POTATO GROWTH AND NITROGEN REQUIREMENTS

by
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Crop production is an intensive process requiring many management decisions during the course of a growing season. This is particularly true in growing high yielding, high quality, marketable potatoes. Many growers are now applying a portion of the crop's N requirement during crop growth. To use this practice successfully, the grower must know the residual soil N, the rate and amount of N mineralized from soil organic sources, and individual crop needs. Information that relates the N required during different crop growth stages is also needed. The proper use of these fertilization practices has the potential of optimizing potato tuber yields and N fertilizer efficiencies. The objective of this study was to show how potato plant growth is affected by different N levels and to present guidelines for maintaining adequate N levels for optimum potato growth.

There are two main advantages in applying N through the growing season compared to N applied all preplant; (1) Increased fertilizer use efficiency and (2) prevention of the delay of tuber enlargement caused by high preplant levels of N.

In 1978 the N fertilizer recovery from a preplant application reached a maximum of 70% on August 21 and then decreased to 51% by September 5 (Table 1). This apparent decrease in recovery was caused by N losses from the vines and roots and from not being able to recover the entire plant sample at the last sampling date. In contrast, 80-90% of the N fertilizer was recovered from the seasonal N applications applied at early tuber set (June 21) and at mid-tuber growth (August 2). Over 80% of the recovered labeled N fertilizer had been translocated to the tubers at the last sampling date. These data indicate that established potato plants can rapidly utilize a high percentage of a seasonal N fertilizer application and that a high recovery of preplant N fertilizer can also be achieved if fertilization rates or irrigation applications causing NO_3-N leaching are not excessive.

Table 1. The percentage of N fertilizer recovered by potato plants for preplant and seasonally applied N fertilizer (1978).

N Fertilizer Treatment	N recovery (%)					
	June 19	June 30	July 11	Aug. 7	Aug. 21	Sept. 5
Preplant N						
120 lbs N/A	29	40	53	60	70	51
Seasonal N						
40 lbs N/A, 6/12-		58	88	84	90	84
40 lbs N/A, 7/14		-	-	-	-	-
40 lbs N/A, 8/2-		-	-	34	76	79

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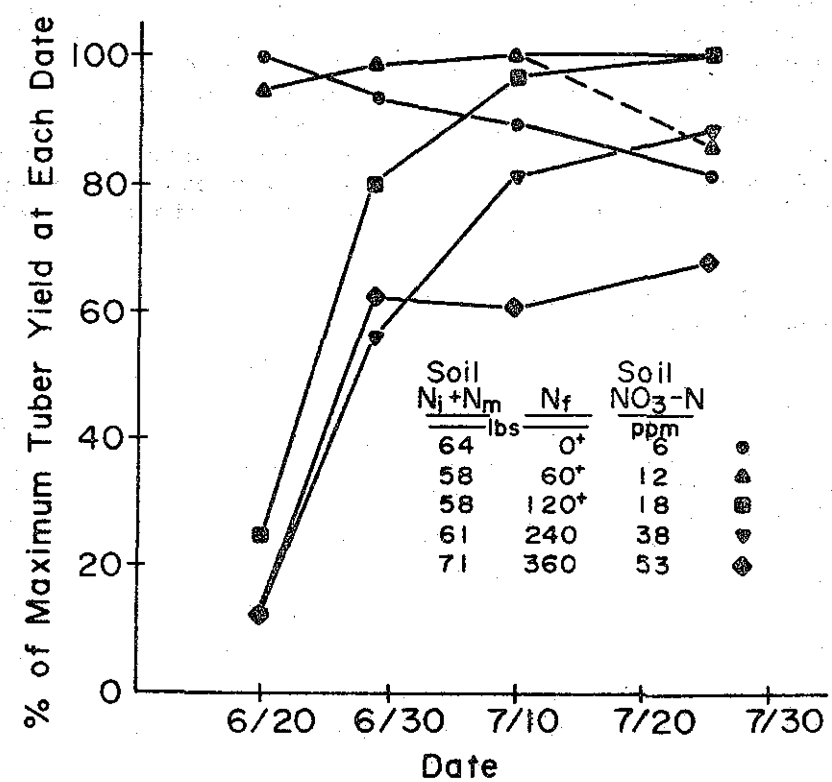
A high preplant N fertility level delayed the linear potato tuber growth period 7 to 10 days. This effect is illustrated in Figure 1. Tuber production was reduced at the early samplings when the N fertilization rate was 120 lbs N/A or greater but had caught up with the lower N rates by about July 10. At higher preplant N fertilization rates, tuber production was still delayed on July 24. Seasonal N fertilizer applications along with the higher preplant N rates (> 120 lbs/A) would probably further depress tuber production at later samplings. Early tuber production was highest when 60 lbs N/A or less was applied preplant; however, tuber production was slower in those treatments receiving no preplant fertilizer because of insufficient top growth (leaf area). Tuber production also decreased after July 10 in the treatment receiving only 60 lbs N/A preplant if no additional N fertilizer was applied. Thus, at these levels of residual soil NO_3-N and minerablizable N, between 60 and 120 lbs N/A applied preplant produced maximum early tuber production and seasonal N fertilizer applications were necessary for continued high tuber production rates. Higher or lower residual soil NO_3-N concentrations and minerablizable N rates would proportionally decrease or increase the amount of preplant N fertilizer required, respectively.

