RESPONSE OF RUSSET BURBANK POTATOES TO SPRINKLER-APPLIED NITROGEN FERTILIZER ON SANDY SOILS

by
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INTRODUCTION

Production of Russet Burbank potatoes under center-pivot sprinkler irrigation is currently a major portion of the total in Washington state. The sand to loamy sand soils commonly irrigated with center-pivot systems have the following characteristics compared to heavier textured soils:

1. Lower water-holding capacities necessitating high-frequency irrigation.
2. Greater potential for N leaching losses.
3. Lower soil organic matter which supplies smaller amounts of microbially released soil N.

All these factors have led to two main changes in N fertilization of potatoes in Washington. First, there has been a trend toward higher rates of fertilization. Secondly, N fertilization timing has changed from all preplant to split applications with only a portion applied preplant and the balance in several small increments applied with the irrigation water at frequent intervals during the growing season.

The objective of the research summarized here regarding N fertilization with split preplant and nitrogation applications was principally to determine the N fertilizer requirements of Russet Burbank potatoes under this high-frequency sprinkler irrigated culture. Other objectives included examining effects on selected tuber quality parameters and determining the partitioning of N between tubers and vines.

EXPERIMENTAL METHODS

Six experiments were done over five growing seasons between 1978 and 1983 on a deep Quincy sand to loamy sand soil typical of many areas developed with center-pivot irrigation. Timing and quantities of N applied are summarized in Tables 1 and 2.

In the line-source experiments, 90 lb/acre of preplant N as NH_4NO_3 was broadcast and incorporated uniformly over the plot. The remaining N was applied during the season in a continuous rate gradient by injecting a urea/NH_4NO_3 solution into the center lateral of three parallel sprinkler laterals. The rate of N applied in the water then decreased with distance from the center lateral. Tuber yields and other measurements were taken from a series of single row plots planted parallel to the laterals.

In 1980 and 1981, conventional randomized complete block (RCB) experiments were done (Table 2). The treatments consisted of various portions of preplant NH_4NO_3 and sprinkler-applied urea/NH_4NO_3 solution. Each treatment was replicated four times.

Measurements included total tuber yield, grade, specific gravity and tuber dry matter. Nitrogen concentration and uptake were measured in vines and tubers in 1980 and 1981 on samples collected at weekly intervals during the growing season.

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Irrigation was applied daily during the peak evaporation period of the season. Scheduling was done using evaportation pan values, crop coefficients and measurements of the amount of water applied.

Table 1. Nitrogen applications and timing for line source experiments.

YEAR	PLANTING DATE	N APPLICATIONS DATES	N APPLICATIONS DAYS	N APPLICATIONS LB N/ACRE
1978	29 MAR	9 JUN - 2 AUG	54	90[2] - 480
1979	10 APR	8 JUN - 3 AUG	56	90 - 460
1980	17 APR	27 MAY - 6 AUG	71	90 - 590
1983	5 APR	27 MAY - 3 AUG	68	90 - 430

[1] Sprinkler N applications.
[2] 90 lb N/A broadcast/incorporated preplant.

Table 2. Nitrogen applications and timing for randomized complete block experiments.

YEAR	PLANTING DATE	N APPLICATIONS PREPLANT	N APPLICATIONS SPRINKLER[1]	N APPLICATIONS TOTAL
		LB N/ACRE		
1980	18 APR	90	90	180
		180	90	270
		270	90	360
1981	22 APR	90	90	180
		180	90	270
		270	90	360
		0	180	180
		90	180	270
		180	180	360

[1] APPLICATION DATES:
1980 27 MAY - 6 AUG FOR 70 DAYS
1981 11 JUN - 24 AUG FOR 74 DAYS

RESULTS

Tuber Yields

Total tuber yields from the line-source experiments are summarized in Fig. 1. Most of the yield increases from N fertilizer occurs between 90 and 200 lb N/acre. Between 200 and 300 lb N/acre the magnitude of the yield response to N declines and levels off or slightly declines beyond about 300 lb N/acre. Maximum yields varied from 29 ton/acre in 1980 to 37 ton/acre in 1983.

