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Nitrogen is one of the most important nutrients influencing potato yields. The potential for environmental pollution from N is also greater than for other nutrients added as fertilizer because excessive amounts applied are subject to leaching into drainage water.

The purpose of this study was to improve N fertilizer recommendations by measuring N taken up and accumulated in Russet Burbank potato plants during the growing season with various rates of N application. The field experiments were conducted in three different geographic locations of Oregon that differ markedly in soil, temperature and length of growing season. Nitrogen uptake and accumulation by whole plants (tops + tubers) was measured when the tubers were 0.75-1.0 inch in diameter and again when the larger tubers were 2.0-2.5 inches long. Nitrogen removed by the tubers at harvest time

was also measured. Amounts of N required to produce the highest total yield and yield of U.S. No. 1 tubers was determined for each location with the field experiments established.

At each location, the amount of N that was removed by the tubers at harvest time was taken up by the plants before the larger size tubers were 2.0-2.5 inches long. This occurred within 97, 69 and 64 days after planting at the Hermiston, Madras and Klamath Falls locations, respectively.

Optimum yield and grade were obtained with 100, 80 and 160 lbs. N/A treatment at the Hermiston, Madras and Klamath Falls locations, respectively. Difference in amounts of N required for optimum yield is a reflection of the length of growing season, N carry over from the previous crop and environmental conditions during the growing season.

This study suggests that most of the N fertilizer should be applied before the larger tubers reach about two inches in diameter and that N taken up and accumulated in the plant tops is translocated to the tubers as the crop matures.

Nitrogen Accumulation During the Growing Season by Russet Burbank Potatoes (Solanum Tuberosum)

by

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INTRODUCTION

Nitrogen (N) is one of the most important nutrients influencing the yield of potatoes. Optimum rates of N fertilizer application vary from 50 to 300 pounds of N per acre (lbs. N/A) depending on the residual N, previous crop grown and length of growing season.

Time of application of N fertilizers, relative to the stage of growth of the potatoes, can affect the grade and yield of tubers. Optimum time and rate of N application to maximize grade and yield has not been established for many areas. In the Pacific Northwest, producers attempt to increase yields and improve grade by N fertilization during the growing season. However, there is little uniformity amongst the producers as to optimum rates and time of N application. Some growers apply N fertilizer at planting time while others prefer split applications.

To determine optimum rate and time of N application, one must measure both the N uptake and accumulation at different stages of plant growth, and the total amount of N removed by the tubers at harvest. With a known N uptake rate, a measured N translocation rate, and a measurement of total N removal, one can improve estimates of desired fertilizer rates and application times.

Objectives

The objective of this investigation was to improve N fertilizer recommendations for Russet Burbank potatoes by studying the uptake pattern of N, its accumulation during the growing season and N removed by tubers at harvest time.

LITERATURE REVIEW

Nitrogen Requirements of Potato Plants

Although plants live and grow in an atmosphere that is 79 percent N (approximately 148, 000 tons of atmosphere N for every acre of land (Miller, 1955), their growth and development is more often limited by the availability of N than of any other element. Nitrogen was the nutrient most closely associated with increased yields of potatoes in more than 80 experiments conducted over 16 years in important potato producing areas in California (Lorenz et al., 1954).

The annual rate of N application needed to produce the highest total potato yield with a desirable grade varies. Painter and Baker (1957) in Idaho found that maximum yields of U.S. No. 1 tubers were obtained by application of 80 lbs. N/A at planting time. Birch et al. (1967) found that maximum yields of Majestic potatoes were obtained with an application of 60 lbs. N/A when a grass and potato rotation was used. When the previous crop was grain, the highest yields were obtained with an application rate of 180 lbs. N/A. At Aroostook Farm, Maine (Murphy, Carpenter and Goven, 1967), maximum yields of Katahdin potato tubers required 150 lbs. N/A. A higher percentage of tubers in the larger size classes occurred with higher levels of N application. Potato yields from the Kennebec and Cherokee varieties increased with up to 210 lbs. of applied

N/A, whereas yields of Mohawk, Russet Burbank and Plymouth potatoes were highest when they were fertilized with 180 lbs. N/A. Jackson (1970) reported that application of 160 lbs. N/A on central Oregon soils which contained 100 lbs. nitrate-N/A at planting time resulted in the highest total yields of Russet Burbank potatoes.

Time of Nitrogen Application

Nitrogen application time can greatly affect growth and yield of potatoes. Nitrogen fertilizer must be applied before peak requirement by the potato plants. Nitrogen accumulates in the above-ground parts of the potato plant during the early part of the growing season and is translocated later during the growing season to the tubers (Dysen, 1965; Hawkins, 1946; Viets, 1965; Werner, 1934; Milthrope and Moorby, 1969).

The relationship between length of growing season and N requirement by potato plants has been studied (Hawkins, 1942; Ivins, 1963; Gunasena and Harris, 1968). Crop response to N fertilization is often determined by the length of growing season. Carpenter (1963) found that total N needs were about 67-87 lbs. N/A and 124-137 lbs. N/A for an early maturing variety, Cobbler, and for a late maturing variety, Russet Burbank, respectively. Kunkel (1968) reported that early crops of potatoes were smaller than late harvested crops and therefore required less N fertilizer.

Doll, Christenson and Wolcott (1971) suggested higher rates of N fertilizer application for maximum yields of Katahdin, Russet Burbank and Sebago potatoes with a 18-21 week growing season; soil nitrate-N values decreased to less than 20 ppm within 10-12 weeks after plant emergence.

Bessey (1967), in his work on N fertilization application times, concluded that the total yield of Red Pontiac potatoes grown in Arizona increased more when 160 lbs. N/A was applied at mid-season than when the same amount of N/A was applied at planting time.

