | 438675.042 | 5536593.392 | 377 | 387 | 257 | 284 | 7 | 6 | | 1.6 | 2.0 | 25 | | 158 | 0.01 | 0.11 | 0.42 | 0.17 | 0.08 | 0.12 | 5.8 | 7.2 | 7.4 | 30 | 19 | 48 | 1.061 | | 64.8 |
| H3 | 438674.216 | 5536525.461 | 408 | 426 | 244 | 273 | 7 | 7 | | 4.5 | 2.4 | 37 | | 131 | 0.04 | 0.06 | 0.18 | 0.25 | 0.09 | 0.15 | 4.9 | 7.1 | 7.2 | 40 | 27 | 56 | 1.072 | | 61.8 |
| I3 | 438673.328 | 5536457.421 | 411 | 399 | 202 | 242 | 7 | 13 | | 2.4 | 1.8 | 2 | | 128 | 0.59 | 0.31 | 0.62 | 0.51 | 0.14 | 0.14 | 7.1 | 7.8 | 7.3 | 45 | 38 | 74 | 1.079 | | 62.3 |
| J3 | 438672.503 | 5536389.524 | 419 | 422 | 94 | 118 | 10 | 15 | 0 | 1.8 | 2.4 | 24 | 161 | 146 | 1.03 | 0.66 | 0.70 | 0.31 | 0.10 | 0.13 | 7.3 | 7.4 | 7.6 | 39 | 34 | 88 | 1.078 | | 55.3 |
| K3 | 438671.534 | 5536321.514 | 417 | 413 | 93 | 112 | 10 | 10 | | 6.9 | 2.9 | 28 | | 172 | 0.63 | 0.41 | 1.05 | 0.27 | 0.09 | 0.14 | 7.4 | 8.0 | 6.9 | 42 | 36 | 82 | 1.075 | | 61.8 |
| A4 | 438752.834 | 5536966.219 | 442 | 495 | 76 | 81 | 9 | 8 | | 3.8 | 2.3 | 26 | | 166 | 0.85 | 0.92 | 1.10 | 0.50 | 0.19 | 0.17 | 7.1 | 7.4 | 5.4 | 58 | 53 | 96 | 1.078 | | 61.3 |
| B4 | 438752.263 | 5536898.3 | 436 | 497 | 82 | 136 | 14 | 40 | | 2.4 | 0.7 | 18 | | 213 | 1.39 | 1.21 | 1.32 | 0.37 | 0.15 | 0.21 | 7.4 | 7.4 | 7.3 | 50 | 44 | 100 | 1.080 | | 59.3 |
| C4 | 438751.451 | 5536830.325 | 470 | 518 | 115 | 181 | 16 | 38 | 0 | 2.5 | 0.7 | 16 | 190 | 205 | 1.40 | 1.48 | 1.57 | 0.38 | 0.19 | 0.25 | 7.5 | 7.1 | 7.2 | 69 | 62 | 92 | 1.082 | | 62.5 |
| D4 | 438750.56 | 5536762.421 | 441 | 479 | 137 | 201 | 8 | 17 | | 1.8 | 4.6 | 16 | | 97 | 0.61 | 0.67 | 1.08 | 0.41 | 0.24 | 0.22 | 6.9 | 6.9 | 5.4 | 61 | 56 | 98 | 1.081 | | 55.5 |
| E4 | 438749.75 | 5536694.55 | 430 | 487 | 144 | 202 | 9 | 15 | | 2.2 | 1.7 | 22 | | 176 | 1.14 | 1.36 | 1.25 | 0.50 | 0.20 | 0.28 | 7.5 | 7.4 | 7.5 | 75 | 68 | 106 | 1.078 | | 63.0 |
| F4 | 438748.917 | 5536626.513 | 422 | 495 | 233 | 218 | 10 | 31 | | 2.6 | 5.9 | 18 | | 144 | 0.13 | 0.27 | 0.47 | 0.29 | 0.14 | 0.20 | 5.7 | 6.8 | 6.3 | 41 | 24 | 57 | 1.082 | | 64.0 |
| G4 | 438748.016 | 5536558.501 | 418 | 468 | 232 | 288 | 8 | 8 | | 4.1 | 1.9 | 24 | | 308 | 0.28 | 0.56 | 0.93 | 0.32 | 0.17 | 0.23 | 6.6 | 7.9 | 6.9 | 48 | 36 | 63 | 1.073 | | 58.5 |
| H4 | 438747.285 | 5536490.606 | 412 | 490 | 167 | 220 | 15 | 30 | | 3.5 | 3.5 | 23 | | 184 | 0.57 | 0.05 | 0.72 | 0.29 | 0.18 | 0.22 | 6.3 | 7.4 | 7.8 | 54 | 42 | 69 | 1.076 | | 53.3 |
| I4 | 438746.373 | 5536422.601 | 439 | 507 | 94 | 144 | 27 | 32 | 0 | 1.1 | 0.7 | 20 | 187 | 178 | 1.48 | 1.13 | 1.38 | 0.37 | 0.19 | 0.24 | 7.4 | 6.7 | 7.5 | 64 | 60 | 105 | 1.080 | | 61.0 |
| J4 | 438745.465 | 5536354.681 | 428 | 493 | 110 | 168 | 29 | 38 | | 4.0 | 0.0 | 12 | | 247 | 2.13 | 1.42 | 1.03 | 0.30 | 0.17 | 0.18 | 7.7 | 7.1 | 7.5 | 60 | 55 | 102 | 1.084 | | 57.5 |
| K4 | 438744.374 | 5536286.5 | 416 | 506 | 72 | 134 | 8 | 30 | | 1.7 | 1.5 | 14 | | 90 | 0.80 | 0.35 | 0.96 | 0.42 | 0.16 | 0.32 | 7.0 | 6.7 | 6.1 | 38 | 30 | 75 | 1.079 | | 59.5 |
| A5 | 438826.358 | 5536999.112 | 512 | 554 | 61 | 80 | 25 | 45 | | 5.6 | 1.5 | 18 | | 176 | 1.40 | 1.70 | 1.55 | 0.75 | 0.29 | 0.19 | 7.5 | 7.2 | 7.9 | 68 | 54 | 127 | 1.077 | 9.0 | |
| B5 | 438825.46 | 5536931.216 | 481 | 514 | 48 | 84 | 27 | 29 | 0 | 1.3 | 0.0 | 13 | 190 | 185 | 0.59 | 0.88 | 0.97 | 0.59 | 0.17 | 0.13 | 7.8 | 7.1 | 7.9 | 71 | 59 | 117 | 1.076 | 8.3 | |
| C5 | 438824.708 | 5536863.288 | 484 | 504 | 70 | 95 | 16 | 37 | | 2.6 | 1.5 | 16 | | 160 | 0.43 | 0.80 | 1.56 | 0.64 | 0.17 | 0.12 | 7.8 | 7.0 | 7.0 | 69 | 46 | 100 | 1.077 | 8.8 | |
| D5 | 438823.788 | 5536795.26 | 466 | 486 | 92 | 108 | 16 | 37 | | 1.9 | 1.3 | 11 | | 113 | 0.38 | 0.65 | 1.34 | 0.60 | 0.16 | 0.13 | 7.8 | 6.7 | 6.6 | 80 | 62 | 119 | 1.078 | 7.5 | |
| E5 | 438822.922 | 5536727.377 | 447 | 451 | 191 | 213 | 8 | 10 | 0 | 3.1 | 3.1 | 19 | 166 | 181 | 0.08 | 0.17 | 0.86 | 0.78 | 0.27 | 0.13 | 7.7 | 7.5 | 6.9 | 55 | 28 | 74 | 1.067 | 8.3 | |
| F5 | 438822.052 | 5536659.395 | 427 | 443 | 173 | 214 | 7 | 11 | | 3.4 | 1.4 | 26 | | 215 | 0.11 | 0.05 | 0.70 | 0.76 | 0.21 | 0.13 | 7.6 | 7.3 | 7.3 | 62 | 30 | 65 | 1.068 | 9.0 | |
| G5 | 438821.264 | 5536591.318 | 406 | 429 | 197 | 217 | 7 | 17 | | 6.8 | 7.3 | 26 | | 112 | 0.03 | 0.05 | 0.33 | 0.71 | 0.23 | 0.14 | 7.2 | 6.4 | 6.4 | 52 | 28 | 70 | 1.072 | 8.0 | |
| H5 | 438820.662 | 5536523.294 | 423 | 475 | 160 | 148 | 10 | 31 | 0 | 2.2 | 1.3 | 24 | 147 | 139 | 0.02 | 0.13 | 0.12 | 0.46 | 0.17 | 0.12 | 6.5 | 7.7 | 7.4 | 0 | | | | | |
| I5 | 438819.477 | 5536455.622 | 450 | 469 | 147 | 121 | 20 | 35 | | 1.7 | 1.7 | 13 | | 278 | 0.10 | 0.02 | 0.15 | 0.23 | 0.09 | 0.08 | 6.3 | 7.4 | 8.0 | 0 | | | | | |
| J5 | 438818.753 | 5536387.448 | 444 | 410 | 129 | 246 | 7 | 8 | | 1.8 | 1.0 | 22 | | 156 | 0.15 | 0.54 | 1.16 | 0.61 | 0.21 | 0.13 | 7.6 | 7.0 | 7.6 | 60 | 41 | 92 | 1.074 | 7.8 | |
| K5 | 438817.96 | 5536319.488 | 424 | 449 | 75 | 129 | 7 | 11 | 0.05 | 0.7 | 1.8 | 15 | 109 | 91 | 0.23 | 0.39 | 1.00 | 0.71 | 0.14 | 0.18 | 7.4 | 7.1 | 6.6 | 46 | 27 | 79 | 1.068 | 8.3 | |
| L5 | 438817.128 | 5536251.791 | 455 | 489 | 83 | 138 | 10 | 25 | | 2.4 | 1.8 | 27 | | 128 | 0.58 | 0.30 | 1.49 | 0.73 | 0.16 | 0.25 | 7.3 | 7.7 | 6.5 | 71 | 47 | 100 | 1.075 | 8.0 | |
| **Means** | | | **428** | **463** | **122** | **168** | **12** | **22** | **0.43** | **3.1** | **2.4** | **21** | **165** | **165** | **0.67** | **0.57** | **0.97** | **0.42** | **0.16** | **0.19** | **7.2** | **7.3** | **7.0** | **53** | **45** | **90** | **1.078** | **8.3** | **59.7** |

**Additional Information, as follows.**

DR – June 19 – September 9, 1998
Kel – Kelowna method
AA – Ammonium Acetate method
DT$^1$ – July 6, 1998
DT$^2$ – July 22, 1998
DT$^3$ – August 10, 1998

