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Nitrogen Management for White Potato Production

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Introduction

One of the challenges of white potato production, as with any crop, is the efficient management of nitrogen (N) fertilizer. Excessive N fertilizer applied at or before tuberization can extend the vegetative growth period and delay tuber development, resulting in a lower tuber yield. However, too much N applied later in the season can delay maturity of the tubers, reducing yield and adversely affecting tuber quality and skin set. Conversely, under-application of N at any point in the season can result in lower tuber yields and reduced profits. Environmental considerations must also be taken into account in N fertilizer management. Nitrogen is a mobile nutrient in the soil and any excess N has the potential to move off-site via leaching or surface runoff. This is particularly true on the coarse-textured, low-organic matter soils common to the Eastern Shore, the premier potato-producing region in Virginia. These factors make the appropriate N rate and N application timing critical for successful white potato production.

N Rate Recommendation

The amount of N required by a potato crop is closely related to yield. As yield potential increases, so does the necessary N rate. Typically, a potato crop will require between 40 and 75 lb N for each 100 cwt of harvested tubers. A portion of the applied N remains in the vines, while most of the N taken up by the crop is removed in the harvested tubers. Current recommendations suggest that 125 to 150 lb N/acre is adequate for white potato production in Virginia. This range was established using over 20 years of field data and is based on a yield goal of 200 to 250 cwt/acre, a realistic goal for the soil and environmental conditions characteristic of the potato producing regions of Virginia. However, a recent survey indicated that 100 percent of the growers polled (approximately 80 percent of the total growers in Virginia) have made a major change in production practices and switched to a new cultivar within the past 10 years. This change has resulted in several growers consistently producing yields >275 cwt/acre, which are well above the state average. These growers also find that the current N rate recommendations are inadequate to support these higher yields. Therefore, we developed the following guidelines for Virginia growers in higher-yielding environments.

Determining N Requirement in High-yielding Environments

Our research was conducted in 11 potato fields on the Eastern Shore from 2000 through 2003 and found that:

- **The current N rate recommendation (125 to 150 lb N/acre) remains accurate for fields with production potentials in the 200-cwt/acre range.**

However, we identified a few farms that consistently had production potentials exceeding 300 cwt/acre and a subsequently higher N rate requirement. When accurately maintained yield records and past experience with a particular field demonstrate a yield potential >250 cwt/acre, adjustments to the recommended N rate are justified and necessary for optimum production. The question is "By how much should the N rate be increased?"

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Based on the research conducted on the Eastern Shore, we concluded the following:

- **For fields with a yield potential >250 cwt/acre, we recommend that growers multiply their expected tuber yield (cwt/acre) by 0.6 to approximate the required fertilizer N rate (lb N/acre).**

For example, the common chipping varieties 'Atlantic' and 'Snowden' frequently yield in the 325- to 350-cwt/acre range; therefore, the recommended N rate would increase to 195 to 210 lb N/acre. Likewise, an optimistic yield potential for the fresh-market variety 'Superior' is 300 cwt/acre; therefore growers with this production capacity should be applying approximately 180 lb N/acre to optimize yield.

Timing of N Applications

The current N management guidelines for Virginia suggest applying 1/3 of the recommended N rate at planting and the remaining 2/3 four to five weeks after planting. All of the growers surveyed indicated that they follow the recommendation to split N applications; however, because it is convenient to combine fertilization with a tillage practice, most growers make their second N application two to three weeks after planting rather than four or five weeks after as stated in the current guidelines. Also, contradictory to current recommendations, approximately one-fourth of those surveyed apply most of the total N requirement at planting rather than later in the season.

Analyses of plant N uptake indicate that approximately 40 percent of the total N requirement is taken up between emergence and flowering and that the N uptake rate is greatest during flowering and tuber bulking (Figure 1). Fertilizer N-use efficiency should be highest when applied just prior to these periods of rapid growth and N uptake. The N uptake pattern in Figure 1 also indicates that the crop requires very little N prior to emergence, suggesting that applying all, or a large portion, of the recommended N rate at planting is inefficient. Calculated physiological development days for potato growth (P-Days, which are similar to growing degree days) show potatoes planted on any day in March in the past five years, which would include 90 percent of Virginia's crop, required at least two weeks to accumulate the P-Days necessary for emergence and closer to three weeks when planted prior to March 15. This time requirement prior to the beginning of substantial N uptake coupled with the high leaching-potential of Eastern Shore soils demonstrates the inefficiency of large N applications at planting. Our research demonstrated the effect of N application timing on tuber yield and we concluded the following:

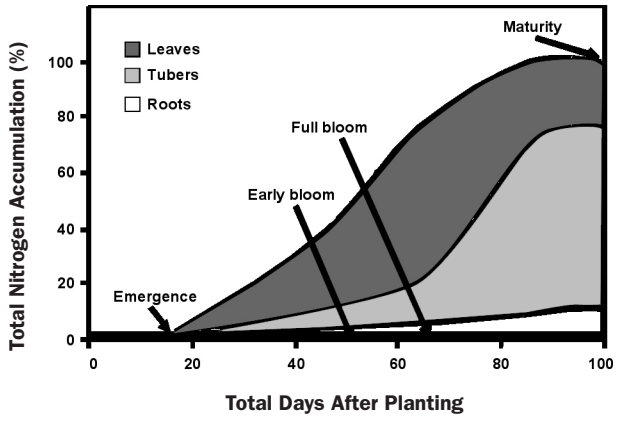

Figure 1. Nitrogen uptake and distribution patterns in a 'Superior' potato plant grown on Virginia's Eastern Shore in 2002.

- **The recommended practice of splitting the N rate into two applications (1/3 at planting and 2/3 at emergence) always increased yield compared with applying all of the N fertilizer at planting.**

- **In higher-yielding environments (>250 cwt/acre), we recommend a three-way split (1/6 to 1/3 of the total recommended N rate at planting, 1/2 to 2/3 at emergence, and 1/6 at flowering), which was shown to increase tuber yield over the standard, two-way split.**

Approximately 50 percent of Virginia growers currently use three or more applications; however, many of them apply as much as 1/2 of the total recommended N rate at planting. While we observed no yield reductions compared to applying 1/6 to 1/3 of the total N requirement at planting, our data demonstrate that 1/2 of the total N rate usually will be in excess of crop N requirements early in the growing season, resulting in potentially lower N use efficiencies.

Late-season N Applications

Additional care is needed when making the late-season N application of a multi-split strategy. Although we suggest that 1/6 of the total N requirement be applied at flowering, our data also indicated that environmental conditions and indigenous N supplies that affect early- and mid-season crop performance can affect yield

potential and crop response to added N late in the season. This can change the optimum late-season N rate that was determined based on yield potential. Failure to make adjustments for these conditions can result in inaccurate late-season N-rate selections and lower tuber yields. Petiole sap NO_3-N measurements might eliminate some of the risk associated with late-season N applications.

Petioles are the slender stems connecting leaves to the main stem of the plant. Nutrients travel to the leaves through the petioles; thus, petiole analyses are frequently used in crop production to determine plant concentrations of various nutrients. Numerous guidelines exist that identify critical petiole nutrient concentrations; however, the fertilizer rate that should be applied is often left up to the discretion of the grower.

- **Based on our data, we recommend that growers refer to Figure 2 to determine late-season N rates.**

Petiole sap NO_3-N concentrations vary across the growing season, but will typically be between 1,200 and 1,500 ppm during flowering, with little variation among varieties. Within this range, growers can apply 20 to 35 lb N/acre with little risk of reducing yield (Figure 2). As petiole sap concentrations drop below 1,200 ppm, up to 45 lb N/acre can be applied. Conversely, at petiole sap NO_3-N concentrations >1,500 ppm, a response to additional N is unlikely.

- **During flowering, applying a N rate exceeding that determined using Figure 2. can result in delayed maturity and yield reductions; thus, the final N application in a three-way split may need to be adjusted.**

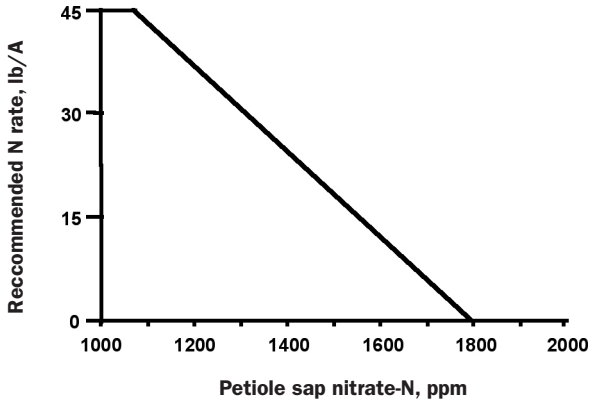

Figure 2. Recommended N rates for late-season (flowering) N applications based on petiole sap analyses.