In contrast to the above findings, Lorenz et al. (1954), from the results of approximately 80 fertilizer experiments on potatoes in California, concluded that total optimum yields of White Rose potatoes, an early season variety, were obtained when N fertilizers were applied at planting. Griffin (1970), from his study in Idaho, showed that when N was applied either annually, monthly or weekly to potato plants, the highest total yield of Russet Burbank potatoes was obtained with three monthly applications (total 225 lbs.) of 75 lbs. N/A. The annual application of 225 lbs. N/A produced the highest yield of marketable potatoes while weekly N applications, totaling 225 lbs. N/A, produced the lowest yield of marketable tubers.

Gunasena and Harris (1968), studying the effect of the time of N application on the growth of Craig's Royal potatoes, found that late application of N increased the dry matter yield of tops and decreased

the tuber yields when compared to early application.

Nitrogen Uptake by Potato Plants

Nitrogen, phosphorus and potassium uptake by potato plants is closely associated with the tuber growth (Lorenz et al., 1954). There is very little nutrient uptake during the first 30 days after planting. About 10 percent of the nutrients taken up by potatoes move into the tops between 30-60 days after planting. As the tuber growth commences, the tuber utilizes or stores the nutrients absorbed, and by harvest time more than two-thirds of the total nutrients assimilated by the plants are found in the tubers.

Carolus (1937), Carpenter (1957) and Hawkins (1946) found that N uptake by potatoes grown in Virginia and Maine increased rapidly between 35 and 50 days and began to decline about 80 days after planting. The N uptake pattern was similar to dry-matter accumulation in Russet Burbank tubers (Soltanpour, 1969). Approximately 35 percent of the total N uptake by the potato plants occurred during the 60 days after planting; the remaining 65 percent of N was taken up between 60-88 days after planting. After 88 days almost all of the N utilized by the tubers was translocated from the tops.

Hawkins (1946) reported that Green Mountain potatoes absorbed 143 lbs. N/A, of which less than 16 lbs. N/A or 11 percent of the total was absorbed during the first 50 days after planting. More than

twice this amount, or about 33 lbs., was accumulated during the next 10 days. Nearly 38 lbs. were accumulated during the 61-70 day period and 25 lbs. during the 71-81 day period. Ninety-six lbs., or about two-thirds of the total N accumulated during the season, were taken up during the 31-day period, 51-81 days after planting. During the period 85-95 days after planting, translocation of N into potato tubers took place more rapidly than absorption into the above-ground parts of the plant. He further observed that although the plant tops lost N, the entire plant continued to gain N until the plants were harvested.

Carpenter (1957) concluded from his N uptake study that at any given stage of plant growth when potatoes have adequate nutrients available, they will accumulate these nutrients in amounts which are nearly constant from year to year.

Nitrate-Nitrogen in Petioles

Identification of specific nutrient levels in the plant tissue to measure deficiencies was first suggested 35 years ago (Macy, 1938). The feasibility of this approach has been thoroughly established (Bould, 1963). In potatoes, the nitrate-N levels in petioles have been used to determine the N status of the plant (Baerug, 1964; Gately, 1971; Lorenz et al., 1954; Terman et al., 1951; McKay, MacEachern and Bishop, 1966; Tyler, Fullmer and Lorenz, 1960). Baerug (1964)

and Tyler et al. (1960) recommended using the fourth petiole below the growing tip of the plant to evaluate the N content of the crop. For White Rose, Kennebec, Pontiac and Russet Burbank varieties, the nitrate-N in the fourth petiole was relatively high in early season before tuber initiation but decreased rapidly as the plant aged. At plant maturity, nitrate-N was present in relatively low concentrations (Lorenz, Tyler and Fullmer, 1964). Nitrate-N levels were considered high enough for maximum yields when the dry weight petiole concentration was 12,000, 9,000 and 5,000 ppm nitrate-N at early, mid and late season, respectively (Tyler, Lorenz and Fullmer, 1961). They found that petiole levels of N varied considerably according to age of the potato plant and to nutrient availability. Baerug (1964) reported that nitrate-N concentration of upper leaves (3rd and 4th petioles) varied from 0.66 percent with early season to 0.09 percent with late season.

Variation in nitrate-N levels during the season and with different plant parts must be recognized when establishing plant sampling procedures.

Nitrogen Fertilization and Tuber Quality

It has long been known that N fertilizers added to potatoes reduce the tuber quality (Smith, 1968). Over-fertilization of N on Norland potatoes reduced the specific gravity of tubers compared to

unfertilized potatoes (Zandstra, Anderson and Dawley, 1969). In Kern County, California, Lorenz (1944) found that the starch content of potatoes decreased from 17 percent in tubers produced without N fertilization to less than 13 percent in tubers grown on plots receiving 210 lbs. N/A. Houghland et al. (1962) reported that when 80 and 160 lbs. N/A were applied to potatoes, the tuber dry matter and percent starch were reduced by 1.6 and 2.5 percent respectively at the higher rate of N application.

MATERIALS AND METHODS

Experimental Areas

Experiments were conducted during the 1972 growing season to evaluate effects of N fertilization and irrigation treatments on yield and grade of Russet Burbank potatoes at three locations--Hermiston, Madras and Klamath Falls, Oregon. These three geographic areas of the state differ markedly in soil and climatic conditions and thus require different fertilizer and irrigation practices with the different length of growing season to obtain optimum tuber yields and grade.