# VII. 1999 Fincastle Grid Sample Data

| **1999 Fincastle Site (FL1625)** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Position Data** | | **Moisture** | | | | **Soil Characteristics** | | | | | | | | **Petiole Nutrient Contents** | | | | | | | | | **Hand-Sampled Tuber Data** | | | |
| Site | Easting (m) | Northing (m) | Irrigation + Precipitation (mm) | Consumptive Use (mm) | Avaliable Water % | | Clay (%) | | $CaCO_3$ (%) | $NO_3$-N (ppm) | | $PO_4$-P (ppm) | K (ppm) | | $NO_3$-N (%) | | | P (%) | | | K (%) | | | Total Yield (t/ha) | Medium Tuber Yield (t/ha) | Mean Tuber Weight (g) | Specific Gravity |
| Info | | | DR | | | | | | | | | Kel | AA | Kel | DT$^1$ | DT$^2$ | DT$^3$ | DT$^1$ | DT$^2$ | DT$^3$ | DT$^1$ | DT$^2$ | DT$^3$ | | | | |
| Depth (cm) | | | | (0-100) | (0-60) | (60-100) | (0-60) | (60-90) | (0-30) | (0-60) | (60-90) | (0-15) | (0-30) | (0-30) | | | | | | | | | | | | | |
| A1 | 434730.679 | 5528125.947 | 334 | 341 | 105 | 89 | 20 | 21 | 3.6 | 1.7 | 2.3 | 16 | 231 | 143 | 0.33 | 0.38 | 0.34 | 0.50 | 0.17 | 0.16 | 9.6 | 8.0 | 5.4 | 32 | 28 | 117.8 | 1.107 |
| B1 | 434729.205 | 5528082.462 | 317 | 321 | 81 | 76 | 22 | 22 | 3.4 | 0.6 | 0.0 | 12 | 180 | 110 | 0.42 | 0.79 | 1.16 | 0.14 | 0.14 | 0.14 | 9.0 | 7.3 | 5.3 | 35 | 32 | 140.0 | 1.104 |
| C1 | 434727.815 | 5528002.959 | 342 | 347 | 68 | 19 | 17 | 23 | 1.1 | 0.0 | 0.0 | 18 | 165 | 90 | 1.22 | 1.09 | 0.62 | 0.33 | 0.31 | 0.22 | 8.6 | 8.2 | 5.3 | 28 | 23 | 129.4 | 1.104 |
| D1 | 434727.121 | 5527924.325 | 313 | 323 | 76 | 42 | 24 | 36 | 2.0 | 0.3 | 0.0 | 27 | 140 | 80 | 1.12 | 0.85 | 0.61 | 0.41 | 0.24 | 0.22 | 8.8 | 7.8 | 5.3 | 37 | 32 | 137.6 | 1.105 |
| E1 | 434726.007 | 5527843.383 | 310 | | 70 | 56 | 15 | 19 | 1.0 | 0.5 | 0.0 | 63 | 164 | 95 | 1.35 | 1.45 | 1.19 | 0.63 | 0.52 | 0.42 | 9.4 | 8.7 | 5.3 | 35 | 31 | 145.5 | 1.097 |
| F1 | 434724.132 | 5527763.290 | 348 | 335 | 108 | 102 | 12 | 20 | 0.6 | 0.4 | 0.0 | 54 | 136 | 83 | 0.43 | 1.49 | 1.71 | 0.72 | 0.47 | 0.41 | 9.3 | 7.8 | 5.4 | 27 | 26 | 131.6 | 1.098 |
| G1 | 434723.837 | 5527683.163 | 349 | 329 | 109 | 152 | 15 | 33 | 0.4 | 0.5 | 0.5 | 54 | 168 | 108 | 0.85 | 1.16 | 1.77 | 0.67 | 0.51 | 0.39 | 9.5 | 8.7 | 5.3 | 31 | 29 | 148.0 | 1.097 |
| H1 | 434722.733 | 5527603.904 | 346 | 295 | 58 | 19 | 11 | 12 | 0.7 | 0.2 | 0.5 | 43 | 161 | 105 | 0.51 | 0.38 | 0.72 | 0.55 | 0.43 | 0.34 | 9.7 | 8.4 | 5.3 | 33 | 28 | 177.2 | 1.100 |
| I1 | 434721.204 | 5527523.984 | 329 | 341 | 40 | 13 | 17 | 31 | 0.6 | 0.6 | 0.0 | 48 | 145 | 92 | 2.06 | 1.46 | 1.10 | 0.65 | 0.59 | 0.47 | 10.4 | 9.3 | 5.2 | 34 | 31 | 132.4 | 1.099 |
| J1 | 434720.141 | 5527442.917 | 344 | 343 | 67 | 63 | 12 | 22 | 0.4 | 0.2 | 0.0 | 35 | 106 | 67 | 0.72 | 1.07 | 1.27 | 0.62 | 0.48 | 0.43 | 9.6 | 8.2 | 5.3 | 42 | 31 | 167.6 | 1.097 |
| K1 | 434720.093 | 5527389.989 | 301 | 391 | 41 | 55 | 12 | 18 | 0.6 | 1.7 | 3.9 | 46 | 203 | 133 | 0.20 | 0.12 | 0.95 | 0.63 | 0.42 | 0.27 | 10.1 | 9.2 | 5.3 | 34 | 31 | 117.7 | 1.103 |
| A2 | 434821.375 | 5528111.025 | 356 | 352 | 159 | 147 | 26 | 28 | 4.6 | 1.4 | 0.7 | 12 | 196 | 118 | 0.93 | 0.48 | 0.66 | 0.29 | 0.17 | 0.16 | 9.8 | 8.1 | 5.3 | 31 | 28 | 121.5 | 1.105 |
| B2 | 434819.845 | 5528041.725 | 327 | 350 | 98 | 35 | 23 | 20 | 6.3 | 0.4 | 0.0 | 19 | 138 | 78 | 1.22 | 0.74 | 0.52 | 0.29 | 0.21 | 0.23 | 8.2 | 7.4 | 5.7 | 36 | 26 | 145.6 | 1.111 |
| C2 | 434818.367 | 5527960.253 | 330 | 342 | 28 | 19 | 24 | 22 | 9.8 | 0.2 | 0.0 | 14 | 118 | 64 | 1.16 | 0.91 | 0.80 | 0.15 | 0.16 | 0.17 | 8.0 | 6.7 | 4.9 | 33 | 28 | 132.1 | 1.110 |
| D2 | 434817.490 | 5527881.581 | 312 | 336 | 40 | 10 | 24 | 26 | 6.4 | 1.1 | 0.8 | 48 | 129 | 71 | 1.08 | 1.04 | 0.78 | 0.47 | 0.24 | 0.21 | 9.2 | 8.0 | 5.0 | 39 | 29 | 188.4 | 1.100 |
| E2 | 434816.193 | 5527802.046 | 362 | 343 | 52 | 32 | 19 | 22 | 2.7 | 1.1 | 0.6 | 48 | 122 | 67 | 1.53 | 1.54 | 1.30 | 0.59 | 0.56 | 0.54 | 8.8 | 7.8 | 5.3 | 33 | 28 | 144.8 | 1.097 |
| F2 | 434815.005 | 5527721.508 | 277 | 293 | 51 | 46 | 13 | 19 | 0.8 | 0.8 | 4.7 | 56 | 152 | 87 | 0.56 | 0.94 | 0.80 | 0.64 | 0.50 | 0.39 | 9.9 | 8.4 | 5.0 | 47 | 33 | 179.0 | 1.097 |
| G2 | 434813.753 | 5527640.814 | 301 | 298 | 56 | 55 | 13 | 20 | 1.5 | 0.6 | 13.4 | 54 | 169 | 100 | 0.57 | 1.24 | 1.33 | 0.68 | 0.53 | 0.43 | 10.0 | 8.9 | 5.3 | 47 | 34 | 185.5 | 1.099 |
| H2 | 434812.930 | 5527561.976 | 287 | 307 | 39 | 48 | 11 | 16 | 1.0 | 0.8 | 7.1 | 46 | 131 | 80 | 0.37 | 0.41 | 0.99 | 0.62 | 0.48 | 0.28 | 9.8 | 8.6 | 5.0 | 39 | 34 | 148.9 | 1.102 |
| I2 | 434811.710 | 5527482.351 | 326 | 332 | 47 | 30 | 11 | 14 | 1.3 | 0.2 | 0.0 | 35 | 103 | 55 | 0.31 | 0.25 | 0.40 | 0.62 | 0.42 | 0.23 | 9.6 | 8.1 | 5.3 | 37 | 31 | 156.8 | 1.113 |
| J2 | 434810.697 | 5527412.397 | 341 | 368 | 14 | -15 | 12 | 12 | 1.0 | 0.2 | 0.7 | 44 | 121 | 70 | 0.76 | 0.49 | 0.78 | 0.68 | 0.49 | 0.33 | 10.1 | 8.5 | 5.3 | 39 | 33 | 140.0 | 1.104 |
| A3 | 434892.218 | 5528136.163 | 224 | 209 | 112 | 100 | 22 | 26 | 4.2 | 10.7 | 1.7 | 50 | 247 | 157 | 0.58 | 0.62 | 1.01 | 0.40 | 0.19 | 0.18 | 9.6 | 8.2 | 5.4 | 34 | 27 | 98.3 | 1.101 |
| B3 | 434891.082 | 5528081.190 | 424 | 400 | 143 | 209 | 28 | 36 | 2.7 | 0.4 | 0.0 | 20 | 178 | 95 | 1.57 | 0.83 | 0.53 | 0.29 | 0.19 | 0.20 | 8.9 | 7.9 | 4.0 | 45 | 35 | 143.5 | 1.103 |
| C3 | 434890.411 | 5528001.030 | 346 | 352 | 78 | 31 | 22 | 22 | 3.1 | 0.3 | 0.0 | 18 | 125 | 73 | 0.72 | 0.66 | 0.34 | 0.30 | 0.17 | 0.25 | 8.5 | 7.4 | 4.0 | 37 | 33 | 119.2 | 1.105 |
| D3 | 434888.758 | 5527920.383 | 278 | 268 | 58 | 19 | 16 | 19 | 1.2 | 0.2 | 0.0 | 26 | 155 | 85 | 0.97 | 0.89 | 0.95 | 0.45 | 0.28 | 0.29 | 9.1 | 8.2 | 3.9 | 35 | 30 | 122.3 | 1.100 |
| E3 | 434887.428 | 5527842.011 | 329 | 343 | 68 | 133 | 19 | 28 | 1.9 | 3.0 | 1.8 | 56 | 143 | 76 | 2.00 | 1.57 | 1.47 | 0.51 | 0.44 | 0.41 | 9.6 | 7.8 | 4.0 | 42 | 36 | 147.6 | 1.090 |
| F3 | 434886.304 | 5527761.250 | 291 | | 34 | 2 | 11 | 23 | 0.6 | 1.0 | 14.3 | 53 | 120 | 70 | 0.20 | 0.85 | 0.98 | 0.56 | 0.49 | 0.45 | 9.1 | 7.8 | 4.0 | 45 | 32 | 150.4 | 1.095 |
| G3 | 434885.096 | 5527681.959 | 276 | 253 | 63 | 14 | 12 | 20 | 0.8 | 1.3 | 11.7 | 59 | 153 | 92 | 0.52 | 0.77 | 0.93 | 0.60 | 0.44 | 0.44 | 9.7 | 8.2 | 3.9 | 47 | 38 | 159.6 | 1.098 |
| H3 | 434884.016 | 5527601.598 | 352 | 333 | 63 | 121 | 10 | 12 | 0.6 | 0.8 | 4.9 | 52 | 138 | 88 | 0.44 | 0.28 | 0.43 | 0.68 | 0.46 | 0.38 | 9.6 | 8.0 | 4.0 | 44 | 37 | 135.8 | 1.100 |
| I3 | 434882.794 | 5527522.059 | 289 | 282 | 57 | 99 | 10 | 10 | 0.6 | 0.8 | 2.8 | 65 | 137 | 92 | 0.64 | 0.42 | 0.68 | 0.69 | 0.43 | 0.37 | 9.9 | 8.5 | 4.0 | 36 | 32 | 169.1 | 1.100 |
| J3 | 434881.429 | 5527441.844 | 324 | 307 | 82 | 90 | 11 | 15 | 0.5 | 1.7 | 13.0 | 63 | 159 | 108 | 1.23 | 0.71 | 1.15 | 0.66 | 0.42 | 0.44 | 10.0 | 8.7 | 3.7 | 20 | 17 | 149.8 | 1.090 |
| K3 | 434880.339 | 5527386.710 | 418 | | 61 | 115 | 10 | 19 | 0.5 | 1.4 | 7.0 | 67 | 199 | 141 | 0.18 | 0.46 | 0.64 | 0.80 | 0.45 | 0.40 | 10.3 | 8.9 | 3.6 | 39 | 34 | 136.4 | 1.102 |
| A4 | 434975.144 | 5528110.152 | 235 | 208 | 57 | 92 | 19 | 23 | 0.8 | 0.7 | 0.0 | 39 | 233 | 129 | 1.86 | 1.14 | 1.16 | 0.37 | 0.22 | 0.16 | 9.1 | 8.4 | 3.9 | 34 | 27 | 117.1 | 1.096 |
| B4 | 434974.128 | 5528040.093 | 263 | 289 | 131 | 110 | 35 | 29 | 4.2 | 0.9 | 0.6 | 16 | 139 | 75 | 1.74 | 1.09 | 0.45 | 0.29 | 0.22 | 0.16 | 8.5 | 7.8 | 3.9 | 38 | 29 | 126.8 | 1.106 |
| C4 | 434972.866 | 5527960.541 | 287 | 302 | 63 | 61 | 15 | 22 | 0.7 | 1.9 | 2.8 | 24 | 174 | 102 | 1.14 | 1.14 | 0.86 | 0.58 | 0.33 | 0.29 | 9.6 | 8.5 | 4.3 | 37 | 32 | 132.3 | 1.102 |
| D4 | 434971.754 | 5527880.276 | 299 | 321 | 50 | 31 | 18 | 21 | 1.0 | 1.1 | 0.8 | 39 | 146 | 85 | 1.77 | 1.83 | 1.58 | 0.50 | 0.50 | 0.50 | 8.8 | 8.2 | 3.7 | 37 | 32 | 131.6 | 1.090 |
| E4 | 434970.519 | 5527800.434 | 250 | 282 | 33 | 6 | 10 | 10 | 0.5 | 1.9 | 14.3 | 63 | 137 | 86 | 1.12 | 0.44 | 0.80 | 0.63 | 0.51 | 0.35 | 10.3 | 9.3 | 3.8 | 42 | 39 | 128.4 | 1.106 |
| F4 | 434969.323 | 5527720.352 | 270 | 283 | 24 | 38 | 12 | 16 | 0.6 | 3.0 | 10.4 | 56 | 157 | 98 | 0.95 | 0.72 | 0.97 | 0.55 | 0.48 | 0.35 | 9.8 | 8.7 | 3.6 | 43 | 26 | 177.5 | 1.094 |
| G4 | 434967.996 | 5527640.531 | 275 | 258 | 31 | 58 | 13 | 22 | 0.7 | 1.3 | 20.7 | 52 | 144 | 85 | 0.85 | 0.99 | 0.82 | 0.66 | 0.53 | 0.48 | 10.2 | 8.7 | 3.6 | 44 | 30 | 123.2 | 1.097 |
| H4 | 434966.619 | 5527560.295 | 387 | 353 | 52 | 62 | 11 | 16 | 0.8 | 0.9 | 4.6 | 42 | 139 | 87 | 0.55 | 0.33 | 0.40 | 0.74 | 0.49 | 0.42 | 10.2 | 8.5 | 3.8 | 46 | 43 | 113.5 | 1.099 |
| I4 | 434965.319 | 5527480.535 | 261 | 253 | 32 | 46 | 10 | 12 | 0.5 | 4.7 | 12.4 | 53 | 169 | 113 | 0.64 | 0.41 | 0.56 | 0.70 | 0.40 | 0.30 | 10.4 | 8.6 | 3.7 | 41 | 37 | 149.0 | 1.099 |
| J4 | 434963.881 | 5527410.613 | 283 | 267 | 37 | 93 | 12 | 21 | 1.0 | 8.0 | 29.8 | 46 | 169 | 106 | 1.45 | 1.50 | 1.51 | 0.67 | 0.49 | 0.44 | 10.8 | 8.8 | 3.9 | 45 | 41 | 127.4 | 1.088 |
| B5 | 435050.858 | 5528079.374 | 158 | 166 | 66 | 102 | 31 | 30 | 4.3 | 23.6 | 8.3 | 23 | 188 | 111 | 1.94 | 1.72 | 1.68 | 0.25 | 0.24 | 0.22 | 8.6 | 8.1 | 4.0 | 36 | 32 | 144.8 | 1.103 |
| C5 | 435050.299 | 5527999.572 | 281 | 316 | 47 | 1 | 22 | 22 | 13.2 | 1.4 | 1.3 | 20 | 146 | 93 | 1.49 | 1.22 | 1.27 | 0.25 | 0.21 | 0.22 | 8.8 | 8.3 | 3.7 | 27 | 26 | 126.4 | 1.106 |
| D5 | 435049.829 | 5527919.449 | 257 | 248 | 67 | 67 | 31 | 37 | 1.1 | 1.9 | 1.2 | 22 | 205 | 119 | 1.92 | 1.57 | 1.48 | 0.35 | 0.28 | 0.35 | 9.1 | 8.6 | 3.5 | 38 | 29 | 139.0 | 1.093 |
| E5 | 435048.239 | 5527839.823 | 329 | 329 | -10 | 41 | 13 | 24 | 0.8 | 4.5 | 18.4 | 72 | 150 | 92 | 0.50 | 0.92 | 1.17 | 0.64 | 0.51 | 0.49 | 10.4 | 8.5 | 3.7 | 40 | 31 | 173.4 | 1.099 |
| F5 | 435046.776 | 5527759.335 | 301 | 308 | 30 | 39 | 10 | 17 | 1.0 | 2.0 | 4.6 | 70 | 193 | 120 | 1.01 | 0.42 | 0.53 | 0.64 | 0.49 | 0.46 | 10.8 | 9.8 | 3.6 | 43 | 36 | 153.2 | 1.098 |
| G5 | 435045.437 | 5527678.991 | 314 | 306 | 57 | 81 | 13 | 25 | 0.8 | 2.1 | 12.1 | 78 | 256 | 168 | 0.96 | 0.87 | 1.02 | 0.70 | 0.58 | 0.47 | 10.7 | 9.8 | 3.4 | 31 | 28 | 110.9 | 1.098 |
| H5 | 435044.123 | 5527599.538 | 360 | 380 | 28 | 31 | 10 | 11 | 1.1 | 2.1 | 13.5 | 40 | 214 | 146 | 0.54 | 0.03 | 0.03 | 0.81 | 0.53 | 0.51 | 10.1 | 8.9 | 3.8 | 44 | 36 | 148.0 | 1.106 |
| I5 | 435042.906 | 5527519.281 | 279 | 317 | 9 | 9 | 10 | 11 | 0.9 | 6.4 | 22.0 | 43 | 384 | 278 | 0.46 | 0.12 | 0.07 | 0.69 | 0.50 | 0.38 | 10.1 | 9.5 | 3.5 | 38 | 34 | 112.0 | 1.101 |
| J5 | 435041.392 | 5527458.930 | 219 | 204 | 28 | 35 | 11 | 25 | 1.0 | 23.9 | 52.1 | 59 | 293 | 201 | 1.45 | 0.86 | 1.03 | 0.73 | 0.56 | 0.60 | 10.7 | 9.8 | 3.1 | 40 | 39 | 142.6 | 1.099 |
| **Means** | | | **308** | **309** | **60** | **59** | **16** | **21** | **2.0** | **2.5** | **6.3** | **43** | **168** | **103** | **0.96** | **0.86** | **0.91** | **0.54** | **0.39** | **0.34** | **9.6** | **8.4** | **4.4** | **38** | **31** | **141.1** | **1.100** |

