PLANT ANALYSIS: A TOOL TO MANAGE POTATO FERTILITY

Soil testing has become a valuable tool in managing potato fertility, taking much of the guess work out of making fertilizer recommendations. Chemical soil test results are used to predict the ability of a soil to supply a given nutrient to a crop during a growing season. Like any other prediction, soil tests have shortcomings. Soil tests do not actually determine how well a potato plant uses the nutrients supplied by either the soil or by fertilizer. Crop growth patterns, weather, or other factors may affect the final seasonal nutrient uptake.

Plant tissue analysis holds great promise for checking nutrient uptake during the growing season, but results must be interpreted carefully to obtain meaningful information.

There are two basic philosophies used when interpreting plant tissue analysis results, the "diagnostic" approach and the "monitoring" approach. Although potato producers can use both interpretation approaches to manage potato fertility, each approach has different applications, uses, and limitations. Most of this discussion focuses on using plant analysis for nitrogen.

How potatoes utilize soil nitrogen

Potato plants obtain nitrogen from the soil via the root system. Plants do not distinguish between nitrogen sources, and take up nitrogen whether from soil organic matter, fertilizer, or manure.

The nitrate form of nitrogen (NO3-N) is soluble and moves readily with water, so seems to be the form most readily taken up by the potato plant. Routine soil analysis measures the quantity of residual nitrate present in the soil between successive crops. Results are used to develop fertilizer nitrogen recommendations.

Soil nitrates are taken up by potato plants as roots take up soil water. Once in the root system, nitrates are translocated through the xylem tissue (or "water tubes") into the leaf tissue. Nitrogen is converted in the leaf from the nitrate form into other soluble nitrogen compounds, like organic proteins and protein-like compounds.

Some of these soluble nitrogen compounds remain in the leaf, but most are eventually translocated into other parts of the potato plant. These compounds help produce vegetative tissue (leaves and stems) and reproductive tissue (blossoms, tubers, etc.).

Plant analysis interpretations (diagnostic or monitoring) depend on which form of nitrogen is analyzed, which plant part is sampled, and during which growth the samples are collected.

The diagnostic approach

When most persons hear the term "plant tissue analysis", they commonly think of what we call the "diagnostic approach". Normal diagnostic sampling procedures for potatoes suggest collecting the entire leaf (third to sixth leaf from the growing tip), before or during early bloom.

"Diagnostic" leaf samples are analyzed for *total* nitrogen (and other nutrients) and the results compared to a set of "norms" or "critical levels". This helps identify if the tissue level of a particular nutrient is "adequate", "deficient", or "excessive". Diagnostic analysis also gives clues about how well the plant had *previously* taken up nitrogen and other nutrients from the soil, then converted them to plant tissue nutrients.

Some agronomists suggest that plant tissue analysis should replace soil analysis. Soil analysis

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indicates how readily soil nutrients are available to a plant root system, but *not* whether those nutrients have been taken up by the plant. Tissue analysis indicates actual nutrient uptake and utilization by the plant.

Ideally, diagnostic analysis could identify a potential or actual nutrient deficiency and be used to develop a corrective fertilizer program "on the grow", during the season. Plant analysis by itself cannot be used to make fertilizer recommendations because of uncertainties involved when interpreting lab results.

Deficiencies are not always "deficiencies"

Low levels of plant tissue nutrients are not necessarily "true" nutrient deficiencies. Plant tissue analysis may show nutrient deficient tissue, even though a soil test from the same area shows nutrient levels adequate for growth.

In such cases, nutrients are available to roots, but the crop simply is not taking up, or is not able to take up, these nutrients. Adding more fertilizer is not the answer. The soil test results are evidence that nutrient availability is not the problem, so we must look for other causes of restricted nutrient uptake.

Anything interfering with root health will also affect nutrient uptake. An important step when diagnosing a nutrient deficiency is looking for a root restriction or poor tuber growth. Some common rooting problems are: soil compaction, root or plant diseases, poor soil drainage, cold temperatures, drought stress, or chemical damage.

