AB-14

Site Specific Management of Potatoes

R.C. McKenzie[1] and S.A. Woods[1]

Acknowledgements

In 1996 a precision agriculture project with potatoes was commenced and operated by an AAFRD team which included M. Eliason, T. Goddard, M. Green, L. Hingley, R. Holm, D. MacKay, J. Panford, J. Payne, D. Penney, J. Rodvang and C. Schaupmeyer.

The project received support from The Alberta Agriculture Research Institute, Potato Development Inc., Agrium, Cargill Ltd., Potash and Phosphate Institute of Canada, Southern Agri Services, Westco. DynAgra. Old Dutch and Alberta Agriculture Food and Rural Development. Laboratory analysis was provided by the AAFRD Soil and Crop Diagnostic Laboratory, Edmonton.

Background

The use of Global Positioning System (GPS) technology has made it possible since 1991 to develop detailed yield maps of various fields. This technology has drawn interest from farmers in the USA as a method to increase profits by optimizing fertilizer applications. In Western Europe it has been used as a method to avoid environmental contamination from excess use of fertilizers. Other computer technology, such as Geographic Information Systems (GIS), makes it possible to overlay on maps field conditions and production data.

Potatoes are a high value crop requiring high inputs. Excess nitrogen will delay maturity, reduce storage quality, contribute to ground water contamination and increase the cost of production, while insufficient nitrogen will reduce yield and will increase the severity of early blight. Potatoes are often grown on coarse textured soils, which have a low nutrient holding capacity and high field variability. Traditional research under small plot conditions can not describe this field variability and current management systems do not account for it. Field variability will become more important as the acreage of potatoes and the size of potato farms increase.

An Alberta team commenced site specific research projects in 1993. Crop specialists, cooperating with farmers, started site specific management projects in several areas of Alberta in 1995. Fields were subdivided based on interpretation of aerial photographs. These subdivided units were sampled separately to determine fertilizer requirements. Global positioning technology used on harvesters, fertilizer spreaders and weed sprayers make it possible to very accurately manage relationships. Site specific management can serve both as a research tool to improve current recommendations and as

[1]AAFRD, Crop Diversification Centre South, Brooks, AB T1R 1E6

a management tool to increase the efficiency of inputs. It will be most useful on high value crops which have large inputs of chemicals, fertilizers and labour. The costs for an experimental project like this are high because of the detailed collection and analysis of the data. In the USA, however, commercial operators are now providing GPS equipment and preparing yield maps of cereals for about $8 to $10 (US) per acre. Interpretation of yield maps is the aspect which requires the most development and the collection of data to provide this interpretation is the expensive part of the operation

Objectives (Key Results Expected)

- 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 production;
- 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.
- To develop a relationship between soil and crop characteristics and processing quality of potatoes;
- To measure the movement of nutrients below the root zone.

Progress To Date

Two potato fields were monitored during each of 1996 and 1997. Each was about 27 ha and was half of a centre pivot irrigation system. One field 11 km south of Hays had hummocky topography and a soil texture which varied from sand to clay loam. The clay content in the 0-0.60 m depth varied from 5% to 50%. Monitoring of Snowden potatoes, a determinate growth medium-late cultivar used for chipping, was done on the east half of the Hays field in 1996 and the west half in 1997. Russet Burbank, a late cultivar with indeterminate growth which is used for french fries and fresh market, was grown 8 km north of Fincastle, was a gently sloping field with a texture varying from loamy sand to silt loam and a clay content from 5% to 25% for the 0-0.60 m depth. The 1997 Fincastle field was about 5 km SW of the site which was used in 1996.

A grid was set out with GPS in October, 1996, to provide locations for detailed sampling in 1997. This grid consisted of 47 sites at the Snowden field and 53 sites at the Russet Burbank field. In October 1996, composite soil samples of 0-0.15 m, 0.15-0.30 m, 0.30-0.60 m and 0.60-0.90 m were taken at each grid location. Nitrogen (N), phosphorus (P), potassium (K), pH, electrical conductivity (EC) and particle size were determined on soil samples. In June. 1997. neutron access tubes and a rain gauge were installed at each grid location. Soil moisture and irrigation plus precipitation readings were taken weekly from June 23 until harvest. During the summer of 1997, composite petiole tissue samples were collected 3 times at each grid location. Nitrate-N, total N, P and K were determined on tissue samples. Fertilizer rates and additional fertilizer application by fertigation were set by the farmer and each farmer had his own soil and plant tissue testing program.