Table 3 is a summary of the tuber yield and other measurements in the 1980 and 1981 RCB experiments. In 1980, there was a decline in total and U.S. No. 1 grade and yield at 360 lb N/acre versus either 180 or 270 lb N/acre.

In 1981, there were no differences in total tuber yield and only a slight increase in U.S. No. 1 tuber yield among the treatments receiving 90 lb N/acre as sprinkler-applied (Treatments 1-3). With no preplant N and 180 lb N/acre sprinkler-applied, a drastic yield decrease resulted from early season N deficiency (Treatment 4). There was a slight increase in total tuber yield but not U.S. No. 1 yield between the treatments totaling 270 lb N/acre (Treatments 2 and 5). No differences in yield were seen with the total of 360 lb N/acre (Treatments 3 and 6). The yields of U.S. No. 1 tubers exhibited a similar pattern of treatment effects as the total tuber yield. From the 1980 and 1981 yield data in Table 3 there is no positive yield response to applications above 270 lb N/acre.

Table 3. Effect of various combinations of preplant and sprinkler-applied N fertilizer treatments on tuber yield, grade, and specific gravity from 1980 and 1981 RCB experiments.

Nitrogen Applied			Yield			Specific‡
Preplant	Sprinkler	Total	Total	U.S. No. 1	Grade†	Gravity
lb N/acre			tons/acre		%	
1980						
90	90	180	31 a§	26 a	84 a	1.088 a
180	90	270	29 a	24 a	81 ab	1.088 a
270	90	360	26 b	20 b	77 b	1.084 b
1981						
90	90	180 (1)*	31 b	22 b	71 b	1.086 a
180	90	270 (2)	31 b	25 ab	78 ab	1.083 bc
270	90	360 (3)	32 ab	26 a	81 a	1.082 c
0	180	180 (4)	25 c	12 c	48 c	1.084 ab
90	180	270 (5)	33 a	25 ab	76 ab	1.086 a
180	180	360 (6)	33 a	27 a	80 a	1.083 bc

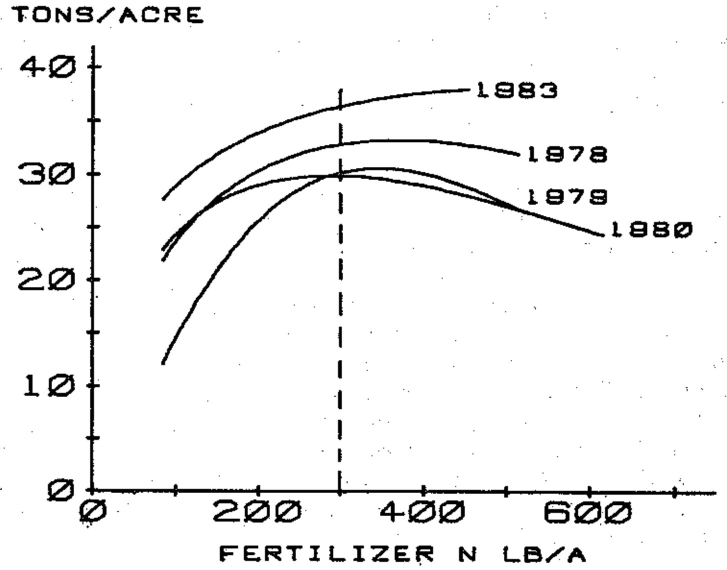
†U.S. number one percentage.

‡Calculated from weight in air and weight in water.

§Means followed by different letters have a 5% probability of being different by chance alone. Separate comparisons made within years.