Plot Design

Each experiment was established with six N treatments replicated six times with both rate and time of application being evaluated. Each replication was 30 ft. x 60 ft. in size, with the sprinkler heads from a 30 ft. x 30 ft. solid set system on the edge of each replication. The N treatments were applied to two rows 30 ft. long with a guard row between each plot plus guard rows between the N plots and the sprinkler line to avoid possible error from leaks in the line. A border of irrigated potatoes 30 ft. wide was maintained around the plot area.

Details on plant sampling, sample preparations and harvesting procedures will be given following the establishment procedures

used at each location.

Hermiston

The experiment was conducted at the Umatilla Experiment Station on a Ephrata loamy sand soil on which a wheat crop was grown in 1971. After primary tillage in the spring of 1972 the soil was treated with Dyfonate for wireworm and Di-syston for aphid control. Soil test analysis showed 106 lbs. N/A as nitrate-N (0-3 ft. depth), 11 ppm P, 290 ppmK and soil pH 7.2 (1:2, soil:water). Prior to planting, a blanket application of 35 lbs. of phosphorus, 133 lbs. of potassium and 5 lbs. of zinc per acre were broadcast and disked into the surface soil to a depth of six inches.

Oregon certified Russet Burbank potato seed was planted on March 17 at a seed piece population of 21,000 per acre. The seed pieces were placed 9 inches apart within the row and the rows spaced 33 inches apart. At planting time, 100 lbs. N and 55 lbs. of phosphorus per acre as 16-20-0 ammonium phosphate was appled in a band 2 inches to the side and 2 inches below the seed piece.

Four N treatments of 100, 180, 260, and 340 lbs/A were applied. Each treatment included 100 lbs N/A as ammonium phosphate-sulfate banded at planting plus the remaining N as ammonium sulfate banded immediately after plant emergence. Two added treatments with N applied during the growing season were compared with

applications of 160 and 240 lbs. N/A applied between 83 and 125 days after planting in equal biweekly applications. Nitrogen treatments thus included rates of 100, 180, 260 and 340 lbs./A.

The experiment was irrigated by replacing 100 percent of the water lost during a 3-day interval from a standard evaporating pan located within the plot area.

Vine, tuber and petiole samples were collected on June 8 and June 22. Tuber samples were also collected at harvest time, September 11.

Madras

The experiment was conducted at the Madras Experiment Station on a Madras loam soil on which irrigated winter wheat was grown during the 1971 season. Soil test analysis showed 94 lbs. N/A as nitrate-N (0-2 ft. depth), 20 ppm P, 350 ppm K and soil pH 7.0 (1:2, soil:water). Di-syston was applied before planting for aphid control; it was disked into the surface soil to a depth of 4-5 inches.

Oregon certified Russet Burbank potato seed was planted on May 5 at a seed piece population of 21,000 per acre. The seed pieces were placed 9 inches apart within the row and the rows spaced 33 inches apart. At planting time 35 lbs. of phosphorus/A was applied banded 2 inches to the side and 2 inches below the seed piece.

Three N treatments including 0, 80 and 160 lbs. N/A as a

band 2 inches to the side and 2 inches below the seed piece were applied. Additional N treatments included 240 lbs. N/A plus a comparison between 160 and 240 lbs. N/A with half of the N applied at planting time and the other half of N applied 55 days after planting.

The experiment was irrigated by replacing 100 percent of the water lost during a 3- or 4-day irrigation interval (twice per week) from a standard evaporating pan located within the plot area.

Vine, tuber and petiole samples were collected on June 29 and July 13. Tuber samples were also collected at harvest time, October 8.

Klamath Falls

The experiment was conducted at the Klamath Experiment Station on a Henley loam soil which had produced an alfalfa crop during the 1971 growing season. Soil test analysis showed 20 ppm P, 370 ppm K and soil pH 7.0 (1:2, soil:water). Soil N was not measured because of alfalfa sod present from the previous crop. Di-syston was applied to the soil in the spring of 1972 after primary tillage for aphid control.

Oregon certified Russet Burbank potato seed was planted on June 1 at a seed piece population of 21,000 per acre. The seed pieces were planted 8-9 inches apart within the row and the rows spaced 32 inches apart. At planting time 35 lbs./A of phosphorus

was applied in a band 2 inches to the side and 2 inches below the seed piece.

Four N treatments including 0, 80, 160 and 240 lbs. N/A as ammonium sulfate were applied at planting time as a band 2 inches to the side and 2 inches below the seed piece. Two additional treatments compared single application at planting time versus half of the N at planting and the other half applied 49 days after planting at 160 and 240 lbs. N/A rates.

The potatoes were irrigated by replacing 100 percent of the water lost on a 3- or 4-day irrigation interval (twice per week) from a standard evaporating pan located within the plot area.

Vine and tuber samples were collected on August 4. Tuber samples were also collected at harvest time, October 16. Petiole samples were collected on July 20 and August 4.

Vine, Tuber and Petiole Sampling

Potato vine (tops) and tuber samples were collected to determine N uptake and accumulation by whole plants (tops + tubers) at different stages of plant growth. The samples were collected when the tuber size was 0.75-1.0 inch in diameter, and about two weeks later when the larger size tubers were 2.0-2.5 inches long. Tuber samples were also collected at harvest time to determine the amount of N removed by the crop.

Whole potato plants were removed from 6 ft. of row for each plot. The tops and the tubers were separated and weighed in the field. Moisture samples were taken to calculate yields on an oven-dry basis. Tops and tuber samples were dried separately in a forced-air oven at 70°C.

Petioles were removed during the growing season for nitrate-N determination. The fourth petiole from the growing tip of the plant was cut close to the stem; the leaves and one inch of the tip end was discarded. This selection usually resulted in sampling the petiole with the most recently matured leaf. Fifteen petioles were collected from each plot between 10:00 a.m. and 1:00 p.m., placed in paper bags and dried in a forced-air oven at 70°C.