**Additional Information, as follows.**

DR – July 2 – September 3, 1999
Kel – Kelowna method
AA – Ammonium Acetate method
DT$^1$ – July 9, 1999
DT$^2$ – July 28, 1999
DT$^3$ – August 13, 1999

# VIII. 1999 Hays Grid Sample Data

| **1999 Hays Site (Snowden)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Position Data** | | **Moisture** | | | | **Soil Characteristics** | | | | | | | | **Petiole Nutrient Contents** | | | | | | | | | **Hand-Sampled Tuber Data** | | | | |
| Site | Easting (m) | Northing (m) | Irrigation + Precipitation (mm) | Consumptive Use (mm) | Avaliable Water % | | Clay (%) | | $CaCO_3$ (%) | $NO_3$-N (ppm) | | $PO_4$-P (ppm) | K (ppm) | | $NO_3$-N (%) | | | P (%) | | | K (%) | | | Total Yield (t/ha) | Medium Tuber Yield (t/ha) | Mean Tuber Weight (g) | Opacity | Specific Gravity |
| Info | | | DR | | | | | | | | | Kel | AA | Kel | $DT^1$ | $DT^2$ | $DT^3$ | $DT^1$ | $DT^2$ | $DT^3$ | $DT^1$ | $DT^2$ | $DT^3$ | | | | | |
| Depth (cm) | | | | (0-100) | (0-60) | (60-100) | (0-60) | (60-90) | (0-30) | (0-60) | (60-90) | (0-15) | (0-30) | (0-30) | | | | | | | | | | | | | | |
| A1 | 438901.353 | 5537802.739 | 202 | 287 | 94 | 75 | 36 | 42 | 1.6 | 0.39 | 0.00 | 24 | 485 | 282 | 1.59 | 1.15 | 0.27 | 0.23 | 0.14 | 0.09 | 9.6 | 5.4 | 4.8 | 30 | 26 | 114.5 | 59.70 | 1.097 |
| B1 | 438900.519 | 5537742.303 | 198 | 319 | 49 | 76 | 31 | 32 | 1.4 | 0.88 | 0.00 | 19 | 237 | 168 | 1.22 | 0.64 | 0.71 | 0.20 | 0.12 | 0.10 | 9.0 | 5.3 | 4.6 | 28 | 26 | 93.9 | 60.50 | 1.098 |
| C1 | 438899.251 | 5537654.886 | 202 | 302 | 12 | 19 | 6 | 5 | 2.1 | 0.00 | 0.00 | 22 | 157 | 196 | 0.27 | 0.85 | 0.04 | 0.22 | 0.14 | 0.12 | 9.4 | 5.4 | 4.7 | 31 | 30 | 105.0 | 61.48 | 1.100 |
| D1 | 438898.355 | 5537577.275 | 202 | 286 | 139 | 94 | 8 | 18 | 2.8 | 1.34 | 2.98 | 25 | 258 | 204 | 1.98 | 1.32 | 1.09 | 0.30 | 0.22 | 0.19 | 10.8 | 5.1 | 4.6 | 30 | 25 | 91.8 | 59.96 | 1.099 |
| E1 | 438897.233 | 5537499.906 | 207 | 294 | 162 | 198 | 7 | 14 | 1.3 | 0.72 | 7.06 | 18 | 185 | 118 | 0.66 | 0.19 | 0.18 | 0.30 | 0.12 | 0.12 | 10.1 | 5.3 | 4.4 | 41 | 35 | 116.3 | 59.96 | 1.102 |
| F1 | 438896.412 | 5537422.836 | 190 | 312 | 145 | 185 | 7 | 10 | 0.9 | 0.52 | 12.70 | 19 | 117 | 91 | 0.76 | 0.31 | 0.01 | 0.23 | 0.42 | 0.24 | 8.9 | 5.3 | 4.6 | 24 | 21 | 84.4 | 58.99 | 1.110 |
| G1 | 438895.245 | 5537345.214 | 191 | 223 | 198 | 204 | 7 | 12 | 1.1 | 0.31 | 0.51 | 21 | 148 | 95 | 1.22 | 0.37 | 0.38 | 0.19 | 0.09 | 0.14 | 10.6 | 5.3 | 4.7 | 28 | 21 | 62.0 | 60.56 | 1.094 |
| H1 | 438894.223 | 5537268.288 | 225 | 302 | 115 | 136 | 7 | 14 | 0.8 | 0.00 | 0.00 | 21 | 121 | 151 | 1.30 | 1.19 | 0.90 | 0.16 | 0.12 | 0.10 | 8.3 | 5.3 | 4.6 | 50 | 45 | 100.9 | 61.78 | 1.090 |
| I1 | 438893.407 | 5537190.871 | 235 | 292 | 140 | 117 | 11 | 31 | 1.2 | 3.17 | 1.25 | 30 | 261 | 160 | 1.21 | 0.62 | 0.06 | 0.20 | 0.19 | 0.09 | 10.3 | 5.3 | 4.7 | 45 | 40 | 91.5 | 60.52 | 1.094 |
| J1 | 438892.435 | 5537113.489 | 214 | 343 | 131 | 218 | 11 | 28 | 0.5 | 0.00 | 0.67 | 21 | 120 | 122 | 0.38 | 1.31 | 0.00 | 0.23 | 0.20 | 0.10 | 9.7 | 5.3 | 4.7 | 30 | 27 | 97.6 | 60.16 | 1.110 |
| K1 | 438891.946 | 5537045.230 | 221 | 308 | 98 | 162 | 16 | 19 | 0.4 | 0.53 | 0.00 | 21 | 155 | 187 | 1.59 | 1.75 | 1.39 | 0.18 | 0.20 | 0.13 | 9.7 | 5.3 | 4.8 | 37 | 32 | 107.8 | 60.69 | 1.091 |
| C2 | 438953.123 | 5537770.223 | 208 | 266 | 106 | 108 | 28 | 50 | 0.8 | 0.95 | 0.00 | 25 | 262 | 206 | 1.43 | 1.37 | 0.95 | 0.17 | 0.13 | 0.10 | 8.3 | 5.3 | 4.3 | 24 | 35 | 175.9 | 61.10 | 1.101 |
| D2 | 438952.023 | 5537693.018 | 205 | 284 | 65 | 91 | 19 | 40 | 1.0 | 0.00 | 0.00 | 23 | 189 | 189 | 0.78 | 1.30 | 0.65 | 0.19 | 0.14 | 0.10 | 9.3 | 4.9 | 4.7 | 18 | 17 | 79.0 | 60.63 | 1.109 |
| E2 | 438951.139 | 5537615.713 | 219 | 315 | 46 | 96 | 20 | 31 | 0.7 | 0.57 | 0.79 | 28 | 211 | 199 | 1.48 | 0.61 | 0.23 | 0.24 | 0.15 | 0.10 | 10.4 | 5.2 | 4.7 | 16 | 35 | 88.5 | 55.57 | 1.097 |
| F2 | 438950.097 | 5537538.058 | 200 | 294 | 66 | 99 | 9 | 9 | 0.6 | 1.44 | 8.44 | 34 | 207 | 162 | 1.34 | 0.34 | 0.02 | 0.36 | 0.15 | 0.11 | 10.6 | 2.7 | 4.7 | 20 | 37 | 111.6 | 56.35 | 1.095 |
| G2 | 438949.070 | 5537461.360 | 191 | 232.5 | 131 | 137 | 11 | 9 | 0.5 | 0.43 | 0.91 | 26 | 128 | 107 | 0.99 | 0.21 | 0.00 | 0.26 | 0.12 | 0.09 | 10.6 | 2.6 | 4.7 | 19 | 33 | 117.3 | 59.68 | 1.101 |
| H2 | 438947.981 | 5537383.411 | 190 | 239 | 198 | 234 | 14 | 11 | 0.8 | 0.00 | 1.03 | 29 | 97 | 91 | 1.30 | 0.12 | 0.00 | 0.26 | 0.17 | 0.11 | 10.3 | 2.5 | 4.8 | 22 | 33 | 125.9 | 57.55 | 1.095 |
| I2 | 438947.748 | 5537306.217 | 183 | 270.5 | 127 | 144 | 12 | 25 | 0.5 | 0.00 | 1.08 | 18 | 129 | 91 | 1.04 | 0.14 | 0.01 | 0.28 | 0.16 | 0.10 | 9.7 | 2.4 | 4.7 | 29 | 40 | 152.9 | 60.06 | 1.098 |
| J2 | 438946.142 | 5537228.829 | 183 | 217 | 178 | 181 | 8 | 9 | 0.7 | 0.00 | 2.02 | 19 | 112 | 106 | 1.19 | 0.04 | 0.00 | 0.28 | 0.13 | 0.10 | 10.5 | 2.6 | 4.8 | 26 | 38 | 92.4 | 61.43 | 1.100 |
| K2 | 438945.078 | 5537151.613 | 187 | 217.5 | 186 | 164 | 18 | 24 | 1.1 | 0.82 | 0.97 | 18 | 149 | 119 | 1.53 | 0.04 | 0.00 | 0.42 | 0.15 | 0.13 | 10.4 | 2.7 | 5.6 | 18 | 12 | 41.4 | 57.08 | 1.108 |
| L2 | 438944.151 | 5537074.166 | 197 | 283 | 106 | 119 | 19 | 22 | 1.9 | 1.08 | 1.10 | 18 | 136 | 184 | 1.58 | 0.89 | 0.27 | 0.21 | 0.15 | 0.12 | 8.4 | 2.6 | 4.7 | 21 | 36 | 88.4 | 58.01 | 1.092 |
| A3 | 439028.024 | 5537801.346 | 184 | 214 | 90 | 80 | 27 | 38 | 0.4 | 1.23 | 0.00 | 21 | 302 | 217 | 1.79 | 0.60 | 1.06 | 0.27 | 0.16 | 0.13 | 9.5 | 2.6 | 4.6 | 21 | 36 | 95.1 | 61.69 | 1.093 |
| B3 | 439026.928 | 5537730.751 | 230 | 288 | 34 | 93 | 11 | 14 | 0.8 | 0.40 | 0.00 | 23 | 222 | 175 | 1.34 | 1.20 | 0.56 | 0.36 | 0.17 | 0.11 | 9.4 | 5.7 | 4.7 | 29 | 32 | 112.9 | 59.76 | 1.101 |
| C3 | 439025.803 | 5537651.912 | 204 | 280 | 78 | 111 | 39 | 41 | 0.8 | 0.94 | 0.00 | 22 | 220 | 139 | 1.83 | 1.35 | 1.20 | 0.24 | 0.13 | 0.11 | 8.8 | 5.3 | 4.2 | 21 | 30 | 101.9 | 57.27 | 1.093 |