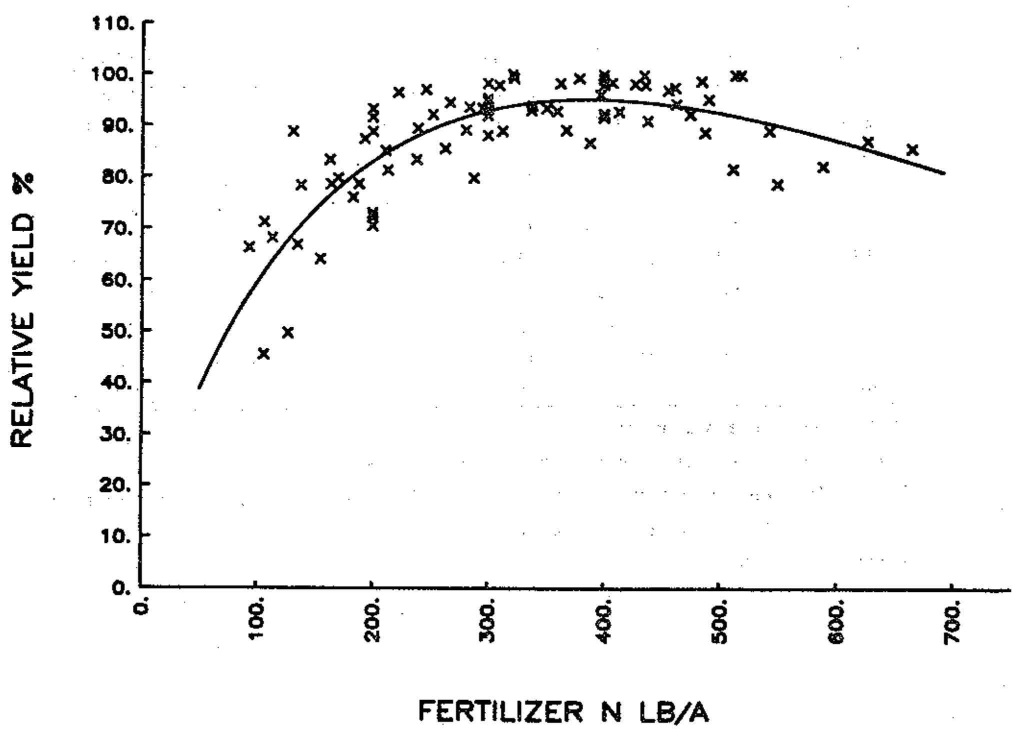
*Treatment number.

Figure 1. Tuber yields from line-source experiments.



Relative yield was calculated by expressing each individual tuber yield value as a percentage of the maximum tuber yield within each experiment. This puts each experiment on the same relative basis and allows the data to be combined across experiments. The resulting combined data was put into Fig. 2 representing yield response to N fertilizer from all six experiments.

Figure 2. Relative tuber yield from all six experiments.



From the curve fit to the data in Fig. 2 and the cost/price ratio of N fertilizer and potatoes an optimum rate of N fertilization can be calculated. The calculation is based on the principle that the last dollar invested in N fertilizer is just returned by the income from an increment of tuber yield. Table 4 is the optimum N rates calculated from a 3.5-fold range of N fertilizer cost and potato prices. Note all the values are below the maximum of 350 lb N/acre. The upper left to lower right diagonal of table values are for a constant cost/price ratio. The 240 and 340 lb N/acre values on the opposite diagonal are a result of the highest cost N and lowest priced potatoes and vice versa. These optimum rates are the range in which the producer should fertilize within this range of fertilizer cost and potato prices.

Table 4. Optimum N fertilizer rates for various fertilizer costs and potato prices.

	POTATO PRICE $/TON					
N COST	35	55	75	95	115	135
$/lb N			lb N/acre			
0.30	310	320	330	330	330	340
0.45	290	310	320	320	330	330
0.60	280	300	310	310	320	320
0.75	270	290	300	310	310	320
0.90	250	280	290	300	310	310
1.05	240	270	290	290	300	310

Tuber Grade

In the 1980 RCB, the % U.S. No. 1 grade declined with increasing N applications (Table 3). This was due to delay of tuber maturity since the grade reduction was mostly for undersized tubers.

In 1981, the U.S. No. 1 grade percentages were the same regardless of the proportion of preplant and sprinkler-applied N at total applications of 270 and 360 lb N/acre (Treatments 2, 5, 3 and 6). However, with 180 lb N/acre split equally between preplant and sprinkler-applied (Treatment 1) there was a lower percentage of U.S. No. 1 tubers compared to 360 lb N/acre (Treatment 3) but not compared to 270 lb N/acre (Treatment 2). With 180 lb N/acre all sprinkler-applied (Treatment 4) the grade was drastically reduced. Figure 3 summarizes grade determinations from the 1980 and 1983 line source experiments plus the values from the 1980 and 1981 RCB experiments. Overall, there is little or no consistent relationship of N fertilizer rate to the U.S. No. 1 grade.