Figure 1. Effect of available N level on early potato tuber production: N_i = initial residual soil NO_3-N; N_m=N mineralized by June 20; N_f=N fertilizer applied preplant. (+) indicates some treatments also received seasonally applied N fertilizer; Soil NO_3-N in the 0 to 18 inch layer was measured on June 20. Dashed lines indicate N treatment without seasonal N fertilizer.



Previously published data show that about 10, 40 and 96% of the total N uptake at the final harvest was contained in the plants by the end of growth stages I (vegetative), II (tuberization), and III (tuber growth), respectively. Nitrogen uptake rates during each of these growth stages depend upon N availability levels and potential plant growth rates. The range of total N uptake rates for growth stage I were 0.5 to 1.2; for II 3.2 to 5.6; and for III, 2.0 to 5.2 lbs N/day-A. These uptake rates were related to the average soil NO_3-N concentration within a sampling interval (Fig. 2). The N uptake rate increased rapidly up to about 10 ppm soil NO_3-N concentrations. The N uptake rate at a given soil NO_3-N concentration tended to increase with increasing air temperatures. Changes in the daily N mineralization rate would also affect the N uptake rate. Thus, 10 and 15 ppm soil NO_3-N were generally sufficient N for a N uptake rate of 3 and 4 lbs N/day-A respectively.

Figure 2. Relationship between average soil NO_3-N concentration (0 to 18 inches) and total plant N uptake rate.