| D3 | 439024.693 | 5537576.041 | 206 | 290.5 | 30 | 112 | 7 | 11 | 0.7 | 0.00 | 0.00 | 20 | 140 | 114 | 1.09 | 0.28 | 0.02 | 0.42 | 0.22 | 0.13 | 9.3 | 5.8 | 4.7 | 20 | 30 | 98.9 | 62.61 | 1.099 |
| E3 | 439023.847 | 5537498.624 | 224 | 316.5 | 107 | 221 | 7 | 17 | 0.8 | 0.00 | 1.21 | 21 | 149 | 189 | 1.62 | 0.49 | 0.04 | 0.35 | 0.17 | 0.13 | 8.9 | 5.7 | 4.7 | 27 | 46 | 116.0 | 61.21 | 1.099 |
| F3 | 439022.916 | 5537421.286 | 183 | 225 | 213 | 127 | 12 | 21 | 0.3 | 1.80 | 0.98 | 29 | 349 | 183 | 2.65 | 1.08 | 1.14 | 0.38 | 0.20 | 0.28 | 10.8 | 5.9 | 3.6 | 23 | 35 | 82.2 | 60.96 | 1.089 |
| G3 | 439021.796 | 5537343.987 | 184 | 275 | 134 | 128 | 11 | 19 | 0.7 | 1.35 | 0.94 | 18 | 153 | 95 | 1.65 | 0.69 | 0.19 | 0.42 | 0.21 | 0.15 | 10.0 | 5.8 | 4.7 | 30 | 46 | 135.4 | 60.49 | 1.095 |
| H3 | 439020.753 | 5537266.777 | 192 | 275.5 | 162 | 243 | 15 | 43 | 0.4 | 0.77 | 0.57 | 24 | 129 | 91 | 1.99 | 1.07 | 0.44 | 0.31 | 0.16 | 0.14 | 9.7 | 5.8 | 4.6 | 25 | 43 | 90.7 | 57.59 | 1.095 |
| I3 | 439019.930 | 5537189.617 | 197 | 234.5 | 186 | 241 | 11 | 20 | 1.0 | 3.25 | 9.33 | 27 | 117 | 114 | 2.81 | 0.85 | 0.41 | 0.43 | 0.20 | 0.17 | 10.1 | 5.8 | 4.7 | 22 | 34 | 142.4 | 58.22 | 1.095 |
| J3 | 439019.162 | 5537111.949 | 196 | 246.5 | 192 | 200 | 11 | 15 | 1.0 | 0.55 | 2.23 | 29 | 146 | 186 | 2.85 | 0.38 | 0.61 | 0.43 | 0.16 | 0.17 | 10.6 | 5.8 | 4.4 | 24 | 39 | 92.3 | 61.38 | 1.098 |
| K3 | 439018.309 | 5537046.828 | 136 | 220.5 | 135 | 176 | 25 | 36 | 0.9 | 2.92 | 2.42 | 29 | 237 | 178 | 2.77 | 2.14 | 1.51 | 0.52 | 0.28 | 0.20 | 11.0 | 5.7 | 3.9 | 20 | 34 | 92.1 | 59.26 | 1.096 |
| B4 | 439105.437 | 5537768.650 | 254 | 299.5 | 101 | 175 | 30 | 46 | 1.1 | 1.06 | 0.00 | 17 | 172 | 114 | 1.63 | 1.47 | 1.06 | 0.22 | 0.13 | 0.09 | 8.4 | 5.6 | 4.4 | 24 | 22 | 110.8 | 62.16 | 1.101 |
| C4 | 439104.332 | 5537691.258 | 236 | 283 | 105 | 196 | 11 | 32 | 0.5 | 1.33 | 0.86 | 21 | 141 | 88 | 1.97 | 1.36 | 0.73 | 0.42 | 0.23 | 0.14 | 9.0 | 5.6 | 4.7 | 30 | 29 | 103.0 | 60.76 | 1.096 |
| D4 | 439103.144 | 5537613.871 | 204 | 275 | 49 | 168 | 9 | 25 | 0.6 | 0.88 | 0.66 | 31 | 96 | 75 | 1.58 | 1.07 | 0.19 | 0.43 | 0.25 | 0.15 | 9.0 | 5.6 | 4.5 | 20 | 19 | 93.7 | 62.31 | 1.103 |
| E4 | 439102.189 | 5537536.393 | 213 | 247 | 148 | 150 | 15 | 23 | 0.4 | 4.21 | 8.48 | 21 | 119 | 83 | 2.50 | 0.37 | 0.05 | 0.51 | 0.27 | 0.20 | 10.7 | 5.9 | 4.4 | 20 | 16 | 63.8 | 60.59 | 1.095 |
| F4 | 439101.235 | 5537459.127 | 211 | 296 | 94 | 135 | 21 | 37 | 0.4 | 0.93 | 0.00 | 15 | 132 | 73 | 1.60 | 1.18 | 0.66 | 0.23 | 0.17 | 0.12 | 8.7 | 5.8 | 4.6 | 27 | 26 | 111.4 | 61.43 | 1.098 |
| G4 | 439100.034 | 5537381.661 | 202 | 263 | 23 | 59 | 12 | 32 | 0.5 | 1.24 | 0.53 | 5 | 125 | 60 | 1.36 | 1.26 | 0.80 | 0.44 | 0.27 | 0.18 | 9.4 | 5.9 | 4.4 | 22 | 20 | 137.9 | 61.49 | 1.095 |
| H4 | 439099.090 | 5537304.598 | 191 | 247 | 30 | 140 | 17 | 39 | 0.6 | 0.43 | 0.00 | 12 | 90 | 85 | 1.02 | 1.04 | 0.60 | 0.27 | 0.15 | 0.12 | 8.2 | 5.4 | 3.6 | 16 | 14 | 78.4 | 60.83 | 1.106 |
| I4 | 439098.094 | 5537227.026 | 193 | 279 | 35 | 88 | 12 | 32 | 0.4 | 1.58 | 1.54 | 25 | 170 | 138 | 1.91 | 1.17 | 0.69 | 0.29 | 0.20 | 0.15 | 8.9 | 5.8 | 4.4 | 35 | 29 | 154.8 | 59.53 | 1.093 |
| J4 | 439097.389 | 5537149.713 | 198 | 276 | 73 | 125 | 11 | 28 | 0.5 | 0.73 | 0.75 | 16 | 225 | 153 | 1.49 | 1.16 | 0.61 | 0.25 | 0.17 | 0.12 | 9.4 | 5.9 | 4.4 | 23 | 23 | 135.0 | 59.85 | 1.094 |
| K4 | 439092.546 | 5537072.361 | 181 | 242 | 60 | 162 | 17 | 39 | 0.6 | 0.87 | 0.53 | 21 | 191 | 108 | 1.92 | 1.42 | 0.84 | 0.37 | 0.18 | 0.15 | 9.8 | 5.9 | 4.4 | 30 | 29 | 124.5 | 61.55 | 1.100 |
| C5 | 439181.201 | 5537649.607 | 207 | 302.5 | -13 | 50 | 8 | 30 | 0.3 | 1.15 | 0.00 | 14 | 104 | 82 | 1.65 | 0.79 | 0.43 | 0.48 | 0.17 | 0.16 | 9.4 | 5.8 | 4.1 | 19 | 19 | 104.7 | 63.54 | 1.106 |
| D5 | 439179.149 | 5537574.110 | 213 | 267 | 17 | 76 | 7 | 8 | 0.8 | 0.52 | 0.00 | 20 | 140 | 83 | 1.61 | 0.71 | 0.17 | 0.55 | 0.18 | 0.14 | 9.9 | 5.9 | 4.4 | 12 | 11 | 109.6 | 58.89 | 1.108 |
| E5 | 439178.921 | 5537496.708 | 203 | 204 | 18 | 77 | 24 | 47 | 0.4 | 0.91 | 0.54 | 15 | 112 | 98 | 1.72 | 1.32 | 0.93 | 0.34 | 0.16 | 0.14 | 8.5 | 5.4 | 3.6 | 24 | 16 | 127.0 | 60.26 | 1.097 |
| F5 | 439178.087 | 5537419.385 | 189 | 181 | 56 | 132 | 25 | 44 | 0.7 | 1.50 | 0.61 | 19 | 159 | 108 | 1.69 | 1.52 | 1.04 | 0.32 | 0.16 | 0.13 | 8.8 | 5.5 | 3.8 | 25 | 24 | 127.1 | 58.50 | 1.097 |
| G5 | 439177.265 | 5537342.207 | 202 | 241 | 59 | 136 | 13 | 36 | 0.0 | 0.80 | 0.60 | 13 | 150 | 93 | 1.78 | 1.20 | 0.85 | 0.41 | 0.19 | 0.15 | 9.6 | 5.7 | 4.3 | 24 | 22 | 106.4 | 58.45 | 1.098 |
| H5 | 439176.047 | 5537264.613 | 213 | 329.5 | 41 | 113 | 10 | 36 | 0.4 | 0.64 | 0.64 | 16 | 123 | 87 | 1.61 | 1.19 | 0.52 | 0.41 | 0.20 | 0.14 | 9.0 | 5.5 | 4.0 | 19 | 16 | 91.1 | 58.39 | 1.101 |
| I5 | 439174.920 | 5537187.333 | 128 | 357 | 2 | 0 | 11 | 36 | 0.3 | 0.71 | 0.83 | 17 | 144 | 85 | 1.70 | 1.12 | 0.59 | 0.48 | 0.20 | 0.18 | 9.9 | 5.6 | 4.4 | 19 | 18 | 56.3 | 58.16 | 1.100 |
| E6 | 439256.758 | 5537534.400 | 155 | 191 | 1 | 44 | 19 | 40 | 1.0 | 2.57 | 8.63 | 19 | 124 | 96 | 2.26 | 1.97 | 1.25 | 0.52 | 0.18 | 0.14 | 9.4 | 5.4 | 4.0 | 16 | 16 | 101.3 | 62.44 | 1.110 |
| F6 | 439256.500 | 5537457.460 | 167 | 266 | 45 | 90 | 18 | 52 | 0.2 | 1.53 | 0.87 | 19 | 153 | 96 | 2.10 | 1.60 | 1.40 | 0.42 | 0.20 | 0.19 | 9.6 | 5.5 | 4.4 | 23 | 23 | 119.0 | 60.68 | 1.104 |
| G6 | 439255.838 | 5537379.924 | 193 | 287 | 35 | 67 | 16 | 46 | 0.5 | 0.82 | 0.55 | 13 | 124 | 81 | 1.98 | 1.51 | 0.90 | 0.46 | 0.18 | 0.15 | 9.6 | 5.5 | 4.4 | 22 | 21 | 157.4 | 61.18 | 1.107 |
| H6 | 439254.010 | 5537302.641 | 146 | 215.5 | 3 | 64 | 15 | 40 | 0.4 | 1.44 | 2.19 | 18 | 126 | 144 | 1.90 | 1.33 | 1.22 | 0.52 | 0.17 | 0.12 | 9.2 | 5.6 | 4.2 | 19 | 18 | 110.0 | 60.60 | 1.106 |
| **Means** | | | **198** | **269.8** | **91** | **129** | **15** | **28** | **0.8** | **0.99** | **1.66** | **21** | **169** | **131** | **1.59** | **0.96** | **0.56** | **0.33** | **0.18** | **0.14** | **9.6** | **5.1** | **4.5** | **25** | **26** | **106.1** | **60.1** | **1.099** |