A yield monitor was used on two potato combines and yields were recorded and positioned with differential GPS using *Omnistar*™ (a commercial satellite which provides a service as a base station). Yields were successfully recorded on most of both fields. There were small blanks in the data due to errors in positioning with *Omnistar*™. Samples of tubers were dug by hand at each of the grid locations on both fields and yield, size and quality measurements were made on these samples.

Data was processed into isobar maps using *Surfer* software package and a kridging option. Maps of soil texture, topography, soil N, P, K nutrient levels, petiole N, P, K nutrient levels, soil moisture, irrigation plus precipitation, consumptive use, tuber yield, tuber specific gravity, small tuber yield, mean tuber weight and tuber chipping or french fry scores were prepared.

Also in 1997, yield maps were made on a 27 ha wheat field near Hays and a 28 ha barley field near Fincastle. These fields are to be used for potatoes in 1998 and the yield will be monitored. In the 1997 Hays field there was a wide range in wheat yield from below 3 t/ha to above 9 t/ha. In 1998, this yield map will be used to determine if the potato yields are closely correlated to wheat yield. In the 1997 Fincastle field, barley yield ranged from below 5 t/ha to above 7 t/ha.

Nitrogen

The total soil (0-0.60) m plus fertilizer nitrogen on the Snowden field was 227 lbs/ac (254 kg/ha) (Table 1). The Russet Burbank field with a slightly higher soil plus fertilizer N was 257 lbs/ac (288 kg/ha). Potato petiole N on the Snowden field in 1997 was marginally adequate to deficient on July 3. By July 23, all potatoes in the field were deficient with most potatoes showing less than half of the minimal level of 1.2% N. By August 12, tissue N levels had dropped further and the potatoes were severely deficient. This occurred despite the farmer adding a series of 6 nitrogen applications (28-0-0) through the irrigation system to provide 79 lbs/ac (89 kg/ha) of N. Petiole N was not as severely deficient in the Russet Burbank field as in the Snowden field. On August 13, 33% of the Russet Burbank tissue samples tested adequate and 67% were deficient in petiole N (Table 2).

Table 1. 1997 Soil fertility on site specific potato fields.

		Snowden	Russet Burbank
Soil N lbs/ac 0-0.60 cm	Oct./96	33	60 (46)
Fertilizer N lbs/ac	Fall/96	80	0
At hilling spring lbs/ac	Spring/97	35	160
6 fertigations of N (lbs/ac)	July 7-Aug.13/97	79	37
Soil P lbs/ac (0-0.15 cm)	Oct./96	21	175
(0-0.30 cm)		-	284 (363)
Fertilizer P_2O_5 lbs/ac	Fall/96	120	0
Fertilizer P_2O_5 lbs/ac	Spring/97	0	15
6 fertigations P_2O_5 lbs/ac	July 7-Aug.13/97	45.5	0
Soil K lbs/ac (0-0.30 m)	Oct./96	612	952 (1728)
Fertilizer K_2O lbs/ac	Fall/96	60	0
Fertilizer K_20 lbs/ac	Spring/97	0	50

Farmers soil test value ( )