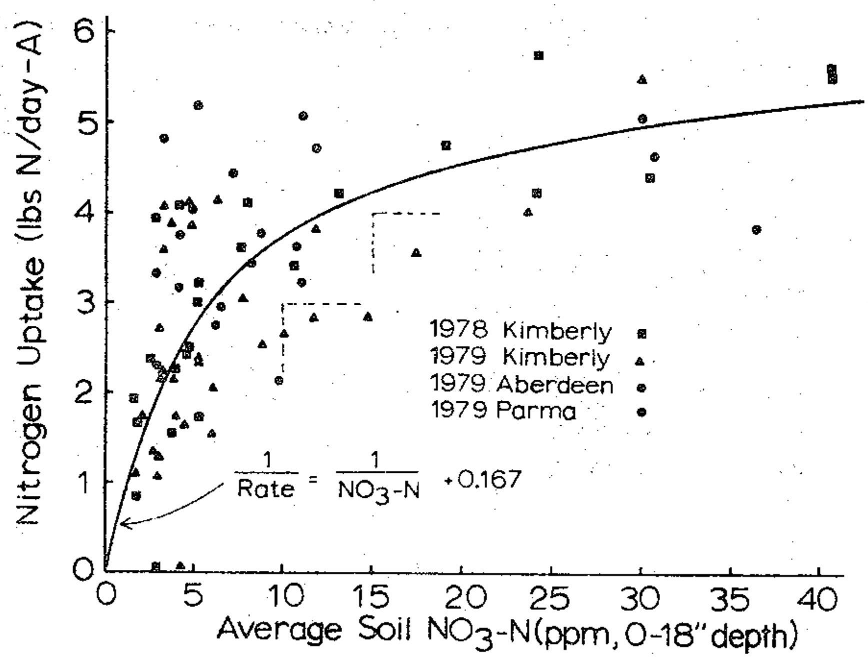
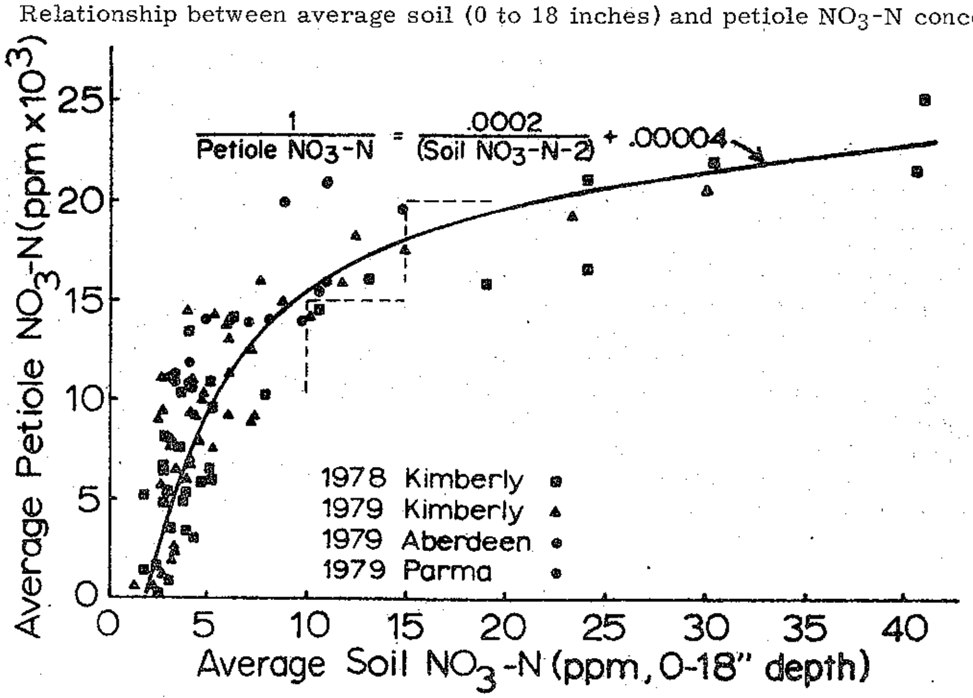


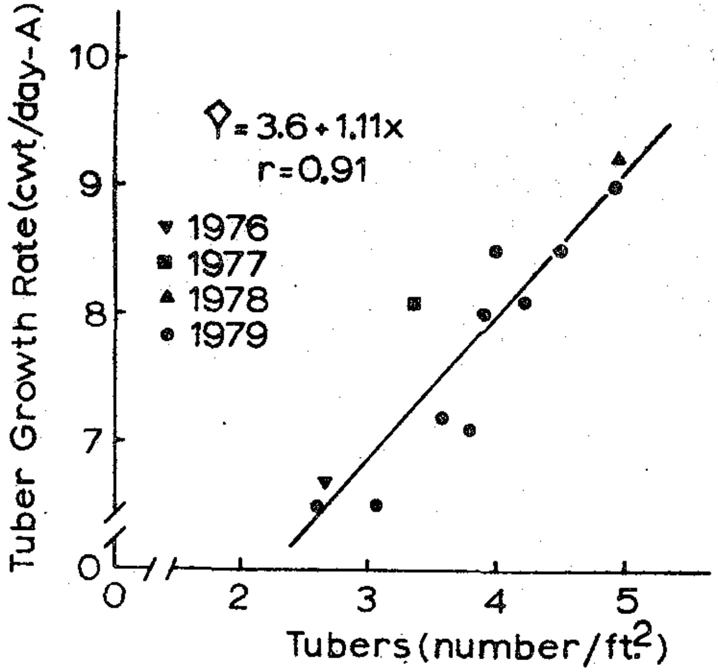
Figure 3. Relationship between average soil (0 to 18 inches) and petiole NO_3-N concentration.