Although, not a total fertilizer rate effect, large grade declines may be caused by N stress or drastic changes in N status. This effect can be seen in the 1981 RCB where 180 lb N/acre was applied entirely through the sprinkler with no preplant application (Table 3). The plants were N deficient early in the season then later supplied with sprinkler-applied N. The resulting sudden shift in N status caused many of the tubers to exhibit a growth constriction giving them a barbell shape.

Figure 3. Lack of relationship between tuber grade and N rate.

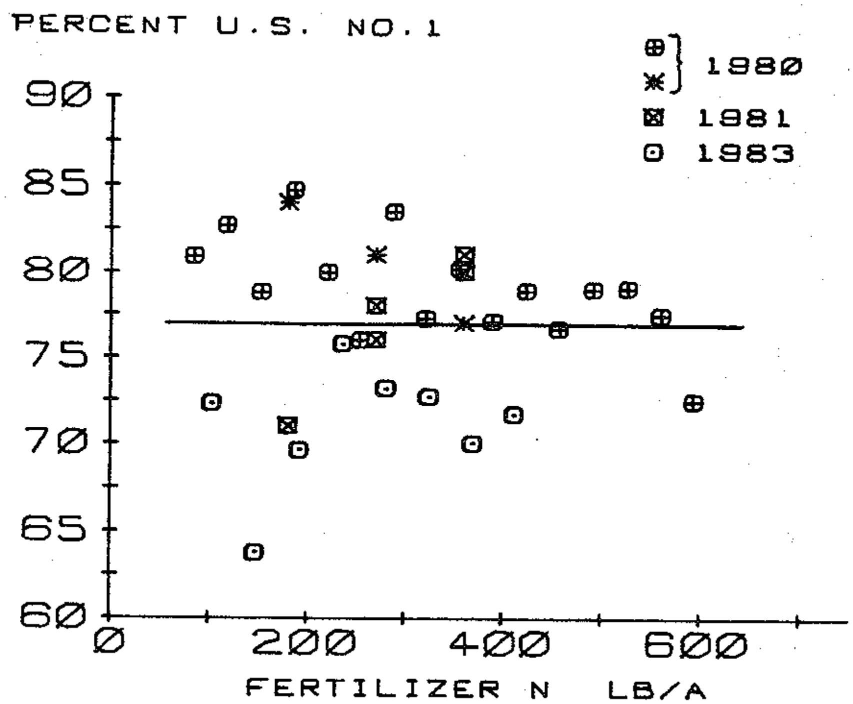
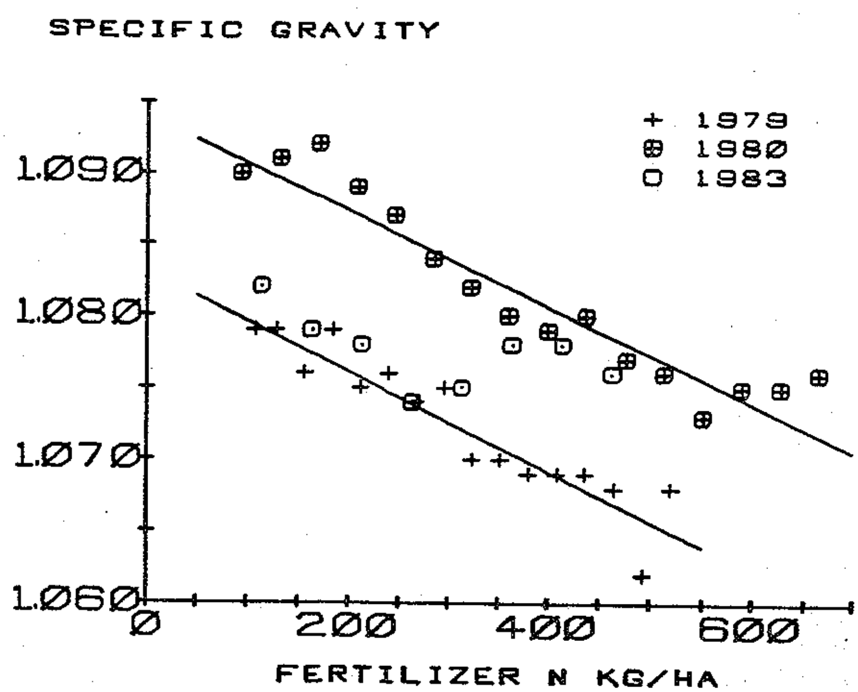