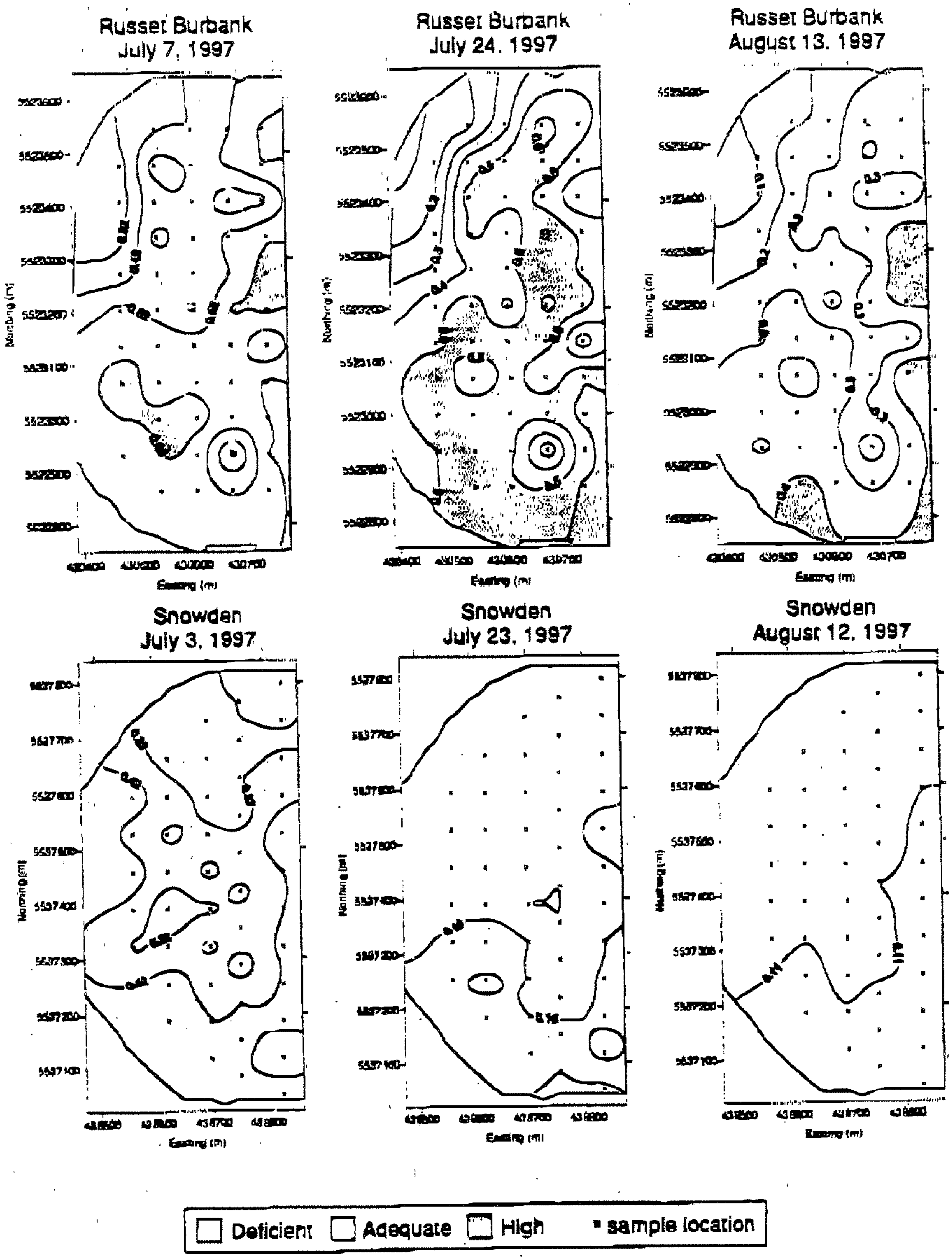
Table 2. Petiole Analysis in 1997 from Site Specific Potatoes

	NO_3-N %			P %			K%		
	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
Standards for adequate level of nutrient	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
Snowden (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
Russet Burbank (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

Phosphorus

Petiole P (Figure 1) was adequate for both fields on the first sampling. It declined rapidly on the Snowden field and by July 23 most of the petiole samples were below 0.15% compared to a

Figure 1. 1997 Petiole Phosphate Phosphorus (%)



minimum recommended level of 0.2% (Table 2). The farmer had applied 120 lbs/ac P_2O_5 fertilizer plus another 45 lbs/ac through fertigation (Table 1). Either the crop lost its ability to absorb P from the soil through disease or the fertilizer P did not remain in an available form to the crop. The soil pH was between 7.0 and 8.0. The calcium (Ca) content of the soil was determined to be 0- 1%, therefore Ca was not responsible for fixation of P. The Russet Burbank field had high soil P because of 8-10 tons/acre of manure applied in 1995. Tissue P on this potato crop remained adequate throughout the season.