Analysis of Samples

The dried vine and tuber samples were ground with a Wiley Mill to pass a 0.0625 inch diameter screen. The plant tissue was sub-sampled and 0.5 gram of each sub-sample was analyzed for total N after digestion by a modified micro Kjeldahl method (Johnson and Ulrich, 1959).

The dried petioles were ground with a Wiley Mill to pass a 20 mesh screen. Each sample (0.5 gram) was analyzed for nitrate-N by the Devarda's alloy steam distillation procedure (Bremner and Keeney, 1965). Ammonium-N was distilled off before Devarda's

alloy was added to reduce nitrate-N to ammonium-N.

Harvesting and Grading

Two rows 20 ft. long were harvested from each N treatment. Total yield was obtained and tubers were hand graded according to standards set by the U. S. D. A. effective September 1, 1971 as amended February 5, 1972 (1972). The U. S. No. 1 and No. 2 grades were separated into 4-6 ounce, 6-10 ounce and 10+ ounce sizes. A minimum size of 4 ounces and 2 inches in diameter was used to separate culls from marketable potatoes.

Statistical Analysis

All the data were analyzed on the 3300 digital computer at the Computer Center at Oregon State University with some additional calculations on a desk calculator.

RESULTS AND DISCUSSION

Nitrogen Uptake and Accumulation at Different Stages of Plant Growth

Hermiston

Nitrogen accumulation in potato tops at the first sampling, 83 days after planting when the tubers were 0.75-1.0 inch in diameter, was 110, 131, 145 and 139 lbs. N/A for the 100, 180, 260 and 340 lbs. N/A treatments, respectively (Table 1). At the same time, N uptake by the potato tubers was 11 lbs./A for each treatment. Thus, total N accumulation by whole plants (tops + tubers) was 121, 141, 155 and 150 lbs./A with increases in N rates (Table 1). At this time, 91, 92, 93 and 93 percent of N was found in the tops and 9, 8, 7 and 7 percent of N was found in the tubers for the respective application rates.

Nitrogen accumulation in the plant tops at the second sampling, 97 days after planting when the larger tubers were about 2.0-2.5 inches long and the vines had formed a complete ground cover, was 83, 125, 139 and 129 lbs. N/A for the 100, 180, 260 and 340 lbs. N/A treatments while the tubers had accumulated 27, 27, 29 and 29 lbs. N/A, respectively (Table 1). Thus, total N accumulation in whole plants was 110, 152, 168 and 158 lbs. N/A with increases in

Table 1. The effect of N fertilization on concentration of N in plant tops and N uptake by Russet Burbank potatoes at different stages of plant growth at three experimental locations.

Location	N applied lbs. /A	Days after planting	Total N conc. percent	N uptake lbs. /A		
				Tops	Tubers	Total
Hermiston		83[a]	4.56	109.98	11.21	121.19
	100	97[b]	3.57	83.42	26.65	110.07
		163[c]	d	d	138.63	138.63
		83	4.66	130.54	10.36	140.80
	180	97	4.12	124.64	27.32	151.96
		163	d	d	137.62	137.62
		83	4.95	144.52	10.70	155.22
	260	97	4.38	139.42	28.68	168.10
		163	d	d	156.58	156.58
		83	5.05	138.89	10.96	149.85
	340	97	4.12	129.47	29.14	158.61
		163	d	d	154.82	154.82
Madras		55[a]	3.80	56.79	12.18	68.97
	0	69[b]	2.76	49.78	31.04	80.82
		133[c]	d	d	86.32	86.32
		55	4.22	76.96	15.66	92.62
	80	69	3.06	80.31	41.54	121.85
		133	d	d	96.25	96.25
		55	4.91	79.95	11.22	91.17
	160	69	4.19	107.69	39.70	147.39
		133	d	d	119.94	119.94
Klamath Falls		49[a]	3.36	d	d	d
	0	64[b]	3.57	82.00	27.46	109.46
		99[c]	d	d	92.68	92.68
		49	3.20	d	d	d
	80	64	3.51	88.94	23.94	112.88
		99	d	d	92.42	92.42
		49	3.91	d	d	d
	160	64	3.49	100.94	28.73	129.67
		99	d	d	101.04	101.04
		49	3.67	d	d	d
	240	64	3.76	86.19	16.53	102.72
		99	d	d	90.93	90.93

[a]Number of days when larger tubers were .75 - 1 inch in diameter

[b]Number of days when larger tubers were 2.0 - 2.5 inches long

[c]Number of days when tubers were harvested

[d]Not determined

N application (Table 1). At this time, 76, 82, 83 and 82 percent of N was found in the tops and 24, 18, 17 and 18 percent of N was found in the tubers for the respective treatments.

At harvest time, 163 days after planting, 139, 138, 157 and 155 lbs. N/A was removed by the tubers with increases in N treatments (Table 1). Nitrogen concentration of vines was not determined at maturity because many of the leaves had died and dropped from the plant. Approximately 80 percent of the amount of N found in the plants (tops + tubers) at the second sampling time, 97 days after planting, was removed by the tubers at harvest.

As plant growth progressed from emergence to the time when the tubers were 0.75-1.0 inch in diameter, the plants continued to remove N from the soil, with most of the N accumulated in the plant tops (Table 1). Vines had the maximum N concentration at this time (83 days after planting, Table 1). An increase in the rate of N fertilizer application generally increased N accumulation in the plant tops but not in the tubers (Table 1). The fourth petiole from the growing tip of the plants showed a similar trend in the nitrate-N percentage. An increase in the N rate from 100 to 180 lbs./A increased the nitrate-N content from 2.41 to 3.25 percent. Additional 80 lb. N increments increased the nitrate percentage to 3.25 at 180, 3.52 at 260 and 3.42 at 340 lbs./A treatments. This is in accordance with that reported by Jacks (1972) who stated that there was an

increase in the petiole nitrate-N level as the level of N fertilizer was increased from 116 lbs. to 356 lbs. with 80 lb. increments at Hermiston, Oregon.

