Measuring Nutrient Accumulation Rates of Potatoes—Tools for Better Management

By Don Horneck and Carl Rosen

Fertilizer can be managed more precisely when both the total nutrient demand and the daily rate of nutrient accumulation of the crop are known. The results of two studies are presented for high-yielding irrigated potatoes grown in Minnesota and in Oregon. Closely matching nutrient availability with crop demand is essential for producing profitable yields of high quality potatoes, while minimizing unwanted nutrient losses to the environment.

Nutrient applications are made on the basis of meeting the plant demand and the existing supply of soil nutrients. But it can be a challenge to precisely meet these nutritional needs. Not only must the total quantities of nutrients be present during the growing season, they must be available at the time they are required by the developing plant. Meeting the nutrient demand may be relatively simple with a turf crop, for example, where seasonal growth rates are fairly constant. However, for other crops such as potatoes, timing nutrient application can be a challenge.

Potatoes require an optimal supply of nutrients throughout the growing season to sustain their growth and tuber development. Their exact nutrient demand is a function of many factors such as the growth rate, the growth stage, the climatic conditions, and the potato variety. Additional factors such as yield goals, economic return, and environmental impacts also need to be considered. Since either deficient or excessive plant nutrition can reduce tuber bulking and quality, fertilizer management must be done with care.

Meeting the seasonal nutrient demand for potatoes is aided by several management tools. These include pre-plant soil testing to estimate future nutrient availability, in-season tissue testing, and mid-season application of nutrients to address any emerging nutrient shortages as the crop develops.

One useful guide for fertilization is knowledge of the nutrient accumulation pattern (plant concentration multiplied by the dry matter content) during the growing season (**Table 1**). Knowledge of the total seasonal demand and the daily nutrient requirement provides a useful guide for both early season fertilization and mid-season adjustments. When graphed, patterns of nutrient uptake generally follow an "***S***-shaped" type of curve. Nutrient uptake is generally most rapid during the time of tuber initiation and bulking, then tapering off during tuber maturation later in the growing season

Table 1. Typical nutrient accumulation in vines and tubers of a 400 to 500 cwt/A Russet potato crop and the general maximum daily uptake rate for the plant during the growing season.

	Total plant uptake, lb/A		Peak daily uptake rate, lb/A/day
	Vines	Tubers	
Nitrogen	140	210	4 to 7
Phosphorus	10	29	0.4 to 0.9
Potassium	275	240	5 to 14
Sulfur	12	22	0.1 to 0.6

Estimates based on data presented here and Stark et al. (2004).

Yield and quality can suffer from either over- or under-supply of N.

The results of two studies are presented where potatoes were grown with non-limiting water and optimal nutritional conditions. The study conducted in Minnesota focused primarily on N, while the study in Oregon collected data on several of the essential plant nutrients.

Minnesota

Russet Burbank potatoes were grown on a sandy soil (Hubbard loamy sand, Entic Hapludolls) on the Sand Plain Research Farm near Becker, Minnesota. The potatoes were fertilized with 240 lb N/A applied in three split applications and irrigated as needed. Samples of vine and tuber were collected seven times during the growing season, weighed, and analyzed for total N. These results are a portion of the data collected in the larger study (Rosen et. al., 1993; Zebarth and Rosen, 2007).

Total dry matter accumulation was most rapid during the period of 40 to 100 days after planting, corresponding to the periods of tuber initiation and early tuber bulking (**Figure 1**). Since the tubers account for up to 90% of the total dry weight at the end of the season, it is important to maintain favorable growing conditions through the entire season to support their growth.

The majority of N acquired by the plant preceded the peak of vine and tuber growth. As tuber development entered the bulking stage, the initially large fraction of N in the vines continually declined until harvest as N was retranslocated to the tubers (**Figure 2**). Potato plants have already taken up over 50% of their total N requirement by the time tuber bulking

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; K_2SO_4 = potassium sulfate; KCl = potassium chloride or muriate of potash.

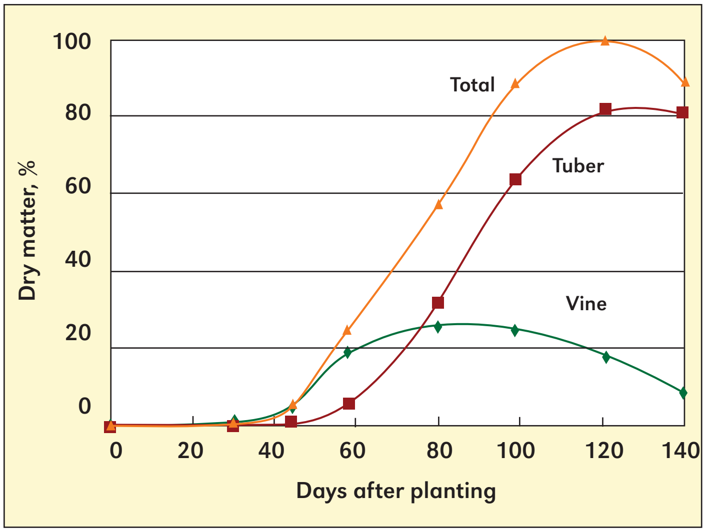

Figure 1. Dry matter accumulation and partitioning by Russet Burbank potato during the growing season near Becker, Minnesota (expressed as percent of total seasonal biomass).