"Dig a hole" is good advice for troubleshooting nutrient deficiencies in the field. Digging a one to two foot deep trench that is perpendicular to the row often uncovers hidden problems. Check for unhealthy roots, abnormal tuber development, or restricting soil layers. If any of these three symptoms are present, correcting these problems can improve nutrient uptake.

Relying on critical levels

"Critical levels" are the boundaries or benchmarks used to determine if a plant tissue sample has a nutrient deficiency. Published critical levels are average values that have been compiled from a large amount of research and observation over a relatively large area (often an entire state or nation). Like any other average number, there is potential for wide variation.

Data used to develop critical levels can include a wide range of climates, soils, varieties, planting and management practices. Critical levels are often developed from a very limited data base, especially the critical levels for minor nutrients, like magnesium (Mg) and boron (B).

Critical levels can be used as starting points and guidelines for making interpretations, but they are not absolute values. We find that "comparison sampling" is the best approach for diagnostic work.

Collecting two sets of plant and soil samples is necessary for comparison sampling, one sample each from the "good" and "bad" areas. Whenever possible, the two sets of samples should be collected at the same time, from areas with the same variety, same irrigation management, etc.

Comparison sampling gives us more information about the field and allows better diagnosis of problems. It compares results from one particular set of plants to one specific set of localized conditions, rather than comparing to a "national average". Differences between comparative tissue results are assumed to be due to plant nutrient uptake and not to location differences.

"Bad" better than "good"

A common surprise when comparing lab results is that the yellow, stunted, "bad" plants have higher tissue nutrient concentrations than green, actively growing, "good" plants.

Normal, healthy, actively growing plants will grow to the limit of the available water, the nutrient supply, and to their own genetic potential. In doing so, they produce relatively large amounts of vegetative growth that "dilutes out" nutrients that have accumulated in the tissue. Tissue nutrient levels decline as plants progress to later growth stage.

Stunted plants also take up nutrients from the soil, but they tend to concentrate nutrients in a smaller amount of top growth. Slower growing plants may also be less developed or "younger" than vigorous plants in the same field. Slower growing plants often have higher tissue concentrations simply due to physiological age, even if they were planted at the same time as healthy plants.

Table 1. Growth and nitrogen uptake of winter wheat at two phosphorus levels.

Phosphorus level	High	Low
Soil test	25 ppm P	6 ppm P
Dry matter	4840 lb/ac	2130 lb/ac
Nitrogen uptake	91.0 lb/ac	45.6 lb/ac
Tissue nitrogen, % N	1.88 %	2.14 %

(after Granade, et. al., 1989)

This "bad-is-good" effect is demonstrated in Table 1, which compares growth, uptake, and tissue nitrogen levels for wheat grown in phosphorus research plots.

Plants growing in high phosphorus plots produced more than twice as much vegetative growth and took up almost twice as much soil nitrogen as plants in the low testing plots. The tissue nitrogen levels were 0.26% *lower* in the *high* phosphorus plots because of this dilution effect.

If interpretations are made by relying on plant analysis results alone, the logical assumption is that the "high" plots were closer to nitrogen deficiency than the "low" plots. A nitrogen application might be recommended in this case by relying on plant analysis alone. The extra nitrogen would not improve yields and would be an unnecessary expense.

Making interpretations using plant tissue levels alone, without additional information about the soil, crop, and weather conditions, can lead to erroneous fertilizer recommendations. Overapplication or unnecessary applications are more serious with nutrients with relatively low soil tolerances, like boron or copper. Nutrients like these have potential to cause plant toxicities at excessive soil levels.

Time of sampling

Diagnostic samples may be taken too late to correct problems in the current growing season. Leaf samples are often part of a trouble-shooting program used to identify the cause of poorly growing crops, especially those suspected of having nutrient deficiencies.

When deficiency symptoms become obvious in the field, plant metabolism and growth have frequently been affected severely enough that some yield loss has already occurred. For example, plants must differ by 6 to 12 inches in height before the difference becomes noticeable from a distance.