Average petiole NO_3-N concentrations were also related to soil NO_3-N concentrations (Fig. 3). The petiole NO_3-N was generally greater than 15,000 ppm when the soil NO_3-N concentration was greater than 10 ppm. Seasonal N fertilizer applications tended to maintain the petiole NO^3-N concentrations at lower soil NO_3-N concentrations. Soil temperatures also appeared to affect petiole NO_3-N concentrations in the same way it affected N uptake rates.

The N uptake rate during mid-season was largely determined by the tuber growth rate. Figure 4 shows the effect of the number of tubers/ft^2 on the average tuber growth rates. Tuber growth increased linearly as the number of tubers/ft^2 increased. The number of hills per unit area and the number of stems per hill both influence tuber numbers.

Figure 4. Relationship between average number of potato tubers and tuber growth rate during growth stage III.



An additional factor affecting the N uptake rate during growth stage III was the change in tuber dry matter percentage with time (Fig. 5). The dry matter percentage increased from about 14% during early growth stage II to about 23% at the start of growth stage IV. This caused the N required per unit of fresh tuber growth to increase with time. The N percentage on a dry matter basis also generally increased with time if sufficient N was available, particularly towards the end of growth stage III and during IV. Both these effects are summarized in Fig. 6. The bottom line shows the relationship between tuber growth rate and tuber N uptake rate during growth stage II and early stage III. The top line shows the relationship for the rest of growth stage III and stage IV. These relationships indicate that there is about a one-lb/day-acre difference between growth stages at a given tuber growth rate. Part of the N requirement for tuber growth late in stage III comes from N being translocated from the vines and roots of the plant, while during stage IV the major portion comes from translocation.

Figure 5. The change in tuber dry matter percentage with time as affected by preplant N fertilization rates.