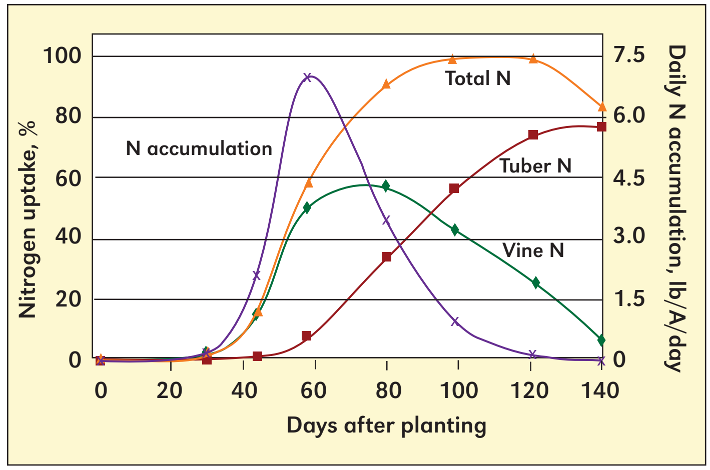

Figure 2. Seasonal N accumulation by Russet Burbank potato vines, tubers, and whole plants (left axis) and the average daily N accumulation rate (right axis) growing near Becker, Minnesota. Nitrogen uptake is expressed as a percent of the total seasonal accumulation.

begins, highlighting the importance of an adequate supply of early season N.

Oregon

Potatoes (Russet Burbank) were grown on a Quincy fine sand soil (Xeric Torripsamments) with non-limiting nutrition and irrigation near Hermiston, Oregon. The potatoes received a total of 325 lb N/A (16% preplant), 220 lb P_2O_5/A (45% preplant), and 240 lb K_2O/A (95% preplant). Nutrients that were not applied preplant were added through the irrigation system during the growing season. Plants were harvested six times and partitioned between vines and tubers. Plant tissue was analyzed for dry matter and nutrient content. Taking the first derivative of the uptake data calculates the daily average accumulation rate between sampling dates.

The pattern of dry matter production was similar to the results of the Minnesota work, where a maximum daily growth rate (DM) was measured 90 to 100 days after planting (**Figure 3**). This maximum growth period occurred 20 to 30 days following the phase of maximum nutrient accumulation. A shortage of essential nutrients during this peak period of uptake would likely have impaired the plant growth occurring several weeks later. This observation that maximum nutrient uptake always preceded maximum growth is a reminder that when nutrient deficiencies occur in the foliage, it is likely that yield losses have already occurred.

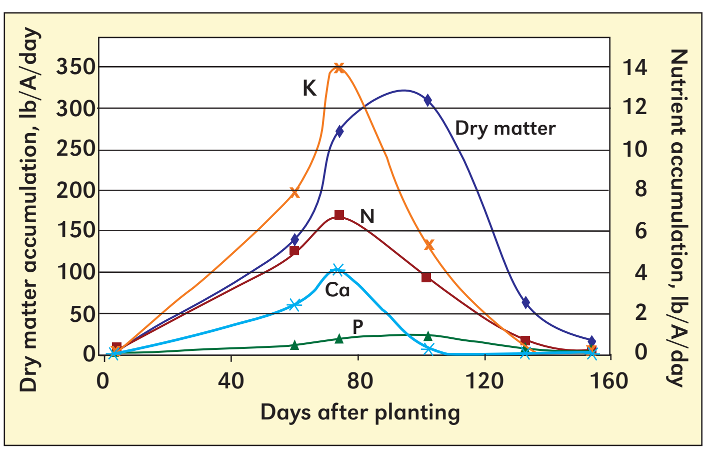

Figure 3. Daily growth rates (left axis) and daily nutrient accumulation (right axis) by Russet Burbank potatoes during the growing season near Hermiston, Oregon.

Nutrition and irrigation were non-limiting in the Oregon Studies. Nutrients not applied preplant were applied through the irrigation system.

The total and daily accumulation of N, P, and K is shown in **Figure 4**. All three of these nutrients have similar patterns of uptake during the growing season. However, the peak period of uptake may occur over a longer time for P than for N and K.

Summary

Nitrogen: Approximately two-thirds of the total plant N is accumulated in the first few months following planting. Therefore, an adequate availability of N must be maintained in the root zone to support this rapid uptake. This is not a simple task, since excessive early season N can increase the susceptibility to brown center, hollow heart, and delays in maturation, while excessive N during the late season can reduce the specific gravity of the tuber and the skin set. Petiole testing is frequently useful for monitoring N availability and determining the need for supplemental fertilization.

During the time of maximum growth during the midsummer, the plants accumulated up to a maximum of 7 lb N/A/day.