The diagnostic plant analysis report often becomes a "post-mortem" or "funeral report", telling us what happened, but not necessarily what to do. At the point where deficiencies or poor growth become visible, it is frequently too late to immediately correct the problem.

Mid-season to late season applications of most nutrients and micronutrients seldom benefit the crop until the following year. These nutrients must be moved into the root zone before they are available for uptake.

Information from "postmortem"diagnostic samples still has value because it can confirm that a deficiency existed. Results can be used to plan next season's fertilizer program and correct problems.

The monitoring approach

If the diagnostic approach is equivalent to a "post mortem", then the monitoring approach is comparable to an "annual check-up".

The diagnostic approach is usually a one-time sample to identify the cause of a growth problem. Tissue (generally the entire leaf) is analyzed for the *total* content of the nutrient(s) in question.

The monitoring approach differs because samples are taken routinely during the season and used to evaluate the rate at which a plant is taking up a particular nutrient. Potatoes are monitored by collecting the petiole of the last, fully expanded leaf, usually the fourth leaf from the top.

The petiole tissue used for monitoring purposes is analyzed for content of *soluble* nutrients, like nitrate and phosphate, not for *total* nutrient content as are diagnostic samples.

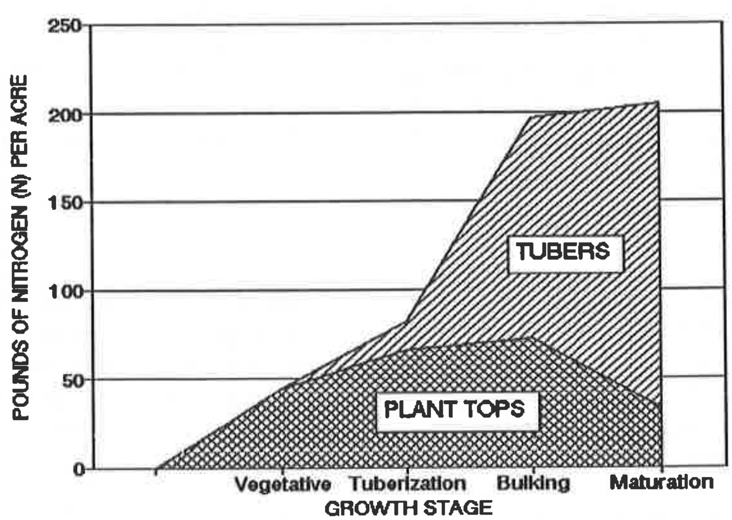
Monitoring nitrogen uptake using petiole nitrates

Leaf tissue nitrogen is found mainly as organic forms, having been converted from the nitrate form. Producers really need to know in short term, for the current crop, how well a potato plant *is* using nitrogen, not how well it *has* used nitrogen. Nitrate concentrations are more suited for monitoring than are total nitrogen levels.

Petiole nitrates are an indicator of the rate at which potatoes are taking up nitrogen from the soil, rather than total uptake. Sampling the potato petiole is like snipping off a short piece of the nutrient pipeline. Petiole nitrate concentrations are similar to the flowmeter scale on a pipeline. Petiole nitrates indicate the rate of soluble nitrate and water movement through the potato plant. High levels correspond to a relatively rapid flow, low levels to a low flow.

Petiole nitrates can tell us something about how the potato plant utilizes nitrogen through the growing season. A typical potato crop takes up an average of two pounds of nitrogen per acre per day during growing season. The amount and rate of

Figure 1. Cumulative nitrogen uptake at various growth stages, Russet Burbank potatoes (after Ojala, et. al., 1990).



uptake differs depending on growth stage (see Figure 1).

Potatoes take up nitrogen at a relatively moderate rate during early growth, from emergence to the vegetative stage. About 15% to 20% of the total seasonal nitrogen requirement is taken up during this period. It is used mainly for vegetative growth.