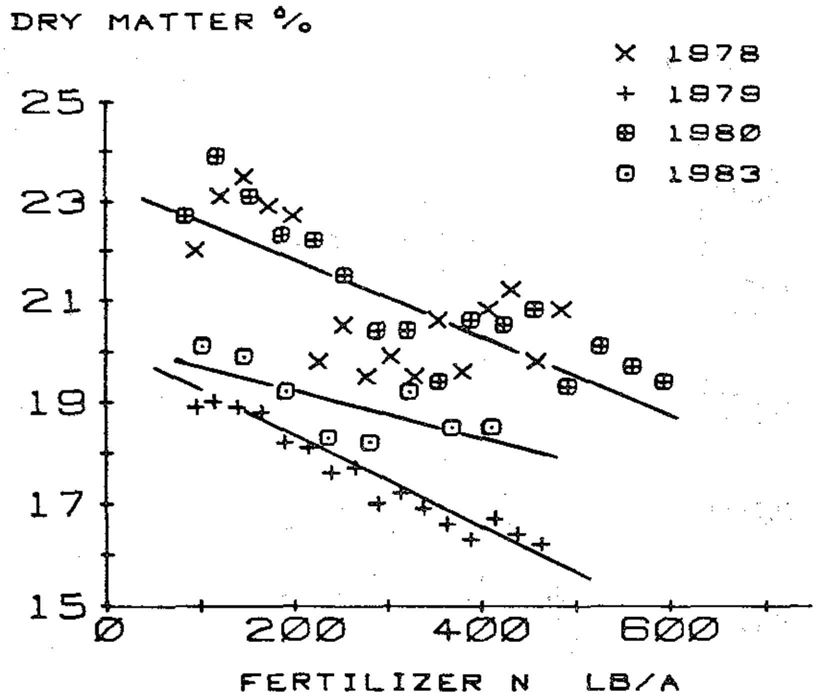
Figure 4. Tuber specific gravity from line-source experiments.



Specific Gravity and Tuber Dry Matter

Generally, there is a decline in specific gravity and tuber dry matter with increasing N fertilizer applications (Table 3, Fig. 4). Tuber dry matter, which is closely associated with specific gravity, consistently decreased in all line-source experiments in 1978, 1979, 1980, and 1983 (Fig. 5). The effect was less pronounced in 1983 than in the other years. The decrease amounts to approximately 0.6% dry matter for each 100 lb N/acre. Fertilization beyond the optimum will likely result in declines in tuber specific gravity and dry matter percentage.

Figure 5. Tuber dry matter from line-source experiments.



Hollow Heart

In the 1981 and 1983 experiments, the tubers were examined for hollow heart incidence. In 1981 only 1.8% of the tubers exhibited hollow heart and these were within 1972 USDA standards for no damage. There was no observable relationship to N fertilization rates or timing. No detectable hollow heart was found in 1983.

Effects of N Fertilization on N Uptake by Vines and Tubers

At fertilizer N rates beyond the optimum range (Table 4) the excess N shows up as large quantities of N in vines and tubers (Fig. 6). This is characterized by vine N uptake rates greater than the tubers for the majority of the growing season. As a result, both the amount of vine growth and N uptake are excessive with large amounts of N still in the vines at harvest. Nitrogen not taken into the plant results in large quantities of residual fertilizer N in the soil following harvest. The tubers also take up N in excess of needs for optimum yield.

By contrast, Fig. 7 shows an uptake pattern in the optimum N fertilizer range. The result is an uptake pattern in which the tubers express dominance for N uptake early in the season with the vines peaking in N uptake within the first one-third to one-half of the post-emergent season. This uptake pattern indicates maximum N fertilizer efficiency on potatoes with minimum soil residual N fertilizer which is achieved by fertilizing in the optimum range (Table 4).