For example, a 400-cwt/acre crop has a N requirement of approximately 240 lb N/acre (400 cwt × 0.6 N factor = 240 lb N/acre). In a three-way split system, we recommend the grower apply 80 lb N/acre at planting, 120 lb N/acre at emergence, and 40 lb N/acre at flowering (1/3, 1/2, and 1/6 of total N). However, suppose that late-season petiole analysis indicated a NO_3-N concentration of 1,450 ppm. According to Figure 2, the recommended N rate would be approximately 20 lb N/acre and the grower should halve the original flowering split recommendation. Applying the full 40-lb rate puts the grower at risk of delaying maturity and subsequent yield reductions. The need to reduce the N rate of the final application is not uncommon, particularly in fields with high concentrations of residual soil N (following a vetch cover crop, manure applications, etc.) or following total pre-flowering N applications greater than 200 lb N/acre. Had the petiole sap concentration in the example above been 1,200 ppm or lower, the full 40-lb N/acre rate could be applied with less risk of reduced yield.

Determining Petiole Sap NO_3-N Concentrations

When using petiole sap NO_3-N to manage late-season N applications, the most important step in obtaining a useful measurement is collecting a good sample. Use the following techniques to ensure that a quality sample is collected.

- Collect samples when the plants are actively growing (typically between 9 a.m. and 4 p.m.).
- Do not collect samples from water-stressed plants.
- Collect samples from a representative area of the field while avoiding problem areas (poor drainage patterns, near field edges, etc.).
- Collect a composite sample from plants located throughout the field (collecting petioles from several different rows will minimize any influence of planter or fertilizer applicator patterns on the measurement).
- Sample the fourth or fifth fully expanded leaf (or about midway down the plant) and remove the whole leaf and the leaflets.
- Complete sample size should be approximately a 1-inch bundle of petioles (depending on petiole thickness, this may require 20 to 50 plants).

Once a representative sample has been collected, the simplest way to measure petiole sap NO_3-N is to use a portable, hand-held meter in the field. Portable NO_3-N meters are easy to use and sap measurements are highly correlated with those obtained using conventional laboratory procedures. Another option is to submit the sample to a commercial laboratory for analysis. When the sample is being sent to a commercial lab, it should be placed in a paper bag and kept cool until shipping. Never use plastic bags for storing petioles due to the increased possibility of sample decay prior to analysis.

Another consideration when using a commercial laboratory is that the analysis performed will likely be based on whole petiole NO_3-N content rather than sap concentration. The N rates recommended using Figure 2 are based on petiole sap NO_3-N and will not be accurate based on whole petiole NO_3-N concentrations.

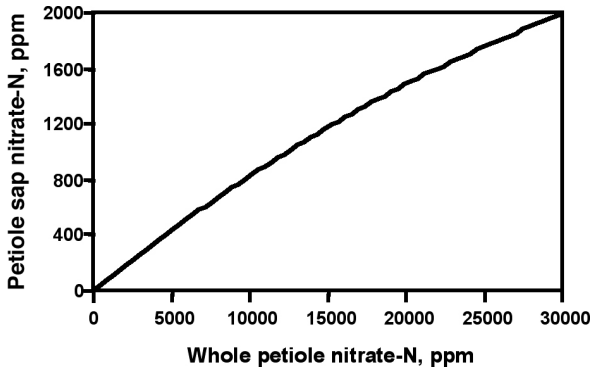

Figure 3. Relationship between petiole sap NO_3-N measured using a hand-held meter and whole petiole NO_3-N determined using conventional laboratory procedures[2].

- **Growers should use Figure 3 to convert whole petiole NO_3-N measurements to petiole sap NO_3-N before using Figure 2 to determine late-season N rates.**

Growers can contact their local Extension agent for more information about purchasing and operating hand-held NO_3-N meters or commercial laboratories in the area that provide petiole analysis.

Summary

For fields with production potentials of 200 to 250 cwt/acre, we recommend applying 50 lb N/acre at planting and another 75 to 100 lb N/acre just prior to emergence. In higher-yielding environments (>250 cwt/acre), we recommend that growers consider the following guidelines:

1. Multiply expected tuber yield (cwt/acre) by 0.6 to approximate the required N fertilizer rate (lb N/acre).

2. Apply 1/6 to 1/3 of the total recommended N rate at planting, 1/2 to 2/3 at emergence, and the remaining 1/6 at flowering.

3. Use petiole sap NO_3-N concentration at flowering to determine if the final N application rate needs to be adjusted.

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Adapted from Zhang, H., D. Smenl, R.N. Arnold, and E.J. Gregory. 1996. Potato Nitrogen Management by Monitoring Petiole Nitrate Level. J. Plant Nutr. 19:1405-1412.