Nitrogen uptake is very rapid during tuberization and bulking. These are critical stages during which the crop utilizes about 65% to 75% of the total seasonal nitrogen requirement. Although total nitrogen uptake is rapid, the plant accumulates little in the top growth. Most of the nitrogen is used to produce tubers.

As the plant matures, the nitrogen uptake rate slows rapidly, as the crop uses the remaining 5% to 10% of the seasonal total. Nitrogen accumulations in the vegetation actually drops as the plant translocates nitrogen from tops to tubers.

If the amount and uptake rate of soil nitrogen is "optimum", total yield and quality are good. If the amount or rate taken up is too low, the potato crop may not have enough nitrogen to produce adequate top or tuber growth, so total yield or quality can suffer.

If nitrogen uptake is too rapid or if it goes on for too long, potatoes tend to remain in vegetative growth and mature slowly. This can result in poor quality or grade.

A potato grower can see trends in growth rate or nitrogen uptake rate by monitoring petiole nitrate levels through growing season. If a problem develops, petiole nitrates can give the producer some advance warning, allowing time to correct it before it seriously affects potato yield or quality.

Using petiole nitrate values

The heavy line in Figure 2 illustrates an average petiole nitrate trend for San Luis Valley Russet Burbanks during the 1990 growing season and is discussed in more detail in case study #1.

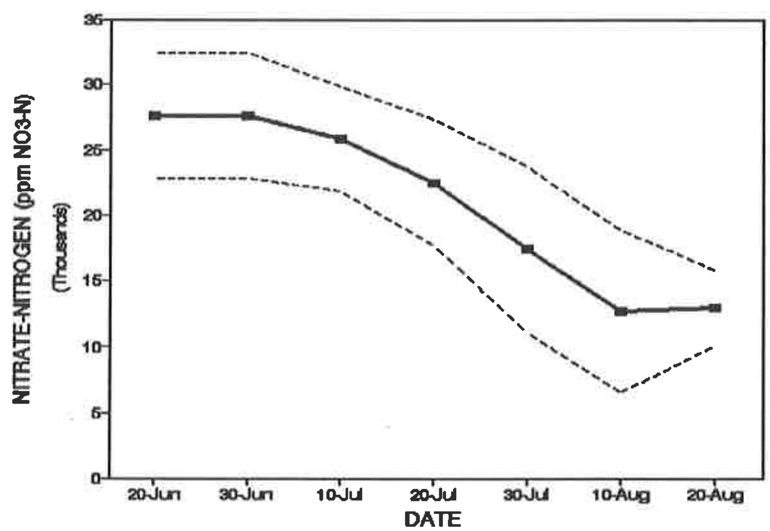
The typical trend is "S" shaped, starting out high, gradually declining, then stabilizing at a lower level. This trend corresponds to the uptake rates for potatoes during tuberization, bulking, and maturity.

Potato growers and consultants use petiole nitrates to compare results of individual fields against long term averages to see if the crop is developing as they expect. They use this information to make timing and rate decisions for in-season nitrogen applications.

The dotted lines in Figure 3 show three potential monitoring situations, average, rapid decline, and slow decline.

A rapid decline from the average, as shown in Figure 3, may be due to a lack of available soil nitrogen. The decline can also be caused by stress that limits water and nitrate uptake (such as weather or a root restriction). In any case, the rapid decline is evidence that immediate action is likely required to prevent yield loss.

Figure 2. Average 1990 petiole nitrate levels, Russet Burbank variety, San Luis Valley.



Petiole nitrates that decline too slowly from the average (also shown in Figure 3) indicate that the plant is maintaining vegetative growth and proceeding slowly toward maturity. The potato crop may mature later than desired, causing potential quality problems.