Table 5 shows that frequently the result of excessive N fertilization is to increase yield of vines with no corresponding increase in tuber yield. The vines may actually compete with the tubers for nutrients and dry matter accumulation under stimulation by excessive N fertilization especially if applied late in the growing season.

Figure 6. Nitrogen uptake pattern with above optimum N fertilization.

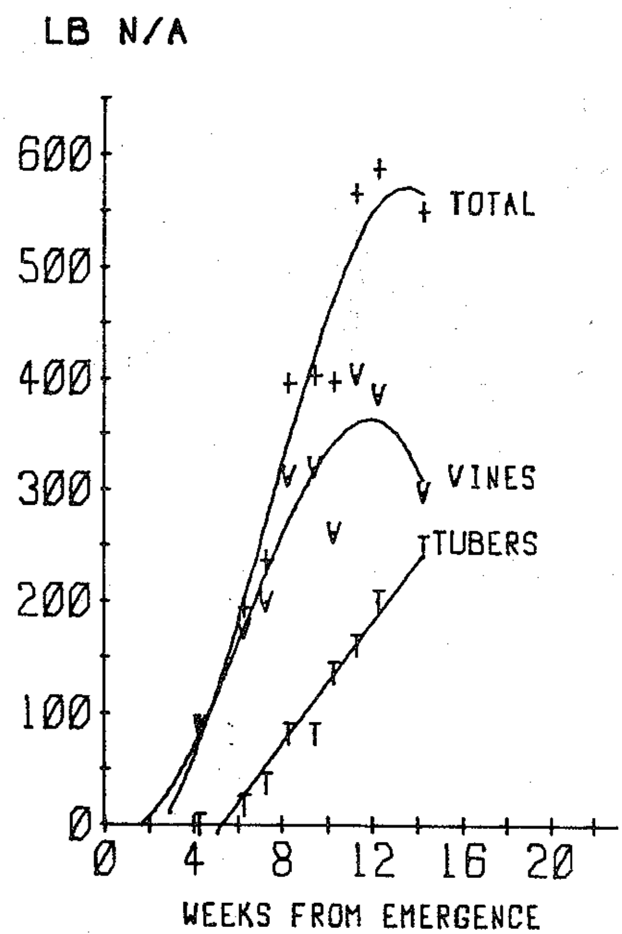


Figure 7. Nitrogen uptake pattern at optimum N fertilization.

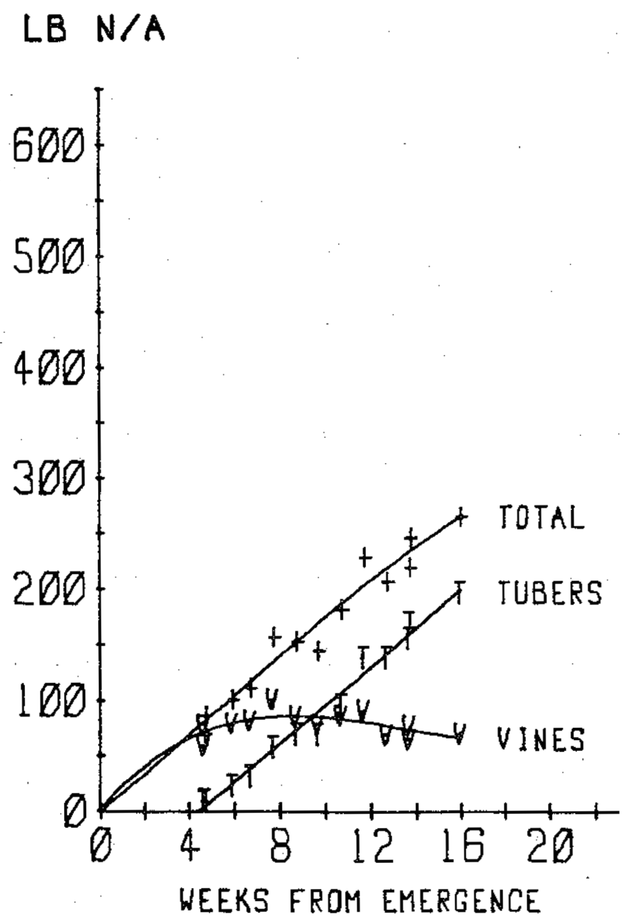


Table 5. Comparison of tuber and vine fresh yields at adequate and excessive N rates.