Carpenter (1963) has also observed that N concentration in Russet Burbank potato vines during the 1960 study was high in early stages of growth (49-55 days after planting) when the growing season was 97 days. He found N concentration varied from 5.19 percent to 2.57 percent with biweekly samplings starting 48 days after planting. He also reported that by increasing the N rates, there was an increase in N accumulation in Kennebec, Katahdin, Cobbler and Russet Burbank potatoes.

At the second sampling time, N accumulation in the tops declined while N accumulation in the tubers increased (Table 1). The plants (tops + tubers), however, continued to take up N from the soil (Table 1). The concentration of nitrate-N and total N of petioles and vines respectively was lower at this time (97 days after planting) but still reflected the increases in N rates applied (Table 1, Appendix Table 1). These data show that an amount of N equal to the total removed by the tubers at harvest time had been taken up and accumulated in the plants by the second sampling time (Table 1, Figure 1).

The N accumulation pattern of potatoes grown at Hermiston agrees with that found by Carpenter (1963) and Ezeta and McCullum (1972). Carpenter (1963) in Maine observed that the amount of N

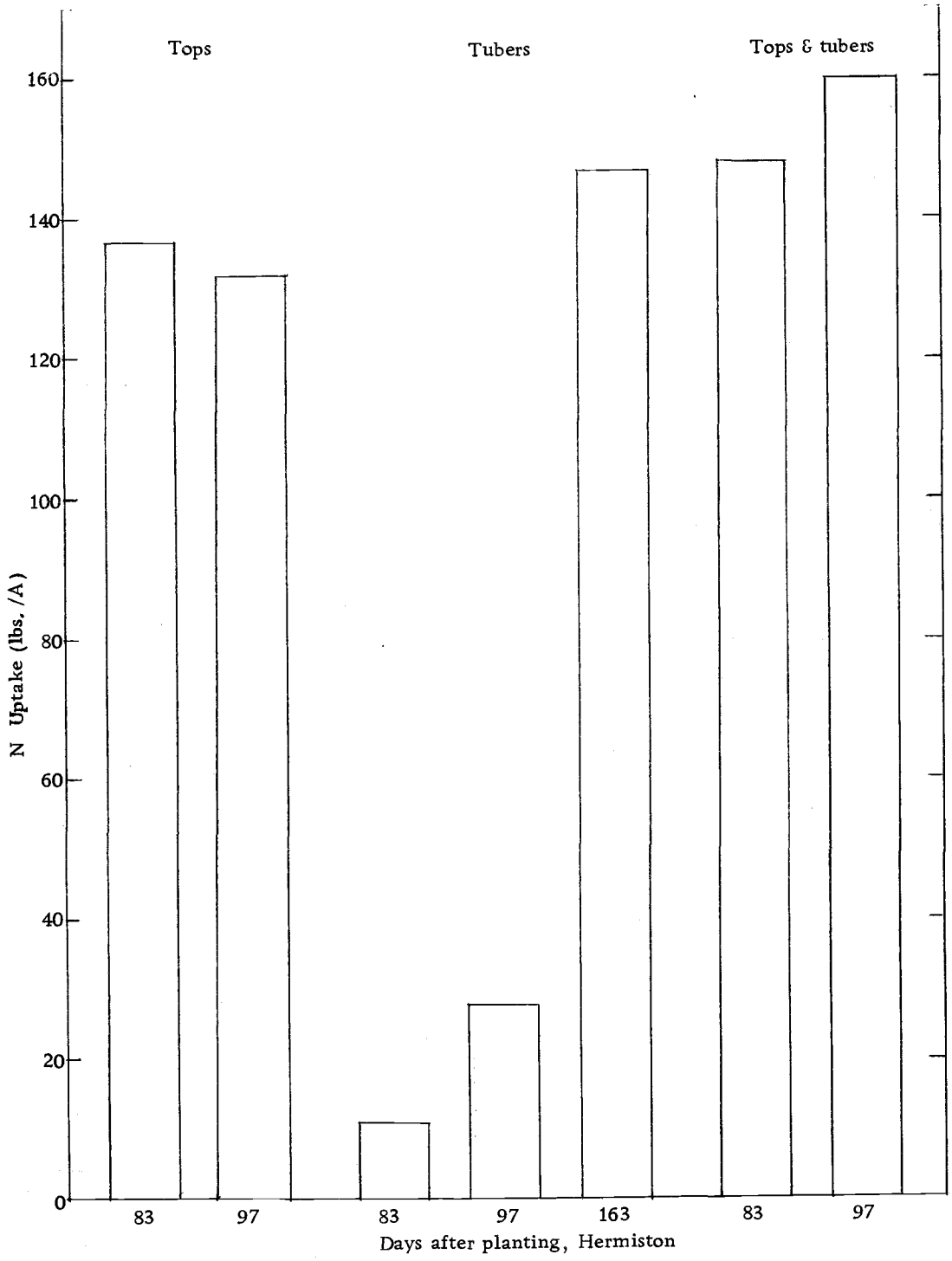

Figure 1. Nitrogen accumulation by tops and tubers of Russet Burbank potatoes 83 and 97 days after planting and at harvest (N removed by tubers), Hermiston (Data from treatments producing optimum yield, 2 and 3, were averaged)

eventually removed by tubers at harvest was taken up by whole plants between 64-72 day interval after planting by Kennebec potatoes with 97 days of growing season. The following year, when the length of growing season was 89 days, all N removed by tubers at harvest had been accumulated in the plants between the 61-68 day interval after planting. Ezeta and McCollum (1972) reported that Solanum Andigena potatoes grown in Peru had accumulated all the N that was removed by tubers at harvest, by the time the tubers were about 1 inch in diameter, about 137 days after planting with a 193 day growing season.