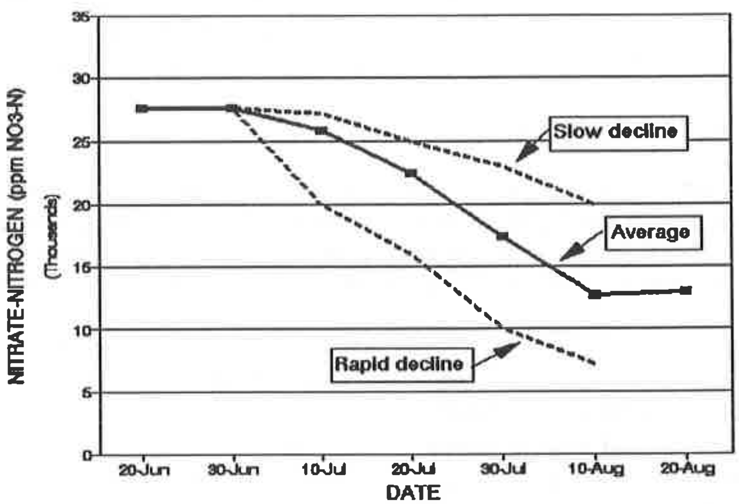
A grower may be able to manage the crop in this situation to either limit nitrate uptake or to push the crop into maturity. Adjusting irrigation to restrict water uptake may help lower nitrate uptake. Vine killing or desiccation may also be needed, depending on the circumstances.

Growers can also use nitrate levels to help set harvest schedules. Fields with the earliest nitrate decline will probably be ready to harvest first. This information can help the grower schedule late-season irrigations, so the soil is in good condition for potato harvest. Information from petiole nitrate results can be used this way to help schedule harvest equipment and labor requirements.

Case studies

Like the diagnostic approach, results of petiole nitrate monitoring cannot be used exclusively to make fertilizer management decisions. The four following examples illustrate how petiole monitoring can be used to manage potato fertility and presents some concepts to consider when interpreting lab results.

Figure 3. Example of petiole nitrate trends, comparison of decline rates.



Case study 1: Weekly variability, San Luis Valley, Colorado

Actual nitrate trends are seldom as smooth and predictable as shown in Figure 2. The heavy dark line is the average nitrate level from a survey of many Russet Burbank petiole samples collected in the San Luis Valley during 1990.

In any given week, petiole nitrates may be well above or below the long-term average. The dotted lines in Figure 2 indicate the typical range over and under the seasonal average for the petioles included in the survey. The dotted lines give some idea of the typical variability expected when monitoring petiole nitrate results.

Nitrate values can vary for many different reasons, so establishing "hard and fast" critical levels is difficult. Nitrogen uptake rates are heavily influenced by the growth rate and water uptake of the potato plant. Several days of cool or cloudy weather prior to the day of sampling seems to depress potato petiole nitrate levels. The amount of soil moisture or the days after irrigation causes nitrate levels to fluctuate because of the availability of soil water needed for nutrient uptake.

It is important to remember that the concept used here is "monitoring". When using the monitoring approach we are not as concerned with the absolute petiole nitrate level on a given day as we are with petiole nitrate trends over the growing season.

Unlike the diagnostic approach, one or two monitoring samples collected during the season is not enough to establish a trend. Weekly petiole samples are needed during critical growth stages to develop and evaluate trends.

"How long are petiole nitrates staying at high levels?", "How fast are levels declining?", and "When are they going to hit bottom?", are questions that growers must ask to interpret these results correctly.

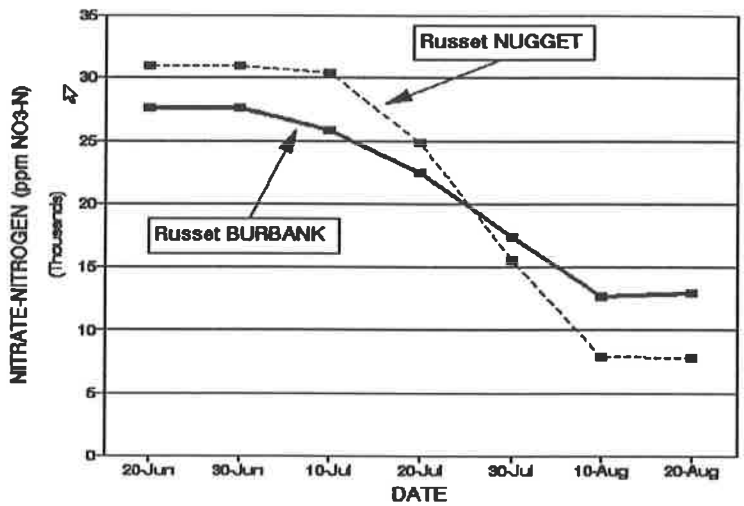
Interpretations must be made by someone who knows what has occurred in that field over the last seven to ten days, typically the grower or the consultant.