**Additional Information, as follows.**

DR – July 7 – September 3, 1999

Kel – Kelowna method

AA – Ammonium Acetate method

$DT^1$ – July 7, 1999

$DT^2$ – July 30, 1999

$DT^3$ – August 17, 1999

# IX. 1999 Vauxhall Grid Sample Data

| | **Position Data** | | **EM38 Soil Salinity Data** | | **Hand-Sampled Tuber Data** | | | |
|---|---|---|---|---|---|---|---|---|
| Site | Easting (m) | Northing (m) | E.C. Horizontal (dS/m) | E.C. Vertical (dS/m) | Total Yield (t/ha) | Medium Tuber Yield (t/ha) | Mean Tuber Weight (g) | Specific Gravity |
| Depth (cm) | | | (0-60) | (0-120) | | | | |
| 2 | 417803.452 | 5545198.060 | 5.0 | 5.7 | 27 | 21 | 99.2 | 1.105 |
| 3 | 417802.606 | 5545208.771 | 0.5 | 4.3 | 36 | 27 | 98.4 | 1.091 |
| 4 | 417803.706 | 5545217.884 | 3.7 | 4.7 | 34 | 24 | 95.8 | 1.086 |
| 5 | 417802.545 | 5545231.981 | 3.7 | 5.4 | 40 | 34 | 122.8 | 1.094 |
| 6 | 417804.655 | 5545250.974 | 3.2 | 5.0 | 40 | 35 | 114.5 | 1.103 |
| 7 | 417804.179 | 5545258.717 | 2.7 | 4.6 | 44 | 31 | 103.5 | 1.102 |
| 8 | 417806.070 | 5545284.676 | 2.7 | 4.7 | 43 | 35 | 105.0 | 1.100 |
| 9 | 417806.324 | 5545311.932 | 3.8 | 5.7 | 30 | 25 | 131.4 | 1.106 |
| 10 | 417807.379 | 5545353.228 | 0.3 | 0.1 | 49 | 40 | 101.6 | 1.110 |
| 11 | 417807.760 | 5545368.950 | 0.3 | 0.2 | 46 | 38 | 107.9 | 1.105 |
| 12 | 417805.729 | 5545433.224 | 0.3 | 0.2 | 35 | 28 | 104.9 | 1.089 |
| 13 | 417734.776 | 5545134.595 | 4.2 | 3.9 | 25 | 14 | 103.0 | 1.097 |
| 14 | 417732.885 | 5545139.708 | 3.8 | 4.1 | 34 | 29 | 118.9 | 1.100 |
| 15 | 417734.047 | 5545146.255 | 2.9 | 3.9 | 38 | 30 | 108.1 | 1.096 |
| 16 | 417735.376 | 5545160.364 | 1.8 | 3.2 | 41 | 36 | 106.0 | 1.098 |
| 17 | 417735.460 | 5545160.352 | 2.7 | 3.7 | 39 | 32 | 112.6 | 1.093 |
| 18 | 417735.746 | 5545177.626 | 3.2 | 4.8 | 38 | 32 | 103.8 | 1.099 |
| 19 | 417735.340 | 5545186.596 | 0.3 | 3.8 | 44 | 34 | 114.2 | 1.100 |
| 20 | 417735.547 | 5545201.099 | 4.7 | 5.3 | 48 | 35 | 91.3 | 1.099 |
| 21 | 417735.846 | 5545227.155 | 2.3 | 4.4 | 41 | 34 | 101.8 | 1.095 |
| 22 | 417736.294 | 5545240.162 | 1.8 | 3.8 | 40 | 29 | 95.8 | 1.099 |
| 23 | 417737.002 | 5545292.974 | 1.6 | 3.3 | 39 | 29 | 82.9 | 1.097 |
| 24 | 417742.783 | 5545420.668 | 0.6 | 2.1 | 36 | 29 | 105.3 | 1.095 |
| 25 | 417741.043 | 5545425.065 | 0.4 | 1.7 | 31 | 20 | 93.3 | 1.100 |
| 26 | 417742.753 | 5545437.498 | 0.3 | 0.8 | 47 | 37 | 105.4 | 1.087 |
| 27 | 417743.677 | 5545453.048 | 0.3 | 0.9 | 40 | 36 | 127.3 | 1.089 |
| 28 | 417744.943 | 5545473.627 | 0.3 | 1.2 | 27 | 18 | 80.6 | 1.085 |
| 29 | 416599.690 | 5545133.444 | 6.4 | 6.0 | 38 | 31 | 118.3 | 1.108 |
| 30 | 416601.295 | 5545137.559 | 6.8 | 6.1 | 28 | 20 | 125.4 | 1.108 |
| 31 | 416604.731 | 5545132.820 | 6.6 | 6.1 | 20 | 14 | 115.6 | 1.111 |
| 32 | 416611.542 | 5545131.133 | 7.0 | 6.1 | 18 | 14 | 101.4 | 1.114 |
| 33 | 416624.477 | 5545146.228 | 6.2 | 6.0 | 20 | 16 | 108.2 | 1.107 |
| 34 | 416628.008 | 5545148.094 | 5.0 | 5.5 | 34 | 27 | 134.4 | 1.104 |
| 35 | 416633.429 | 5545150.672 | 1.8 | 3.4 | 50 | 40 | 124.9 | 1.092 |
| 36 | 416637.308 | 5545159.760 | 0.5 | 2.2 | 56 | 48 | 148.9 | 1.096 |
| 37 | 416643.724 | 5545165.115 | 2.9 | 4.2 | 32 | 21 | 119.5 | 1.098 |
| 38 | 416652.716 | 5545157.126 | 1.9 | 3.4 | 48 | 40 | 138.4 | 1.099 |
| 39 | 416663.907 | 5545183.050 | 1.0 | 2.5 | 46 | 41 | 134.2 | 1.101 |
| 40 | 416671.818 | 5545173.875 | 0.4 | 1.6 | 49 | 43 | 147.6 | 1.101 |
| 41 | 416677.985 | 5545170.589 | 0.6 | 2.2 | 46 | 38 | 153.3 | 1.100 |
| 42 | 416684.811 | 5545190.281 | 0.4 | 1.8 | 49 | 37 | 157.0 | 1.101 |
| 43 | 416689.479 | 5545197.304 | 0.2 | 1.6 | 55 | 50 | 142.5 | 1.098 |
| 44 | 416704.301 | 5545206.294 | 0.3 | 1.2 | 44 | 37 | 147.9 | 1.097 |
| 45 | 416712.669 | 5545218.766 | 0.3 | 1.2 | 52 | 47 | 154.4 | 1.103 |
| 46 | 417011.817 | 5545102.675 | 5.9 | 7.3 | 10 | 4 | 86.2 | 1.113 |
| 47 | 417009.936 | 5545087.434 | 6.1 | 6.7 | 43 | 17 | 81.7 | 1.096 |
| 48 | 417011.213 | 5545067.675 | 7.8 | 8.5 | 27 | 12 | 117.2 | 1.097 |
| 49 | 416989.494 | 5545069.341 | 2.0 | 3.2 | 32 | 10 | 60.1 | 1.080 |
| 50 | 416990.820 | 5545052.866 | 1.5 | 2.6 | 25 | 13 | 78.9 | 1.078 |
| 51 | 416988.397 | 5545040.775 | 1.8 | 2.7 | 27 | 8 | 37.6 | 1.085 |
| 52 | 417010.838 | 5545041.948 | 5.2 | 5.5 | 28 | 13 | 89.6 | 1.088 |
| 53 | 417014.113 | 5545023.477 | 3.5 | 4.6 | 27 | 17 | 79.9 | 1.084 |
| 54 | 417012.063 | 5545009.248 | 3.1 | 4.6 | 6 | 3 | 19.4 | 1.129 |
| 55 | 417010.002 | 5544984.904 | 1.6 | 3.0 | 58 | 48 | 172.1 | 1.097 |
| 56 | 417011.943 | 5544966.075 | 1.4 | 2.7 | 45 | 38 | 186.5 | 1.092 |
| 57 | 417011.061 | 5544955.561 | 0.5 | 1.9 | 51 | 48 | 224.0 | 1.089 |
| 58 | 417014.215 | 5544939.563 | 2.4 | 4.0 | 36 | 32 | 179.8 | 1.101 |
| 59 | 417020.608 | 5544932.424 | 1.5 | 3.4 | 37 | 33 | 140.2 | 1.103 |
| 60 | 417020.454 | 5544919.843 | 0.2 | 1.7 | 49 | 44 | 157.8 | 1.091 |
| 61 | 417010.756 | 5544922.446 | 0.3 | 1.7 | 58 | 52 | 176.1 | 1.090 |
| 62 | 417025.447 | 5544919.278 | 0.5 | 1.9 | 51 | 46 | 150.4 | 1.092 |
| **Means** | | | **2.5** | **3.6** | **38** | **30** | **117.1** | **1.098** |

# ESTIMATING POTATO PETIOLE NITRATE NITROGEN USING REMOTE SENSING TECHNIQUES

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## Introduction

Potato, a high value crop in southern Alberta, requires large amounts of fertilizers, pesticides and irrigation water. With respect to nitrogen (N), a balance between supply and utilization is required to optimize crop growth and economic return as well as minimize environmental impact. Application of excess N results in delayed maturity, reduced tuber set and dry matter yield, and increased incidence of hollow heart. Thus, too much nitrogen leads to a reduction in net returns and potentially ground water contamination due to leaching. Conversely, too little N reduces profitability due to a reduction in yield and an increase in susceptibility to blight (Schaupmeyer 1992). Early detection of N deficiency in crops such as potatoes allows producers an opportunity to more closely match their application rates to the real time N requirements of the crop thereby optimizing returns and alleviating concerns about environmental contamination.