Potassium

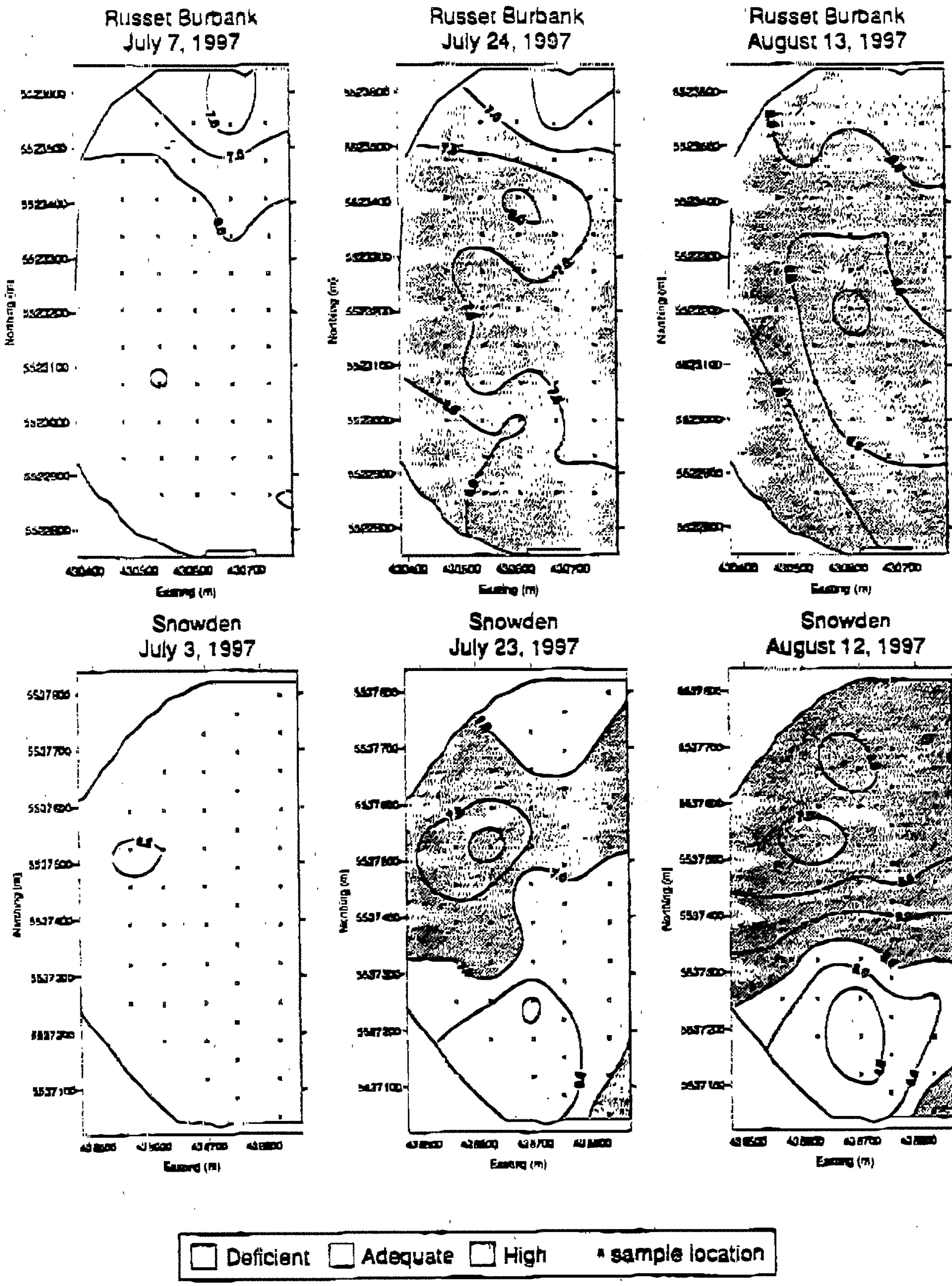
The Snowden field had marginal levels of soil K (75-150 ppm) on 66% of the sample sites. The Russet Burbank field had adequate levels of soil K (>150 ppm) at all sample sites. Both fields had deficient levels of petiole K (<7%) in the first week of July (Figure 2). By the fourth week of July, petiole K had increased by about 0.6% at the Snowden field and by about 1.2% at the Russet Burbank field. This may be a result of lower than normal temperatures prior to the time of the first sampling. From June 28 to July 1, the average maximum daily temperature at Brooks was about 14°C in 1997, compared to a 30-year average of 22°C for that period. Uptake of K is reduced by low soil temperatures. Standards for adequate and deficient petiole K are not well established for potatoes. These standards may also need to be adjusted for crops growing under cold conditions.