Case study 2: Varietal differences, San Luis Valley, Colorado

Potato varieties take up nitrogen at different rates through the season, possibly because of differences in internal nitrogen metabolism, in maturity length, or in growth pattern (e.g. indeterminate vs. determinate varieties). Figure 4 demonstrates a varietal difference between Norgold Russets to Burbank Russets.

Norgolds started out the 1990 season with higher petiole nitrate levels than did Burbanks. As the season progressed, the Norgold petioles declined faster and reached lower nitrate levels at maturity than did the Burbanks.

Figure 4. Petiole nitrate differences between two varieties, Russet Burbank and Russet Nugget, San Luis Valley, 1990.



Each variety has it's own particular nutrient uptake trend. Growers and consultants must consider these variety differences when interpreting petiole nitrates. Collecting petiole nitrate information over several seasons to establish petiole nitrate curves for individual areas and varieties is essential for making good interpretations.

Case study 3: Seasonal differences, San Luis Valley, Colorado

Seasonal weather patterns can affect the physiological development of the potato crop. Relative length of the various growth stages may vary, so nutrient uptake patterns may differ from season to season.

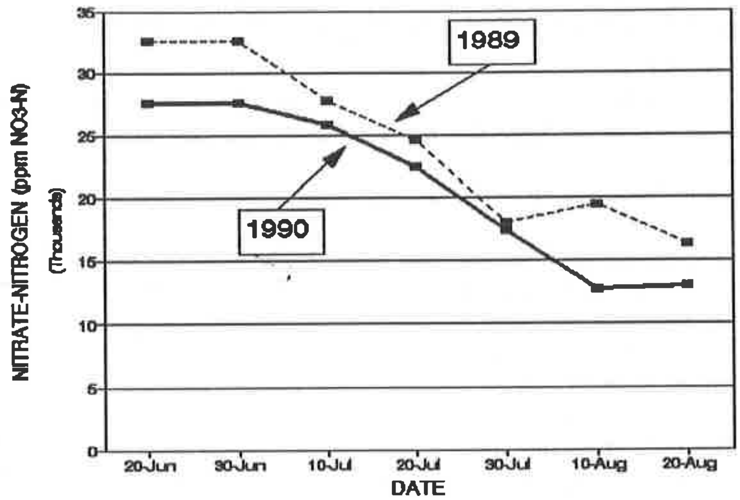
Nitrate interpretations should not necessarily be based solely on calendar dates. It is essential to compare the current physiological growth stage and current weather patterns to long term averages.

Figure 5 illustrates the difference in average nitrate levels between 1989 and 1990 due to seasonal weather. San Luis Valley weather patterns during 1990 tended to be cooler and cloudier, with more rainy days than normal. This apparently caused petiole nitrates to trend lower than in 1989.

Petiole nitrate levels vary not only between seasons, but also between climates. Interpretations developed for Idaho conditions may not be valid for the San Luis Valley, nor San Luis Valley interpretations for northeast Colorado.

Nitrate levels and trends from other areas can be used to develop preliminary interpretations, but it is important to keep records and to develop local information for the particular area, climate, and varieties.

Figure 5. Average petiole nitrate differences between two growing seasons, Russet Burbank variety, San Luis Valley, 1989 and 1990.



Case study 4: Field comparison, Yuma area, Colorado

Growers can use the current petiole results and historical trends - plus his own experience and knowledge - to make fertilizer management decisions. Figure 6 offers a practical field example.