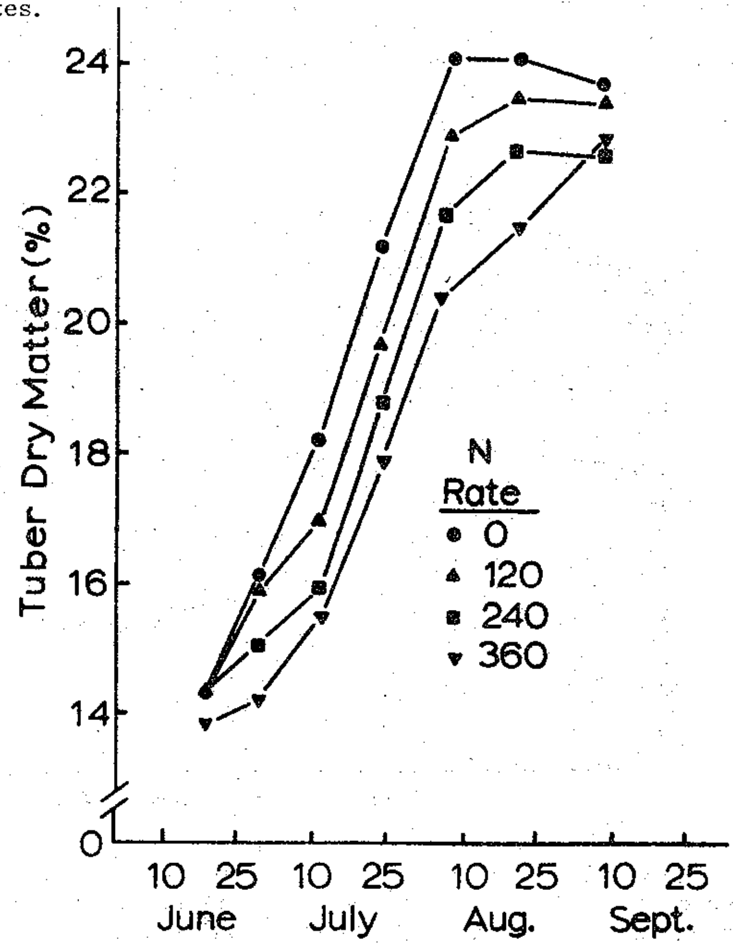
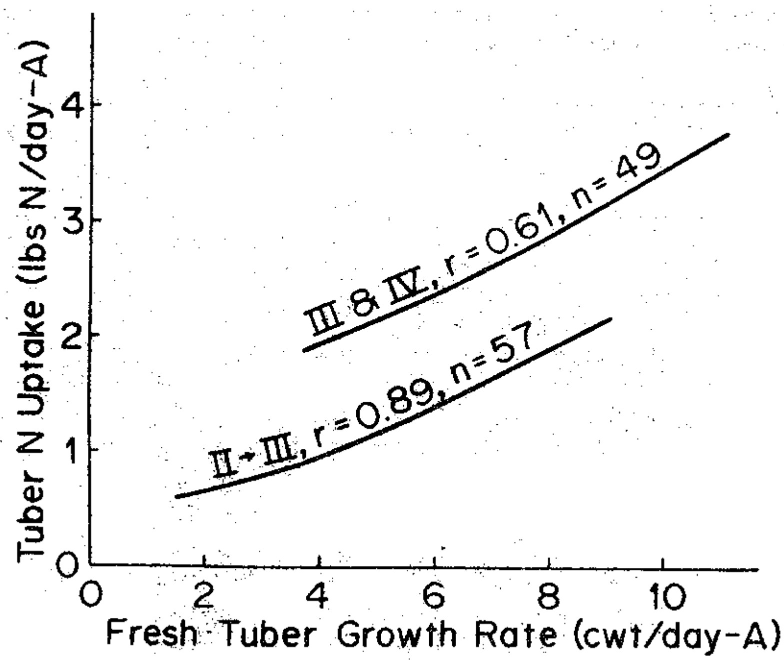
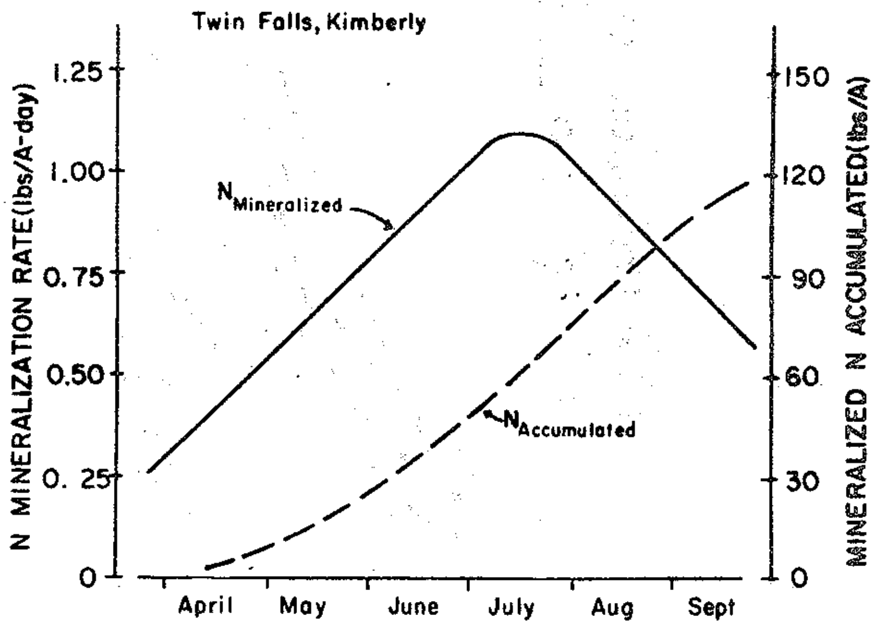


Figure 6. The average effect of tuber growth on tuber N uptake at different plant growth stages.



An important source of N available to the growing potato crop is that from mineralization. Figure 7 shows the rate of N released from organic sources increases up to mid-season and then declines. The total accumulated N varies from field to field and year to year, however, many soils have a relatively constant supply of N for each crop in rotation.

Figure 7. The rate and amount of N mineralized during a typical growing season at Kimberly, Idaho.



Our results indicated that soil and plant tissue could be used to manage N fertilizer applications to promote early tuber growth and to maintain the maximum tuber growth rate until scheduled vine kill. The soil and petiole NO_3-N concentrations that we suggest for different growth stages are shown in Table 2. These concentrations provided adequate N for early plant growth without delaying early tuber growth and for a N uptake rate of at least 3 lbs N/day-A. Soil and petiole NO_3-N concentrations should be monitored during the growing season in order to adjust seasonal N fertilizer applications for different plant growth rates.