Irrigation and Precipitation

In 1996, water application on the Snowden field was not uniform. The high pressure circular pivot was operated at below optimum pressure which resulted in more water at the center and less at the outside of the field. The farmer had this irrigation system redesigned and converted to a low pressure pivot. Irrigation applications were more uniform but irrigation and rainfall on the outer portions of the pivot were about 40 mm (or 10%) more than the center portions of the pivot. The Russet Burbank potato fields in 1996 and 1997 were irrigated by two different corner pivots. The Russet Burbank field in 1997 showed uneven water applications on the main portion of the field with applications from 360 to 500 mm. The edges of this corner pivot system also received less water than the main part of the field.

The uneven water applications by the pivot influenced the size of tubers, with the wetter areas producing a greater number of small tubers than the dryer areas. The Snowden field had lower mean tuber weights on the outer portion of the field than near the center of the pivot. The Russet Burbank field had lower mean tuber weights on the center part of the field than on the outside and the corners.

Figure 2. 1997 Petiole Potassium (%)



Nitrogen Fertilizer Rates

A series of strips of different rates of N fertilizer were applied in April, 1997 on both potato fields. Each strip was 8 rows wide or 6.9 metres on the Snowden field and 7.3 metres at the Russet field. The strips were each about 800 m long and were repeated twice on each field. The treatments (Table 3) consisted of ammonium phosphate at the farmer's rate plus 3 different rates of urea. N_1 provided nitrogen below the farmer's rate. N_2 equals the farmer's rate and N_3 exceeded the farmer's rate. These strips also received the same fertilizer by fertigation as the rest of the field (Table 1).

Table 3. Nutrients lbs/ac applied on fertilizer strips

	Snowden			Russet Burbank		
Treatment	N	P_2O_5	K_2O	N	P_2O_5	K_2O
N1	27	120	60	47	12	50
N2	82	120	60	157	12	50
N3	162	120	60	277	12	50

Table 4. Potato yields in tons/acre (tonnes/ha) on fertilizer strips.

	Snowden		Russet Burbank	
Treatment	Yield	◊ Gross value	Yield	◊ Gross value
N_1	17.5 (39.2)	$1680	17.6 (39.4)	$1690
N_2	18.9 (42.5)	$1814	19.0 (42.7)	$1824
N_3	19.5 (43.6)	$1872	18.7 (42.0)	$1795

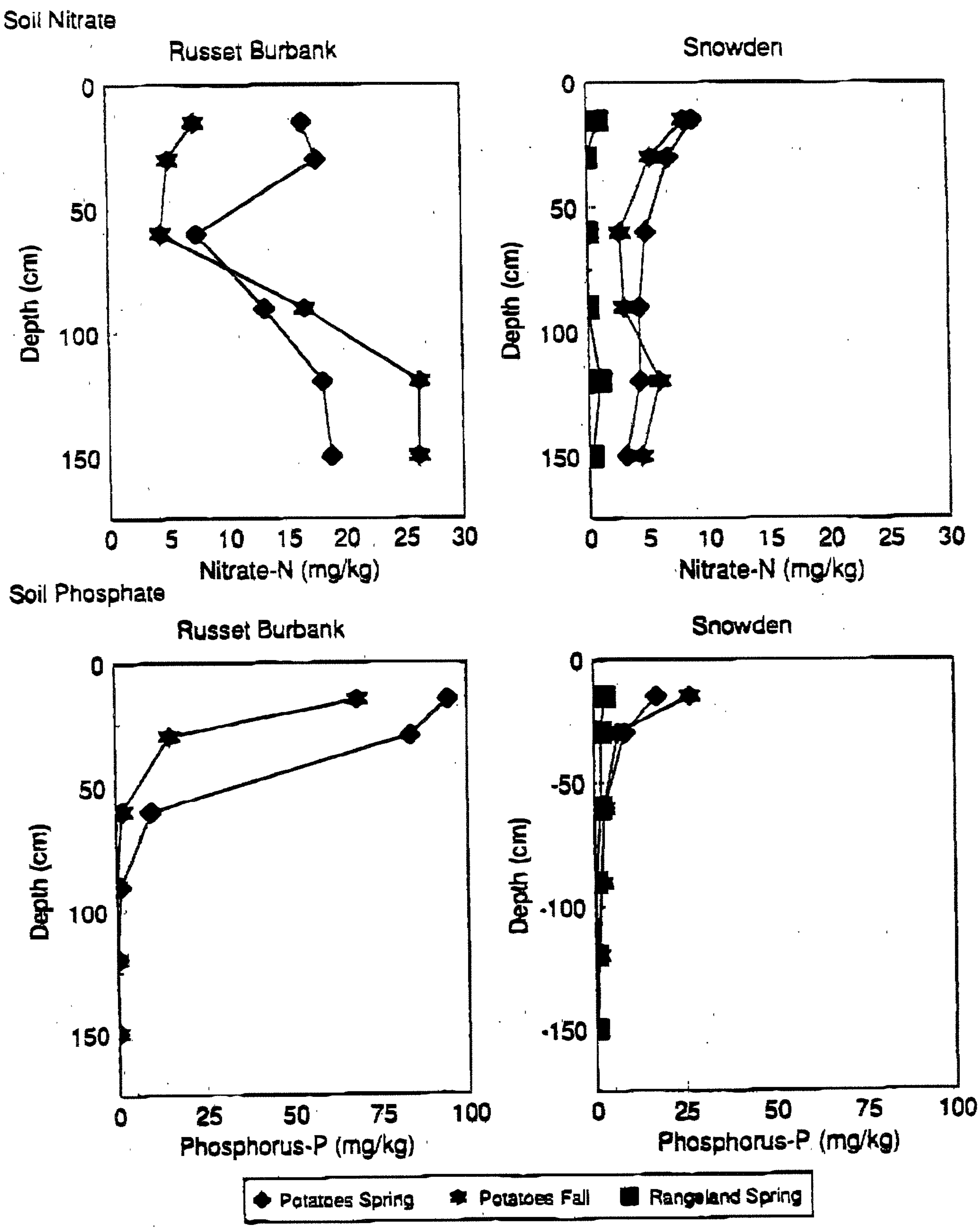
◊Value is based on 80% marketable at $120/ton