Potato fields are closely monitored during the growing season for the onset of nutrient deficiencies, disease and pests. With respect to nutrients, typically test areas are established in a field and 40 to 50 petioles from representative plants are collected at each sampling date for determination of primarily N but also P and K content. In Alberta in mid-July, the target range for petiole nitrate N for potatoes under irrigation is 1.0 to 2.0%; below 1.0% the plants are considered to be deficient in N. Based upon the petiole sampling, N can be applied through fertigation. This method of petiole sampling provides only limited information regarding spatial variability across the whole field and does not provide information suitable for use with variable rate equipment.

Remote sensing data offers one source of spatial information suitable for use in site-specific management systems. Digital imaging systems provide the potential to delineate management zones within a field based upon soil characteristics and the detection of crop stresses both in the short and long term (Brisco et al. 1998, Moran et al. 1997). A number of algorithms have been proposed to measure chlorophyll or N content of plants using remote sensing (Table 1). The close correlation between leaf chlorophyll and N availability suggests that chlorophyll content can be use to characterize N status and vice versa (Filella and Peñuelas 1994). The majority of the algorithms or indices are based upon reflectance in the green (530-600 nm), red (670-680 nm) or so-called ‘red-edge’ (690-710 nm) normalized to reflectance in the near-infrared (750-900 nm) range of the electromagnetic spectrum. Reflectance at wavelengths above 735 nm is relatively insensitive to chlorophyll or N levels while reflectance at 550 and 690-710 nm is most sensitive. Sensitivity to N stress at 670-680 nm is variable due to the signal being saturated and reflectance reaching a minimum at relatively low chlorophyll levels (Gitelson et al. 1999). The objective within this study was to test, using airborne remote sensing imagery, the suitability of the reported algorithms to estimate petiole-N content in potatoes and examine the spatial information regarding N status across the field.

## Materials and Methods

### Fields Sites

Two field sites were identified one near Fincastle and the other at Hays, Alberta. The producers used their normal methods for seeding, cultivation, irrigation, pest control and harvesting of the potato crop. The characteristics of the sites and fertilizer applications are given in Table 2.

### Petiole Sampling

A sampling grid was set up in each field in the fall of 1998; the grid sampling points were located with differential GPS methods. Petiole samples were collected at each grid sampling point at Fincastle on July 9, July 28 and August 13 and at Hays on July 7, July 30 and August 17, 1999. Within 5 m of each grid sampling point, 45 to 70 petioles were taken from the fourth leaf of representative plants. The tissues were analyzed to determine nitrate N and total N as well as a number of other elements (McKenzie et al. 2002). The N levels in the tissues were compared to sufficiency limits used by various Alberta and USA soils laboratories. The geographic coordinates of the grid points together with their associated petiole nitrate N values were imported into the grid-based graphics program Surfer? (Golden Software Inc, Colorado, USA). The data between the grid points were interpolated using kriging to produce a map delineating petiole nitrate N levels across each of the test fields.

### Remote sensing data

On July 28, 1999, Itres acquired digital images over the test fields. The image data were acquired over the spectral range 420-965 nm using a Compact Airborne Spectrographic Imager at 2 and 3-m resolution. The spectral bands in which data were acquired varied with the resolution from 36 to 48 respectively. The image data were radiometrically corrected and geocoded by Itres.

The data were imported into the ENVI? image analysis software package (Research Systems Inc. Colorado, USA) and converted from spectral radiance units (µW $cm^{-2}$ $sr^{-1}$ $nm^{-1}$) to surface reflectance (%) using the FLAASH (Fast Line-of-sight

Atmospheric Analysis of Spectral Hypercubes) atmospheric correction model (Anon 2001). The input parameters used in the model are shown in Table 3.

Images of the various chlorophyll/N indices outlined in Table 1 were created using the band math function in the image analysis software. The spatial patterns of the indices across the sites were visually examined and compared to those in the kriged maps derived from the ground based petiole nitrate N samples. The grid sampling points were overlaid on the imagery and the reflectance values under a 3 x 3-pixel window centered over each grid point were extracted for each band and each chlorophyll/N index. The relationship between the various chlorophyll/N indices and the petiole nitrate N values was assessed using correlation and regression analyses.

## Results & Discussion

True colour images derived from the 2-m resolution airborne imagery for both the Fincastle and Hays sites are shown in Figure 1. Both the 2 and 3-m resolution images were processed but due to the similarity in the information content only the 2-m data will be discussed. The images show differential “greeness” across the fields, particularly in the Hays field. The spatial patterns tend to correspond to soil texture, particularly in the northern end of the field at Hays and likely results from poorer growth on the coarse textured soils. Consistent with the observation that many of the proposed indices involve reflectance in similar wavebands, the spatial patterns in the images derived for the various indices were similar (Table 1). Only the images showing the spatial variability in the index $SR_{550\_850}$ derived from reflectance at 550 and 850 nm are shown (Figures 2 and 3). Visual comparison of the petiole-N maps derived in Surfer? using the grid point petiole nitrate N data and the index $SR_{550\_850}$ shows similarities in the patterns across both fields. Generally, areas of low petiole nitrate N exhibited high values for the $SR_{550\_850}$ index. Correlation analysis showed a strong relationship between most of the chlorophyll/N indices and petiole nitrate N for the Fincastle site (Table 4). The strongest relationships were evident with simple ratios involving either reflectance in the green band (550 nm) or the red-edge (700-710 nm) and the near infrared reflectance (750-850 nm). These observations can be attributed to the greater range of chlorophyll/N content to which reflectance at 550 and 700-710 nm responds. The absorption feature at 660-680 nm saturates at relatively low chlorophyll content and thus relative to 550 or 700-710 nm is insensitive to variation in chlorophyll/N.

At the Hays site, visually there were some similarities between the spatial patterns within the image of the $SR_{550\_850}$ index and the kriged map of the ground based sampling. The extent of the N deficient areas in the remote sensing image appeared less than in the kriged map. The imagery may provide a more accurate representation of the spatial variability given that each pixel in the remote sensing image represents information from an area of 2 x 2 m on the ground while the ground data is an interpolation from grid points at greater than 100 m apart. Quantitative analysis showed only a limited number of indices were significantly related to petiole nitrate N. The strength of the relationship was poor compared to that at the Fincastle site. The lack of a strong relationship may reflect uncertainty in the georeferencing of the airborne imagery and the sampling sites and the heterogeneity of the crop reflectance in the areas selected for sampling. (Deguise et al. 1998).

## Conclusions

The results of the study indicated that potato petiole nitrate N could be estimated from remote sensing imagery at one test site but not the other. At the second site, visually the spatial patterns in the remote sensing derived maps for N levels and those derived from ground based plant sampling were similar. Errors in the overlay of petiole sampling points on the remote sensing imagery may account for the lack of a significant quantitative relationship at the second site. Further studies are being conducted to determine the ability to estimate plant N content using remote sensing techniques.

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TABLE 2. PUBLISHED ALGORITHMS FOR CHLOROPHYLL/N ESTIMATION USING REMOTE SENSING DATA

| Index | Formula | Citation | CASI bands |
|---|---|---|---|
| Simple ratio | | | |
| $SR_{800\_670}$ | $(R_{800nm}/R_{670nm})$ | | 17, 25 |
| $SR_{695\_430}$ | $(R_{695nm}R_{430nm})$ | Carter 1994 | 1, 18 |
| $SR_{605\_760}$ | $(R_{605nm}/R_{760nm})$ | Carter 1994 | 12, 23 |
| $SR_{695\_760}$ | $(R_{695nm}/R_{760nm})$ | Carter 1994 | 18, 23 |
| $SR_{695\_670}$ | $(R_{695nm}/R_{670nm})$ | Carter 1994 | 17, 18 |
| $SR_{750\_705}$ | $(R_{750nm}/R_{705nm})$ | Gitelson and Merzlyak 1996,<br>Sims and Gamon 2002 | 19, 22 |
| $SR_{750\_550}$ | $(R_{750nm}/R_{550nm})$ | Gitelson and Merzlyak 1996,<br>Lichtenthaler et al. 1996 | 9, 22 |
| $SR_{667\_717}$ | $(R_{667nm}/R_{717nm})$ | Leblon et al. 2001 | 17, 20 |
| $SR_{550\_850}$ | $(R_{550nm}/R_{850nm})$ | Schepers et al. 1996 | 9, 28 |
| $SR_{710\_850}$ | $(R_{710nm}/R_{850nm})$ | Schepers et al. 1996 | 19, 28 |
| $SR_{800\_680}$ | $(R_{800nm}/R_{680nm})$ | Sims and Gamon 2002 | 17, 25 |
| $SR_{735\_700}$ | $(R_{735nm}/R_{700nm})$ | Gitelson and Merzlyak. 1999 | 19, 21 |
| Pigment specific simple ratio (PSSR) | $(R_{810nm}/R_{676nm})$ | Blackburn 1998 | 17, 26 |
| Normalized difference index | | | |
| Normalized green difference vegetation index (NGVDI) | $(R_{750nm} - R_{550nm})/(R_{750nm} + R_{550nm})$ | Gitelson et al. 1996 | 9, 22 |
| Photochemical reflectance index (PRI) | $(R_{531nm} - R_{570nm})/(R_{531nm} + R_{570nm})$ | Gamon et al. 1992 | 8, 10 |
| Pigment specific normalized difference (PSND) | $(R_{810nm} - R_{676nm})/(R_{810nm} + R_{676nm})$ | Blackburn 1998 | 17, 26 |
| Normalized difference index ($NDI_{750\_700}$) | $(R_{750nm} - R_{700nm})/(R_{750nm} + R_{700nm})$ | Gitelson and Merzlyak 1994,<br>Sims and Gamon 2002 | 19, 22 |
| Normalized difference index ($NDI_{800\_680}$) | $(R_{800nm} - R_{680nm})/(R_{800nm} + R_{680nm})$ | Sims and Gamon 2002 | 17, 25 |
| Normalized pigments chlorophyll ratio index (NPCI) | $(R_{680nm} - R_{430nm})/(R_{680nm} + R_{430nm})$ | Peñuelas et al. 1994 | 1, 17 |
| Structure-insensitive pigment index (SIPI) | $(R_{800nm} - R_{445nm})/(R_{800nm} + R_{680nm})$ | Peñuelas et al. 1995 | 2, 17, 25 |
| Others | | | |
| Modified simple ratio ($mSR_{750\_445}$) | $(R_{750nm} - R_{445nm})/(R_{705nm} - R_{445nm})$ | Sims and Gamon 2002 | 2, 19, 22 |
| Modified normalized ratio ($mNR_{750\_445}$) | $(R_{750nm} - R_{705nm})/(R_{750nm} + R_{705nm} - 2*R_{445nm})$ | Sims and Gamon 2002 | 2, 19, 22 |
| Optimized soil adjusted vegetation index (OSAVI) | $(1 + 0.16)*(R_{800nm} - R_{670nm})/(R_{800nm} + R_{670nm} + 0.16)$ | Rondeaux et al. 199 | 17, 25 |
| Modified chlorophyll absorption in reflectance index (MCARI) | $[(R_{700nm} - R_{670nm}) - (0.2*(R_{700nm} - R_{550nm}))*(R_{700nm}/R_{670nm})]$ | Daughtry et al. 2000 | 9, 17, 19 |
| Transformed chlorophyll absorption in reflectance index (TCARI) | $3*[(R_{700nm} - R_{670nm}) - (0.2*(R_{700nm} - R_{550nm}))*(R_{700nm}/R_{670nm})]$ | Haboudane et al. 2002 | 9, 17, 19 |
| Plant senescence reflectance index (PSRI) | $(R_{680nm} - R_{500nm})/(R_{750nm})$ | Merzlyak et al. 1999 | 6, 17, 22 |
| Carotenoids | $[4.145*(S_{760nm/}S_{500nm})*(R_{500nm}/R_{760nm})]-1.171$ | Chapelle et al. 1992 | 5, 23 |
| Chlorophyll b | $2.94*[((S_{675nm/}R_{650nm}*S_{700nm})*(R_{650nm}*R_{700nm}/R_{675nm}))]+0.378$ | Chapelle et al. 1992 | 15, 17, 18 |
| Chlorophyll a | $22.735[=(S_{675nm}/S700_{nm})*(R_{700nm}/R_{675nm})] - 10.407$ | Chapelle et al. 1992 | 17, 18 |