The variations in N uptake rates under different growing conditions and with different varieties make it important to study these problems in the areas where the specific N fertilizer recommendations being established will be used.

Madras

Nitrogen accumulation in plant tops at the first sampling, 55 days after planting when the tubers were 0.75-1.0 inch in diameter, was 57, 77 and 80 lbs. N/A for the 0, 80 and 160 lbs. N/A rates (Table 1). At the same time, N uptake by the tubers was 12, 16 and 11 lbs./A (Table 1). Thus, total N accumulation by whole plants was 69, 93 and 91 lbs./A with increases in N treatments (Table 1). At this time, 83, 83 and 88 percent of the N was found in the tops with 17,

17 and 12 percent in the tubers for the respective N treatments.

Nitrogen accumulation in the plant tops at the second sampling, 69 days after planting when the larger tubers were 2.0-2.5 inches long and the vines had formed a complete ground cover, was 50, 80 and 108 lbs./A while the tubers had accumulated 31, 42 and 40 lbs. N/A with 0, 80 and 160 lbs. N/A treatments respectively (Table 1). Thus, total N accumulated by whole plants was 81, 122 and 147 lbs./A with the increases in N application (Table 1). At this time, 62, 66 and 74 percent of the N accumulated by the plants was found in the tops and 38, 34 and 26 percent was found in the tubers for the respective treatments.

At harvest time, 133 days after planting, 86, 96 and 120 lbs. N/A was removed by the tubers with increases in N treatments (Table 1). Nitrogen removed by the tubers at harvest was higher with increased N application rates (Table 1). Sixty-three, 54 and 67 percent of the N removed by the tubers at harvest time was translocated there after the second sampling, 69 days after planting.

As plant growth progressed from emergence to the time when the tubers were 0.75-1.0 inch in diameter, the plants continued to remove N from the soil, with most of the N accumulated in the plant tops (Table 1). The vines had the maximum N concentration at this time (55 days after planting, Table 1). The fourth petiole from the growing tip of the plants showed a similar trend in the nitrate-N

concentration. An increase in the rate of N fertilizer application increased the nitrate-N concentration in the petiole (Appendix Table 1). Increasing the N rates to 160 lbs./A increased the N accumulation in the plant tops but not in the tubers. The largest amount of N removed by the tubers occurred with the 80 lbs./A rate of N; this treatment also produced the highest yield of tubers (Tables 1 and 2).

At the second sampling time, N accumulation in the tops declined with the low N treatment but increased with the intermediate and the high levels of N application (Table 1). Thus, in this experiment the N accumulation pattern was not consistent. During the same growth period, N accumulation in the tubers increased (Table 1). The percentage of nitrate and total N in petioles and tops respectively was decreased at this time (69 days after planting, Appendix Table 1 and Table 1). Thus, these data (Figure 2, Table 1) show that an amount of N equal to the total removed by the tubers at harvest time had been taken up and accumulated in the plants by the second sampling.

Klamath Falls

At the first sampling, 49 days after planting when the tubers were 0.75-1.0 inch in diameter, the nitrate-N concentration of the fourth petiole was 2.43, 2.64, 2.60 and 2.58 percent and the total N concentration was 3.36, 3.20, 3.91 and 3.67 percent for the 0, 80, 160 and 240 lbs. N/A treatments, respectively (Appendix Table 1 and