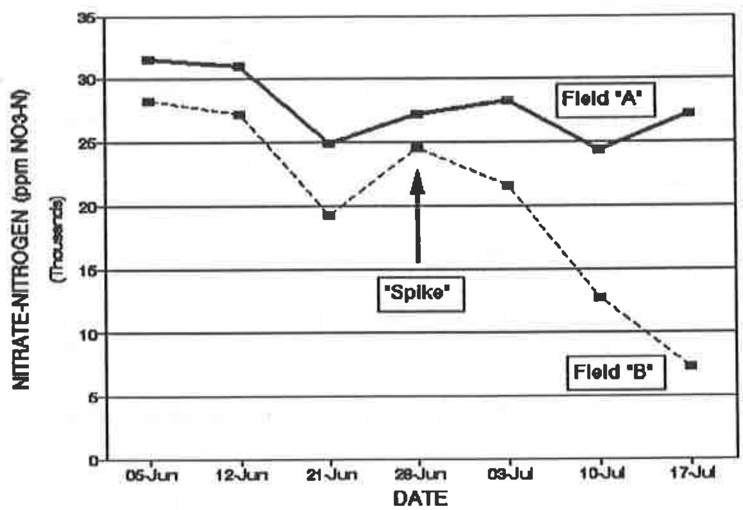
Field "A" was planted to Hilites, field "B" to Atlantics. Both fields were planted to edible beans in 1989, then seeded with rye as a cover crop. The rye was plowed under in late March. Both fields had similar soil nitrate carryover and received the same amounts of preplant fertilizer.

The grower had applied about 60 lb N per acre on field "A" and about 15 lb N per acre on field "B". Plant and soil samples taken June 12 showed both high petiole nitrates and high levels of soil nitrate and ammonium.

Although the petiole nitrates declined on both fields during the next week (week of June 19), the grower's consultant suggested delaying further nitrogen until the next set of petiole results were available.

Samples taken the week of June 26 showed rising nitrates, so nitrogen applications were stopped. This upward "spike" of petiole nitrate was attributed to the previous mineralization and final release of the nitrogen contained in the plowed-down rye.

Figure 6. Field example, potato petiole nitrate trends, Yuma, Colo. 1990.



Field "A" petiole nitrates (which had 60 lb additional nitrogen) remained at relatively high levels during the rest of the season. Field "B" (with less applied nitrogen) showed a gradual decline, closer to typical petiole nitrate trends.

Applying additional nitrogen to field "B" would have elevated nitrogen uptake and likely resulted in delayed maturity. This potential problem would not have been obvious without petiole nitrate results.

Summary

Plant analysis is one of many tools available to producers and consultants. Like any other tool, it must be used properly to obtain best results. Diagnostic sampling is probably most suited for troubleshooting field problems and to help plan for the next crop.

Petiole monitoring is most useful for making short-term management decisions during the current season, but is also useful to plan for the next season. The key to making petiole monitoring work is to:

(1) establish trends for particular fields and varieties, then

(2) make decisions on a case-by-case basis.

Petiole monitoring probably provides not only the most information, but the most valuable information, that producers need to help improve potato yields, quality, and profits.

References:

Granade, G.V., et.al. 1989. Phosphorus, potassium, and chloride effects on selected diseases for six wheat cultivars in southeastern Kansas. Rep. of Progress 587, Dept. of Agron., Kansas State Univ., Manhattan, Kans. pp. 38-44.

Kleinkopf, G.E., G.D. Kleinschmidt, and D.T. Westerman. 1987. Tissue analysis: A guide to nitrogen fertilization for Russet Burbank potatoes. Current Info. Series No. 743., Coop. Ext. Serv., Univ. of Idaho. 4 pp.

Ojala, J.C., J.C. Stark, and G.E. Kleinkopf. 1990. Influence of irrigation and nitrogen management on potato yield and quality. American Potato Journal 67:29-43.

Ferarri, M. 1991. Personal communication. Servi-Tech Inc., Yuma, Colo.

Salazar, L. 1991. Personal communication. Agro-Engineering, Alamosa, Colo.