The treatments were harvested with the farmer's potato harvester and yields were measured with the yield monitor. The N_3 treatment on the Snowden field gave the highest yield. The extra value of the crop on the N_3 treatment over that of the N_2 treatments was $58/acre while the cost of the additional fertilizer was $24/acre. This increase in yield and value does not account for changes in quality such as a low specific gravity which may occur on the high nitrogen treatment. The N_2 treatment or the farmer's rate showed the highest yield on the Russet Burbank field. This field was showing losses in nitrogen below the root zone at the N_2 rate.

Nutrient Accumulation and Movement

Soil N (Figure 3) was low at the Snowden site and there was no N present in the shallow groundwater at several of the sampling sites in 1997. The odour of H_2S was also noted when

Figure 3. 1997 Soil Nutrient Levels at Groundwater Well Sites



collecting water samples at this site. H_2S is produced under anaerobic conditions after all N has been reduced to N_2 or N_2O. Reduction takes place under saturated conditions when organic matter is present in the groundwater. Loss of N by reduction to N_2 is desirable since groundwater is not contaminated by N but loss of N to nitrous oxide (N_2O) is a cause of global warming. A sample taken on adjacent rangeland to the Snowden site showed almost no nitrogen to 1.5 m. Soil N (Figure 3) increased from spring to fall at the Russet Burbank site by about 8 ppm at the 1.25 and 1.50 m depths. This indicates a substantial movement of N below the root zone which can lead to contamination of groundwater.

Soil P for Snowden slightly increased at the surface during the season. This was because the farmer applied 45 lbs/ac of phosphate through the irrigation system during the growing season. The amount of soil P on the adjacent rangeland on the Snowden site was very low. Soil P (Figure 3) was high in the spring at the Russet Burbank site and declined during the season. The large reduction may indicate errors in sampling. The high initial levels of P at this site are due to the field having received manure.

Conclusions

Total N for the crop from soil reserves and fertilizer applications were high yet both fields showed deficiencies in petiole N. Further applications of N fertilizer will cause increased losses of N to groundwater. Improvement in the efficiency of uptake of N may be obtained by the use of slow release N fertilizers. Strip trials of N fertilizer indicated one farmer's rate was appropriate for maximum yield and the other's was slightly low.

Soil P and petiole P were adequate on the field which had received manure. The other field had low levels of petiole P on and after July 23 despite large amounts of phosphorus being added as fertilizer. This may indicate the fertilizer phosphorus was no longer available or that disease restricted phosphorus uptake.

Petiole K was low on the first sampling and later became adequate or high. Low temperatures may be the cause of low tissue K in early July.

Irrigation applications were found to be uneven on both sites. The amount of water influenced the size of tubers with more and smaller tubers being found in portions of the fields which received higher than normal amounts of water.