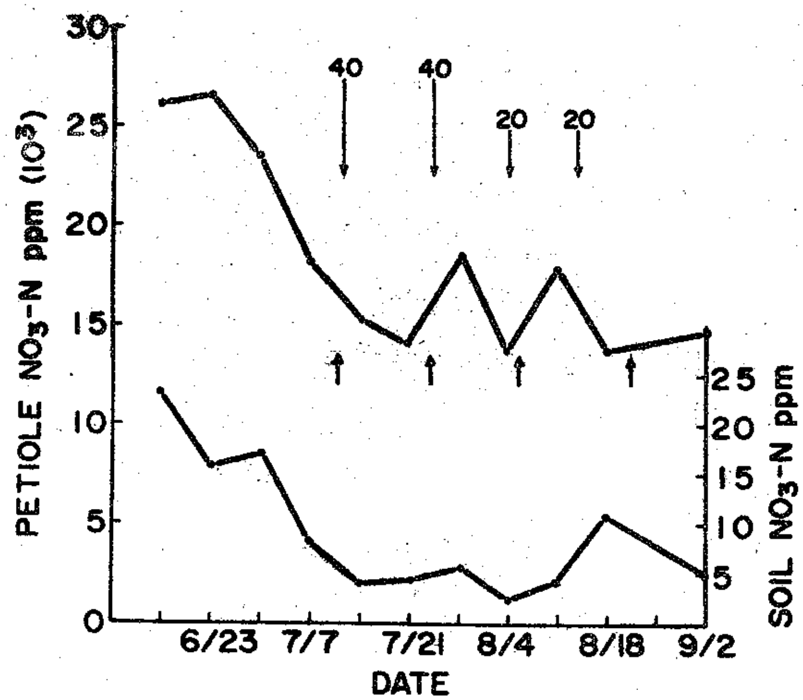
Table 2. Suggested soil and petiole NO_3-N concentrations during different potato growth stages for scheduling seasonal N applications (Kimberly, Id).

NO_3-N	NO_3-N concentration (ppm)			
	I	II	III	IV
Soil (0-18 inches)	15†	10-15	10	<10
Petiole (4th)	--	15,000	15,000	<10,000

† Soil NO_3-N concentration by end of growth stage I (June 20). Nitrogen fertilizer, if needed, should be applied before plant emergence.

A fertilization management program based on plant growth rates and N availability is being developed that can be used to predict N fertilizer requirements during the growing season. This program predicts the amount and timing of fertilizer N applications necessary to produce an anticipated yield. A result of field testing this prediction model is shown in Figure 8. Petiole and soil analyses were maintained in the desired range by seasonal applications of N at 40 lbs/A or 20 lbs/A. Additional results from ten grower fields show this program to be an effective N management tool for higher yields and quality.

Figure 8. Measured petiole and soil NO_3-N levels from field testing of N management program. Lower arrows represent dates of predicted N applications. Upper arrows are actual dates and amounts of grower applied nitrogen.



Several advantages and disadvantages of applying N seasonablly versus a preplant application are listed in Table 3. Use of this program allows the producer to adjust his N fertilizer applications based on crop growth rates and length of season. Also disease incidence and N leaching can be minimized due to greater flexibility in amount of N applied. The overall N usage may be decreased due to better management and increased efficiencies, resulting in increased yield and quality.

Table 3. Advantages and disadvantages of using a N management program for predicting N needs of the potato crop.

Advantages	Disadvantages
1. Management flexibility	1. Handling - sprinkler
A. Growth rates	A. Tanks
B. Disease	B. Injectors
C. Leaching	2. Analysis costs
D. Length of season	3. Monitoring time
2. Savings of nitrogen	4. Scheduling irrigation and
3. Potential yield increases	fertilization applications
4. Higher quality	

The primary disadvantages are associated with increased analysis and monitoring time. Howevery, nitrogen applications can be scheduled using the NO_3-N concentrations listed in Table 2 assuming a N mineralization rate, a plant N uptake rate, and a N fertilizer-use efficiency. Adjustments can then be made during the growing season based on soil and petiole NO_3-N tests. Applying N fertilizer during the growing season according to crop needs should enhance N fertilizer efficiencies, reduce energy requirements, and maximize potato tuber production.