TABLE 3. SITE CHARACTERISTICS

| | Fincastle | Hays |
|---|---|---|
| Field size (ha) | 31 | 28 |
| Soil type | Chin light loam, fluvial lacustrine | Aeolian loamy sand overlying fine lacustrine till |
| # of grid sampling points | 51 | 54 |
| Type of irrigation | High pressure corner | Low pressure |
| Cultivar | Frito-Lay 1625 | Snowden |
| N Fertilizer | Fall 1998 112 kg/ha<br>At hilling 20 kg/ha<br>Fertigation 30 kg/ha | Fall 1998 157 kg/ha,<br>At hilling 41 kg/ha<br>Fertigation 50 kg/ha |
| P Fertilizer | Fall 1998 39 kg/ha<br>Spring 1999 29 kg/ha | Fall 1998 59 kg/ha<br>Spring 1999 0 kg/ha |
| K Fertilizer | Fall 1998 56 kg/ha<br>Spring 1999 0 kg/ha | Fall 1998 56 kg/ha<br>Spring 1999 0 kg/ha |
| Petiole N sampling | July 9, 28 and August 13 | July 7, 30 and August 17 |
| Seeded | April | April |
| Hilled | April | April |
| Harvested | September 15-17 | September 20, 24-25,27 |

TABLE 4. INPUT PARAMETERS FOR THE FLAASH ATMOSPHERIC CORRECTION MODEL.

| Parameter | Input |
|---|---|
| Latitude/Longitude | 49.9867N, 111.8523W |
| Sensor altitude | 2.286 km |
| Ground elevation | 0.786 km |
| Atmospheric model | Sub-Artic Summer |
| Aerosol model | Rural |
| Visibility | 40 km |

TABLE 5. RELATIONSHIP BETWEEN THE VARIOUS PROPOSED INDICES AND PETIOLENITRATE N SAMPLES

| Index | Fincastle | Hays |
|---|---|---|
| **SIMPLE RATIO** | | |
| SR$_{800\_680}$ | 0.751 | NS |
| SR$_{695\_430}$ | -0.734 | -0.356 |
| SR$_{605\_760}$ | -0.781 | NS |
| SR$_{695\_760}$ | -0.748 | NS |
| SR$_{695\_670}$ | 0.449 | -0.318 |
| SR$_{750\_705}$ | 0.820 | NS |
| SR$_{750\_550}$ | 0.821 | NS |
| SR$_{677\_717}$ | -0.639 | NS |
| SR$_{550\_850}$ | -0.832 | NS |
| SR$_{710\_850}$ | -0.832 | NS |
| SR$_{735\_700}$ | 0.821 | NS |
| PSSR | 0.764 | NS |
| NORMALIZED DIFFERENCE INDEX | | |
| **NGVDI** | 0.809 | NS |
| PRI | 0.770 | NS |
| PSND | 0.706 | NS |
| NDI$_{750\_700}$ | 0.809 | NS |
| NDI$_{750\_705}$ | 0.696 | NS |
| NDI$_{800\_680}$ | 0.707 | NS |
| SIPI | -0.660 | NS |
| **OTHER** | | |
| mSR$_{750\_705}$ | 0.821 | 0.326 |
| mNR$_{750\_705}$ | 0.813 | 0.308 |
| **OSAVI** | 0.722 | NS |
| MCARI | 0.445 | -0.298 |
| TCARI | -0.800 | -0.317 |
| PSRI | -0.597 | |
| Carotenoids | 0.746 | NS |
| Chlorophyll a | -0.448 | 0.313 |
| Chlorophyll b | -0.674 | NS |
| PSRI | -0.597 | NS |
| NPCI | -0.702 | NS |
| # OF OBSERVATIONS | N=51 | N=54 |

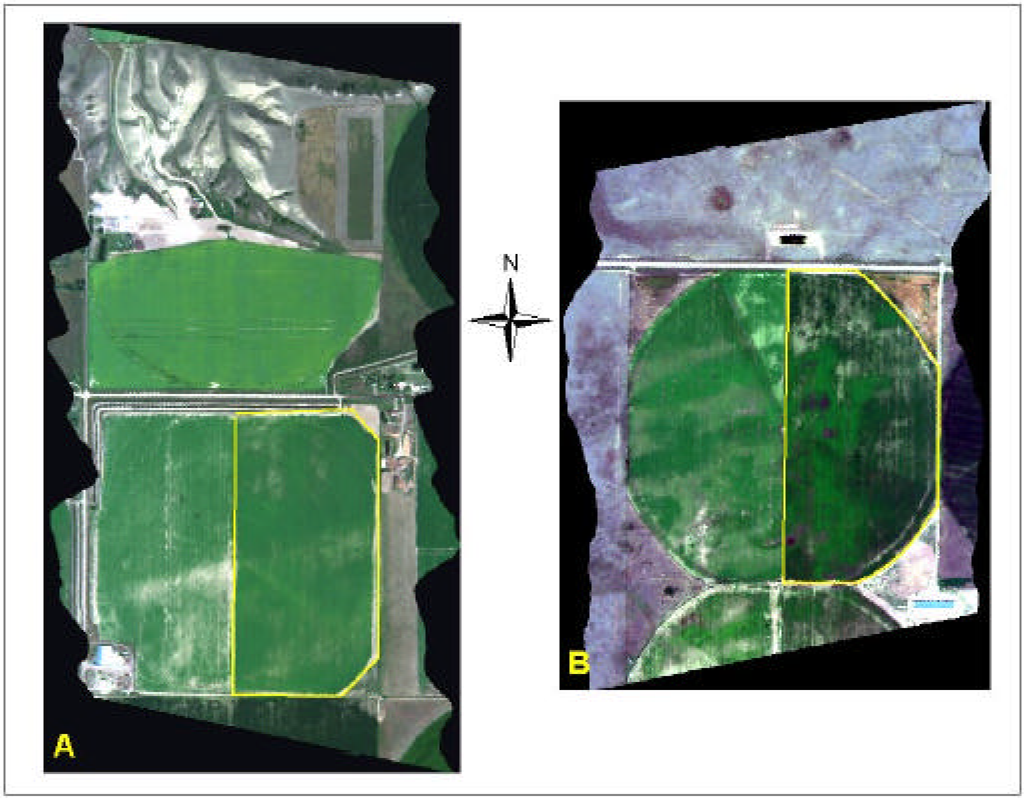

FIGURE 1. TRUE COLOUR COMPOSITE IMAGES ACQUIRED JULY 28, 1999 OF THE FINCASTLE (A) AND HAYS (B) SITES.

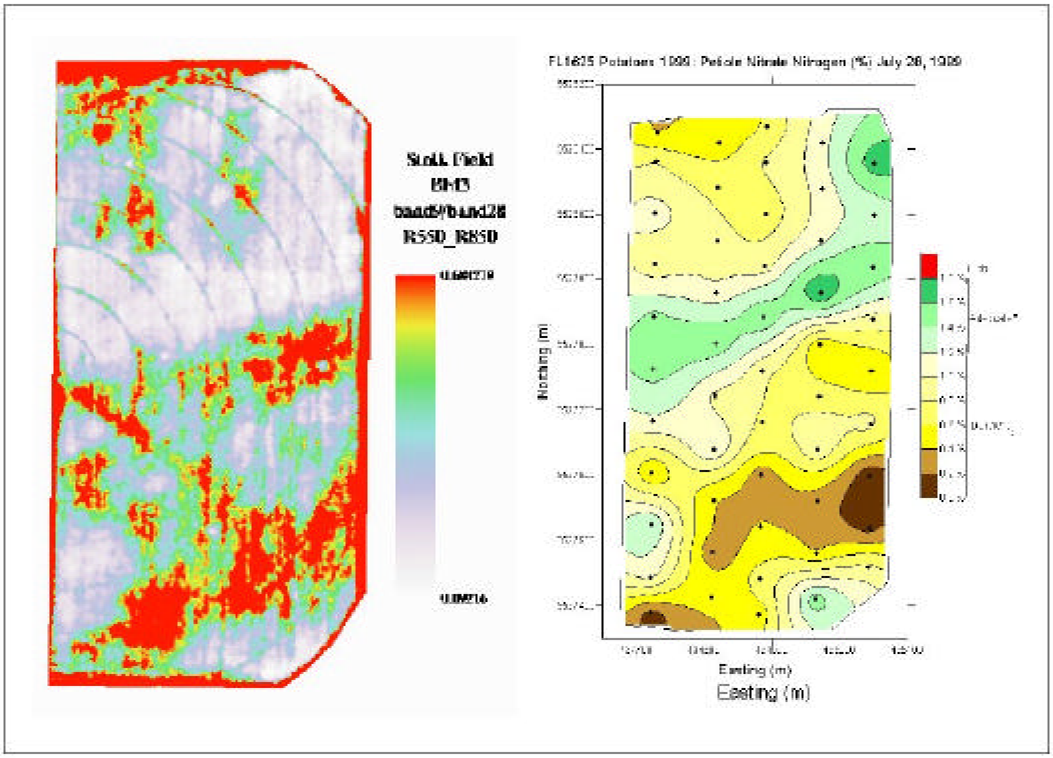

FIGURE 2. FINCASTLE SITE: $SR_{550\_850}$ INDEX IMAGE AND PETIOLE-N MAPS DERIVED FROM GROUND-BASED SAMPLING

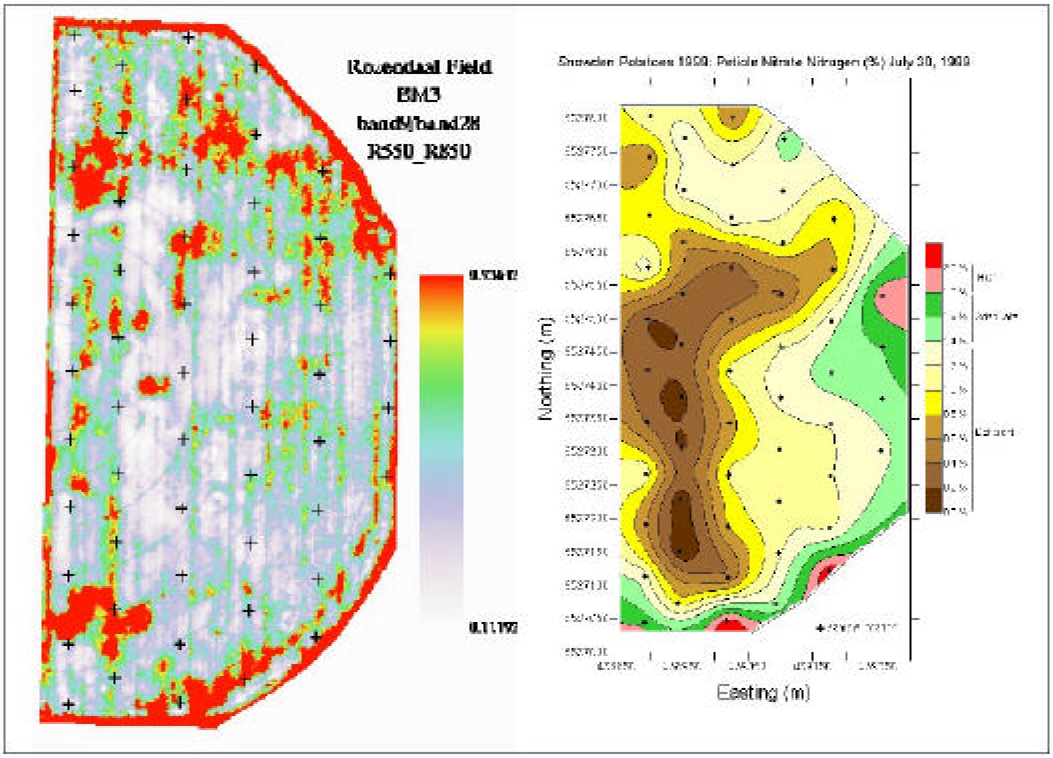

FIGURE 3 HAYS SITE: $SR_{550\_850}$ INDEX IMAGE AND PETIOLE-N MAPS DERIVED FROM GROUND-BASED SAMPLING.