Year	Nitrogen Applied	Fresh Yields: Tubers Total (No. 1)	Fresh Yields: Vines
	lb N/acre	ton/acre	ton/acre
1979	225	28 (18)	11
	425	29 (19)	20
1980	200	32 (26)	15
	400	30 (23)	25
1981	180	31 (22)	10
	270	31 (25)	13
	360	32 (26)	17

CONCLUSIONS AND RECOMMENDATIONS

1. The optimum range of N fertilization of Russet Burbank potatoes under high-frequency irrigation and nitrogation on sandy soils is between 240 and 340 lb N/acre depending on fertilizer cost and potato prices. For management purposes about 300 lb N/acre is the best single rate.

2. Close control and management of irrigation is essential to efficient N fertilizer use to minimize leaching losses of nitrogen. Rooting depth of potatoes in sandy soils is frequently confined to about 1 to 1-1/2 feet which leaves little margin for over-irrigation.

3. The principal reason for splitting N fertilizer applications between preplant or at-planting and nitrogation is to maximize plant use of the fertilizer and give the grower a wide latitude of management. Plant response per se is not a major factor since yields and quality are frequently no different when comparing all preplant applications and split applications under optimum water management. Split application offers these advantages:

   3.1 Minimizes probability of early season N leaching losses by making less N available for leaching when plants are small and demand less water and N.

   3.2 Allows for less than perfect water management.

   3.3. Maximizes chances for plant uptake by supplying N during period of maximum plant need.

   3.4 Favors tuber growth by not over stimulating vine growth early in the season.

4. Managing nitrogation.

   4.1 While it is relatively easy to begin a schedule of nitrogation, many questions still are unanswered regarding how to split the application, how fast to apply N through the sprinkler, and when to stop.

   4.2 On the research results summarized here and the advantages stated in (3) above the following statement regarding how to split the application is based.

      4.21 Apply between 1/3 and 1/2 of a the total of approximately 300 lb N/A at-planting or preplant. Preplant applications would then be between 100 and 150 lb N/acre.

      4.22 Apply balance through the sprinkler system (nitrogation).

   4.3 The questions of how fast to apply sprinkler N, that is rate per day or week, and when to stop are related. Generally, the total application period will probably be between 70 and 90 days after emergence.

      4.31 There is presently little firm information justifying systematic changes in nitrogation application rates during the season. Some adjustments are necessary in normal management during the season but drastic changes in application rates should be avoided since these may induce "roughness" in the Russet Burbank tubers. Until more is known, a level or constant application rate during the season is as good as any. Decisions based on petiole nitrate monitoring, while convenient and tangible, have limited predictive value because of extreme sampling variation. Petiole nitrates are general guidelines and do diagnose extremes of deficiency or excess but after the fact.

4.32 One key is the general condition and appearance of the vine canopy. As the vine canopy shows significant degradation or die-back this signals that N application should no longer be continued. There is at present no definitive evidence that nitrogen has a preventative role in disease occurrence or that nitrogation will reverse or lessen vine disease effects. On the contrary, lush and excessive vine growth stimulated by excessive N fertilizer may promote disease producing conditions in the vine canopy under high-frequency sprinkler irrigation.

4.33 Late season N applications may be injurious to tuber quality and possibly yield in some cases. Late sprinkler-applied N can stimulate regrowth of deteriorating vines and actually remove nutrients and dry matter from the tubers. A decrease in specific gravity of the tubers would indicate this. There is little danger of too early a cutoff, within limits, since the vines have a reserve of N that the tubers can draw from if vine regrowth is not stimulated by more N applications. After all, potato plants grown on rill-irrigated heavier soils with all preplant N fertilizer rely on translocation from vines to tubers.

5. The vines and tubers are competitors in the Russet Burbank potato. The program of N management outlined here for split application of preplant and nitrogation is designed to give the tuber the competitive edge.