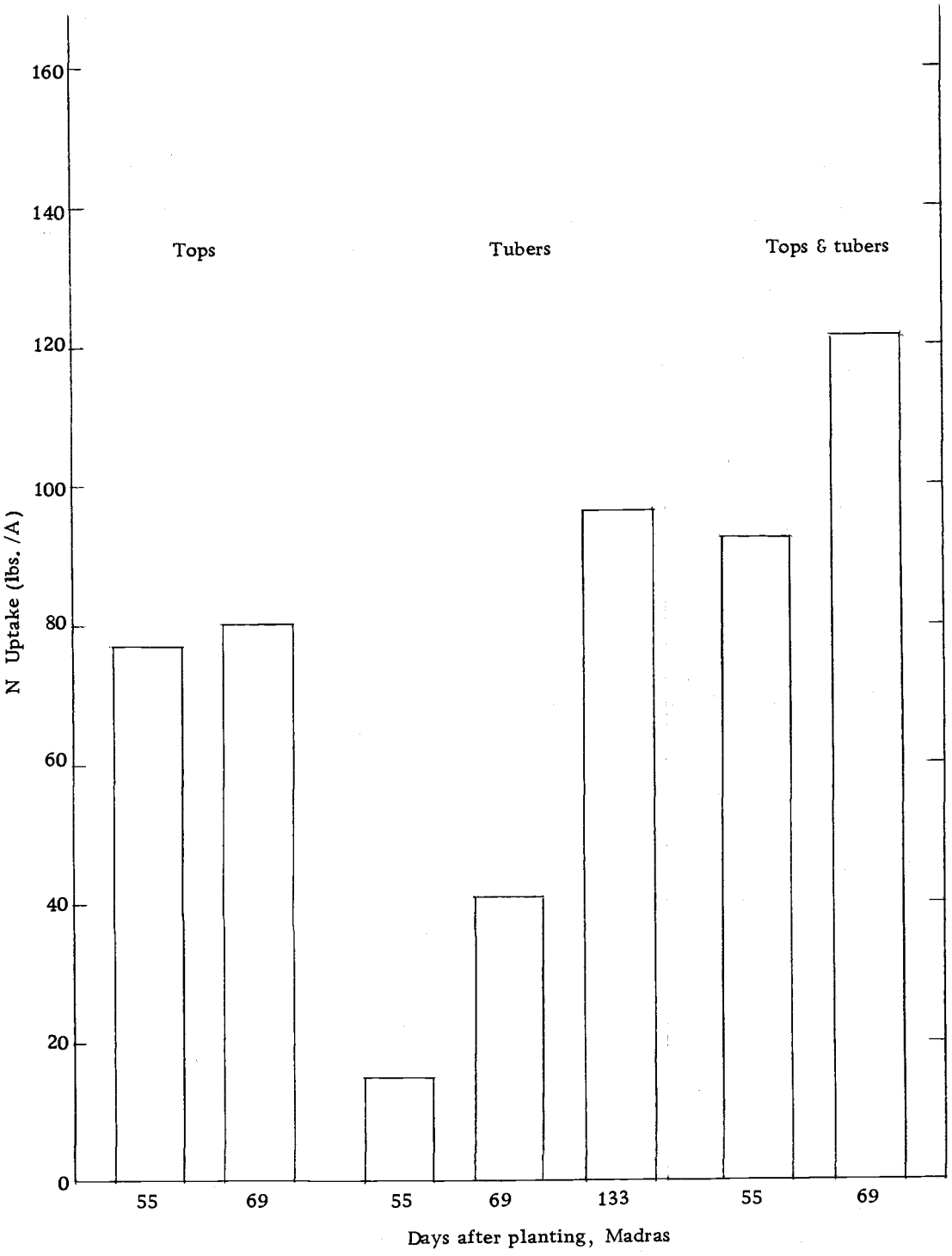

Figure 2. Nitrogen accumulation by tops and tubers of Russet Burbank potatoes 55 and 69 days after planting and at harvest (N removed by tubers), Madras (Data from treatment 2 producing optimum yield)

Table 1).

Nitrogen accumulation in the plant tops, 64 days after planting when the larger size tubers were 2.0-2.5 inches long and the vines had formed a complete ground cover, was 82, 89, 101 and 86 lbs./A while the tubers had accumulated 27, 24, 29 and 17 lbs. N/A with the 0, 80, 160 and 240 lbs. N/A treatments, respectively (Table 1). Thus, total N accumulated by whole plants was 109, 113, 130 and 103 lbs./A with increases in N application rates (Table 1). At this time, 75, 79, 78 and 83 percent of the N accumulated by the plants was found in the tops and 25, 21, 22 and 17 percent was found in the tubers for the respective treatments.

At harvest time which was 99 days after planting, 93, 93, 101 and 91 lbs. N/A was removed by the tubers with increased N application rates (Table 1). Approximately 74 percent of the N removed by tubers at maturity was translocated into the tubers after the second sampling, 64 days after planting.

The nitrate-N content in the petiole declined from an average of 2.56 percent at the first sampling (55 days after planting) to an average of 1.72 percent 64 days after planting for the four N treatments (Appendix Table 1). However, on this location where an alfalfa crop preceded the potatoes, the average total N concentration in the plant tops increased from 3.54 percent, 55 days after planting, to 3.73 percent, 64 days after planting for the four N treatments.

Nitrogen accumulation in the plant tops 64 days after planting when the larger size tubers were 2.0-2.5 inches long, increased with increase in N treatment rates from 0 to 160 lbs./A but decreased with the additional 80 lb. increment (Table 1). Nitrogen accumulation in the tubers was inconsistent; it varied from 17 lbs. N/A with the highest N rate, 240 lbs./A, to 29 lbs. N/A with the 160 lbs. N/A treatment (Table 1).

These data (Figure 3, Table 1), thus, show that an amount of N equal to the total N removed by the tubers at harvest time had been taken up and accumulated in the plants at 64 days after planting when the larger tubers were 2.0-2.5 inches long.

Nitrogen Fertilization, Total Yield and Grade

Hermiston

Total tuber yields of 31.1, 30.8, 30.9 and 30.1 tons per acre (T/A) were obtained with the 100,180, 260 and 340 lbs. N/A treatments respectively (Table 2). The highest percentage of U.S. No. 1 tubers, 80 percent of the total yield, was obtained with the 260 lbs. N/A treatment. There was little difference between the percent U.S. No. 1 tubers for the 100, 180 and 260 lbs. N/A treatments; the percent of U.S. No. 1 tubers was reduced to 75 for the 340 lbs. N/A application (Table 2).