## *Research Team Information*

| | | |
|---|---|---|
| **a) Research Team Leader:** | | |
| **Title:** Dr. | **First Name:** R. Colin | **Last Name:** McKenzie |

**Position:** Research Scientist, Soil and Water Agronomy *(deceased)*

**Organization/Institution:** Crop Diversification Centre South

**Department:** Alberta Agriculture, Food and Rural Development

| | | |
|---|---|---|
| **Address:** | **City:** | **Prov./State:** |

| | |
|---|---|
| **Postal Code/Zip:** | **E-mail Address:** |
| **Phone Number:** | **Fax Number:** |

**Past experience relevant to project:**

1. Determining nutrient content of feedlot manure (2001-2002).
2. The influence of compost and phosphorus fertilizer on disease in potatoes (1999-2000).
3. Response of irrigated potatoes to phosphorus fertilizer and compost (1999-2001).
4. Site specific management of irrigated potatoes (1996-1999).
5. Salinity tolerance of forage and turf grasses (1993-1995).
6. Phosphorus and potassium requirement of irrigated alfalfa (1989-1994).

| **Degrees /Certificates /Diplomas:** | **Institution Received From**: |
|---|---|
| Ph.D., The effect of subsoil acidity on root development and crop growth of several crops. | Univ. of Alberta (1970-1973) |
| MSc., The effect of coal humic acids on soil structure and as a slow release source of nitrogen. | Univ. of Alberta (1968-1970) |
| BSA in Agriculture | Univ. of Saskatchewan |

**Publications and Patents:**

| | |
|---|---|
| **# of Refereed papers:** 15 | **Conference proceedings:** 16 |
| **Relevant Patents obtained:** 0 | **Other relevant citations:** 3 Chapters in Books |

**Other evidence of productivity during past 6 years:**

- Invited speaker at International Drainage Conference in India (Feb. 2000).
- External examiner for 2 Ph.D. graduate students (2000-2002).
- Provided a course on measurement of salinity for Pakistan engineers and soil specialist (2001-2002).

**b) Research Team Members**

| ***Name*** | ***Institution*** |
|---|---|
| 1. R. C. McKenzie | CDC South, AAFRD |
| 2. C.A. Shaupmeyer | AAFRD |
| 3. M. Green | AAFRD |
| 4. T.W. Goddard | AAFRD |
| 5. D.C. Penney | AAFRD |

# *Personal Data Sheet for Research Team Members*

| | | | |
|---|---|---|---|
| **Title:** Ms | **First Name:** Shelley A. | | **Last Name:** Woods |
| **Position:** Soil and Water Research Scientist | | | |
| **Organization/Institution:** Crop Diversification Centre South | | **Department:** AAFRD | |
| **Mailing Address:** SS #4 | **City:** Brooks | **Prov:** AB | **Postal Code:** T1R 1E6 |
| **E-mail Address:** Shelley.A.Woods@gov.ab.ca | | | |
| **Phone Number:** (403)362-1352 | | **Fax Number:** (403)362-1311 | |

**Past experience relevant to project:** (Point form, concise.)

Involved as junior research scientist and senior technologist in the following relevant projects. Duties included management of field work, data organization and analysis, report writing and presentation of results.

- Phosphorus and Compost on Potatoes 2000-2001
- Precision Farming of Potatoes 1996-1999
- Precision Farming of Dry Beans and Peas 1995, 1997-1998
- Salinity Tolerance of Forage and Turf Grasses (1991-1993, 2002)
- Nutrient Requirements of Irrigated Alfalfa (1994-1997)

| **Degrees /Certificates /Diplomas:** | **Institution Received From:** |
|---|---|
| Ph.D. (Soil Physics) - <u>In Progress</u> | University of Saskatchewan |
| Master of Environmental Design (Env. Sci.) 1992 | University of Calgary |
| Bachelor of Science (Physics) 1989 | University of Alberta |

**Publications and Patents:**

| | |
|---|---|
| # of Refereed papers: 2 | Conference proceedings: >15 |
| Relevant Patents obtained: 0 | Other relevant citations: 1 Master's thesis. 1 textbook chapter, 2 magazine articles, 2 Ropin' the Web articles |

**Other evidence of productivity during past 6 years:** (Point form, concise)

- currently completing a Ph.D. in soil physics (AAFRD sponsored)
- managed the Alberta component of a national agricultural greenhouse gas emissions study
- successfully solicited Potato Growers of Alberta for substantial funding
- completed program reviews and published annual report in the absence of my supervisor
- gave seminars to a variety of college, university and industry groups
- presented papers, posters and oral reports at provincial, national and international conferences
- won second prize for student presentations at the 2002 Alberta Soil Science Workshop
- two-year recipient of the University of Saskatchewan's Soil Science tuition scholarship (2000 and 2001)

# *Personal Data Sheet for Research Team Members*

The personal information being collected is subject to the provisions of the Freedom of Information and Protection of Privacy Act.

**Title:** Mr.
**First Name:** Clive A.
**Last Name:** Schaupmeyer
**Position:** Potato Specialist *(retired)*
**Organization/Institution:**
**Department:** AAFRD
**Mailing Address:** 2207 – 16 Ave.
**City:** Coaldale
**Prov:** AB
**Postal Code:** T1M 1N7
**E-mail Address:** clives@shaw.ca
**Phone Number:** (403)345-6457
**Fax Number:** n/a

**Past experience relevant to project:**

1. Agronomic research projects aimed at improving potato plant stands, population, plant performance, quality and yields.
2. Effects of in-row spacing on yield and size distribution of potatoes (1993-1996).
3. Development of optimum management profiles for new potato varieties (1995-1998).

| **Degrees /Certificates /Diplomas:** | **Institution Received From:** |
|---|---|
| M.Sc. (Extension Education) | Univ. of Guelph (1976) |
| B.Sc. (Soils/Horticulture) | Univ. of Alberta (1968) |

**Publications and Patents:**

# of Refereed papers: 10
Relevant Patents obtained: 0
Conference proceedings: Several
Other relevant citations:

**Other evidence of productivity during past 6 years:**

# *Personal Data Sheet for Research Team Members*

The personal information being collected is subject to the provisions of the Freedom of Information and Protection of Privacy Act.

**Title:** Mr. | **First Name:** Murray | **Last Name:** Green

**Position:** Farm Machine Engineer *(retired)*

**Organization/Institution:** | **Department:** AAFRD

**Mailing Address:** | **City:** | **Prov:** | **Postal Code:**

**E-mail Address:** murray.green@shaw.ca

**Phone Number:** | **Fax Number:**

**Past experience relevant to project:**

1. Variable rate fertilizer application system to control the input of fertilizer based on prescribed requirements (1994-1996).
2. Precision farming systems to maximize profits and miniize environmental impacts (1993-1996).
3. Site-specific management of potatoes (1996-1999).
4. Yield mapping of irrigated edible beans (1997-1998).

| **Degrees /Certificates /Diplomas:** | **Institution Received From:** |
|---|---|
| B.Sc.Eng. (Agricultural Engineering) | Univ. of Saskatchewan (1967) |

**Publications and Patents:**

| | |
|---|---|
| # of Refereed papers:<br>Relevant Patents obtained: 0 | Conference proceedings:<br>Other relevant citations: |

**Other evidence of productivity during past 6 years:**

# *Personal Data Sheet for Research Team Members*

The personal information being collected is subject to the provisions of the Freedom of Information and Protection of Privacy Act.

**Title:** Mr.
**First Name:** Thomas W.
**Last Name:** Goddard
**Position:** Soil Conservation Specialist
**Organization/Institution:** AAFRD
**Department:** Conservation & Development
**Mailing Address:** 7000-113 St.
**City:** Edmonton
**Prov:** AB
**Postal Code:** T6H 5T6
**E-mail Address:** Tom.Goddard@gov.ab.ca
**Phone Number:** (780) 427-3720
**Fax Number:** (780) 422-0474

**Past experience relevant to project:**

1. Development and evaluation of precision farming technologies for canola production and research (1996-1999).
2. Landscape analysis for precision farming and model applications (1996-1999).
3. Geographic management of agronomic practice. (1995-96)
4. Precision farming to optimize yields and minimize environmental impact (1993-1997).

| **Degrees /Certificates /Diplomas:** | **Institution Received From:** |
|---|---|
| M.Sc. (Soil Science) | Univ. of Alberta (1988) |
| B. Sc. (Agriculture) | Univ. of Alberta (1979) |

**Publications and Patents:**

| | |
|---|---|
| # of Refereed papers: 8 | Conference proceedings: 45 |
| Relevant Patents obtained: 0 | Other relevant citations: 4 |

**Other evidence of productivity during past 6 years:**

1. Development of Scientifically Defensible Estimates of $N_2O$ Emissions from Agricultural Ecosystems in Canada (CCAF, 00-03), Grant, Juma, Goddard, Kryzanowski, Zhang Solberg, Pattey.
2. Assessing the Nitrous Oxide Tradeoffs to Carbon Sequestering Management Practices (CCAF, 00-01) Lemke, Desjardins, Keng, Kharabata, Smith, Goddard, Ellert, Monreal, Drury, Rochette, Pattey.
3. Landscape dynamics and crop-soil model verification. (ARI, AESA, 99-01) Kryzanowski, Grant, Goddard.
4. Impacts of Cropping Systems to Climate Change and Adaptation Strategies for Agriculture in the Prairie Regions. (PARC, 00-01) Manunta, Goddard, Cannon.
5. Phosphorus mobility in soil landscapes: a site-specific approach. (CABIF, 99-02). Li, Chang, Amrani, Goddard, Heaney, Olson, Zhang, Feng.
6. Soil landscape management study crop yields. (MII, 01) Nolan, Lohstraeter, Coen, Brierley, Pettapiece, Goddard
7. Carbon sequestration and greenhouse gas flux in selected Alberta catenas containing wetlands (IWWR 02-07) Goddard/Fuller, Kryzanowski, Brierley, Zhang.
8. Emissions of $N_2O$ from Cereal-Pea and Cereal-Lentil rotations in western Canada (NRCan 01-02). Lemke, Goddard, Selles.
9. Soil Variability for Agronomic and Environmental Crop Production - SVAECP (boardmember)
10. Advisory committee member – Land Information Systems program, Olds College
11. Invited committee member – Managed Ecosystems program development, Canadian Institute of Advanced Research (CIAR).

# *Personal Data Sheet for Research Team Members*

The personal information being collected is subject to the provisions of the Freedom of Information and Protection of Privacy Act.

| | | | |
|---|---|---|---|
| **Title:** Mr. | **First Name:** Douglas C. | **Last Name:** Penney | |
| **Position:** Head, Soil Fertility and Agronomy Section *(retired)* | | | |
| **Organization/Institution:** | | **Department:** AAFRD | |
| **Mailing Address:** | **City:** | **Prov:** | **Postal Code:** |
| **E-mail Address:** dpenney@mail.telusvelocity.net | | | |
| **Phone Number:** | **Fax Number:** | | |

**Past experience relevant to project:**

1. Precision farming technologies for canola production and research (1996).
2. Precision farming systems to maximize profits and minimize environmental impacts (1996).
3. Precision farming management systems for potatoes (1995).
4. Optimal seedplaced fertilizer for airseeded crops (1994).

| **Degrees /Certificates /Diplomas:** | **Institution Received From:** |
|---|---|
| M.Sc. (Soil Fertility) | Univ. of Alberta (1973) |
| B.Sc. (Soil Science) | Univ. of Alberta (1962) |

**Publications and Patents:**

| | |
|---|---|
| # of Refereed papers: | Conference proceedings: |
| Relevant Patents obtained: 0 | Other relevant citations: |

**Other evidence of productivity during past 6 years:**