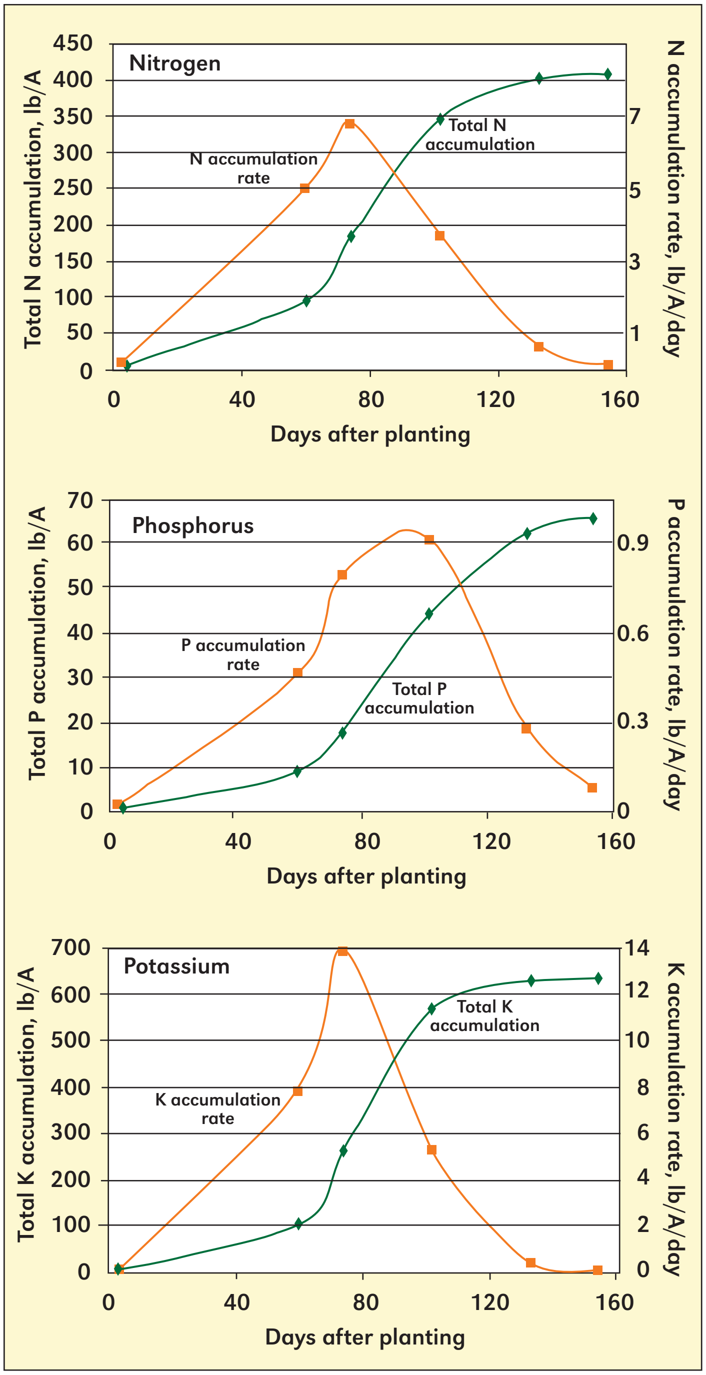

Figure 4. Total (left axis) and daily rate (right axis) of N, P, and K accumulation by Russet Burbank potatoes grown with non-limiting nutrition and water near Hermiston, Oregon.

This large amount of N can come from N already in the soil, N released from organic matter, N in the irrigation water, or from fertilization. Since yield and quality suffer when N is over- or under-supplied, close monitoring of the plant N status is recommended.

Phosphorus: The rate of plant P uptake generally peaks during the middle of the growing season, with a daily demand of between 0.4 and 0.9 lb P/A/day depending on the variety and location. The amount of P present in the soil solution at any time is generally low and is regulated by the buffering capacity of the particular soil. Each soil has a different capacity to replenish the roots with soluble P from mineral and organic sources.

When P concentrations are inadequate to meet peak demands, tuber size and yield are diminished. Fertilizer P is generally applied prior to planting based on soil tests, but monitoring petiole P concentrations is also common for determining the need for additional mid-season P. Sprinkler application of soluble P can be effective for supplementing the P supply if active roots are very near the soil surface. With a full plant canopy, potato root density will typically be high near the soil surface. This is important since P fertilizer applied through the sprinkler system rarely moves more than a few inches into the soil. A week or two may be required before a response to added P is measurable, so applications should be made in advance of possible deficiencies.

Potassium: Potatoes typically accumulate more K than any other nutrient. During the peak uptake period, daily accumulation rates can exceed 5 to 14 lb K/A/day, and over 600 lb K/A was accumulated by the crop. An adequate supply of K can help prevent a variety of tuber quality defects, such as blackspot bruising, low specific gravity, and poor storage quality. Excessively high K may also be detrimental and should be avoided. Potassium application rates should be based on soil testing and crop removal rates.

The majority of K fertilizer is usually applied prior to planting. At typical application rates, there is no consistent difference between K sources. At high K application rates, K_2SO_4 or a blend of KCl and K_2SO_4 may tend to produce slightly larger potato yields with higher specific gravity compared with KCl alone. The timing and rate of application, as well as the product blend, are important considerations when making K applications to potatoes. BC

References

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