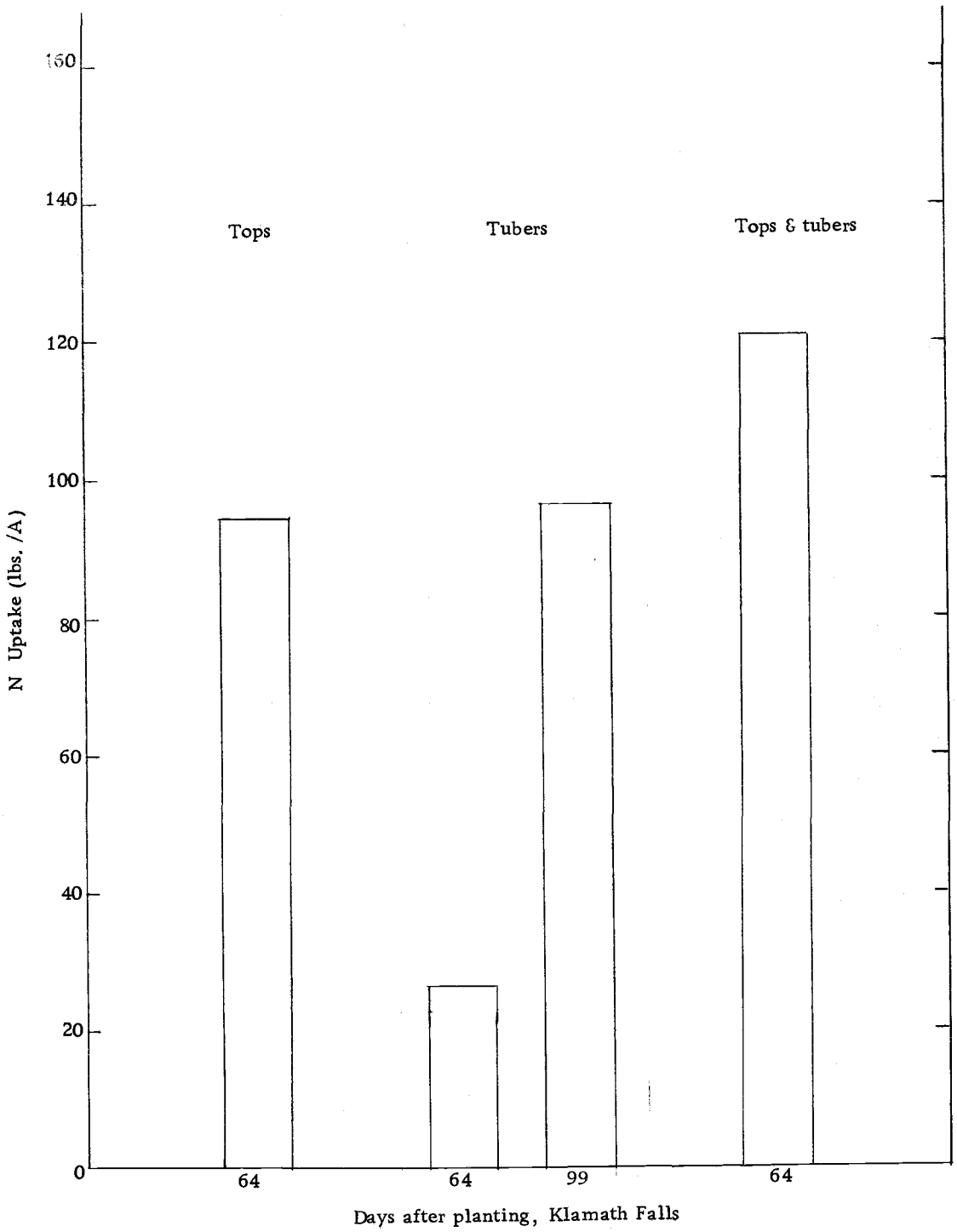

Figure 3. Nitrogen accumulation by tops and tubers of Russet Burbank potatoes 64 days after planting and at harvest (N removed by tubers), Klamath Falls (Data from treatments producing optimum yield, 2 and 3, were averaged)

Table 2. The effect of N fertilization on tuber yield and grade of Russet Burbank potato at three experimental locations

Location	N applied lbs. /A	Yield Tons/A	USDA No. 1 (%)	Size distribution 4-6 oz (%)	6-10 oz (%)	10+ oz (%)
Hermiston	100	31.1	78.8	17.0	43.5	35.4
	180	30.8	77.3	16.6	39.1	40.5
	260	30.9	80.0	13.4	41.8	41.4
	340	30.1	75.4	15.6	40.7	40.2
Madras	0	18.3	71.6	24.2	41.7	12.6
	80	19.6	71.4	27.4	37.2	12.7
	160	18.6	67.7	22.7	38.1	18.0
Klamath Falls	0	13.9	62.3	37.5	24.9	5.2
	80	14.2	63.3	36.7	28.2	7.1
	160	16.0	68.5	33.6	29.9	8.7
	240	13.8	64.4	32.5	27.4	6.3

Increasing the N application rates did not increase the total tuber yield. The higher N treatments tended to increase the dry matter of vines and reduce the tuber dry matter (Appendix Table 2).

Ivins (1964) likewise found that excess N fertilization of potatoes did not increase the total tuber yield, but rather increased the dry matter of the tops and reduced the tuber yields by delaying the maturity. Yungen, Hunter and Bond (1958) obtained a maximum total yield of tubers with a 100 lbs. N/A treatment rate.

Madras

Total tuber yields of 18.3, 19.6 and 18.6 T/A were obtained with the 0, 80 and 160 lbs. N/A treatments, respectively (Table 2). The highest percent of U.S. No. 1 tubers, 72 percent of total yield, was obtained with the 0 lbs. N/A treatment, whereas 71 and 68 percent U.S. No. 1 of total yield was obtained with the 80 and 160 lbs. N/A treatment rates, respectively (Table 2).

Increasing the N fertilizer treatment rate from 0 to 80 lbs./A increased the total tuber yield by 1.3 T/A. The second 80 lbs. N/A increment reduced the total yield by 1 T/A (Table 2). The maximum U.S. No. 1 tuber yield was obtained with the 0 and 80 lbs. N/A treatment; the additional N increment reduced the U.S. No. 1 tubers by four percent (Table 2). The lower yield of tubers at this location, 19 T/A, compared to the Hermiston experiment with 31 T/A, was probably

due to the shorter growing season (Table 2).

Jackson (1970), in unpublished data, reported that the yield of Russet Burbank potatoes decreased 6.4 T/A when the planting date was delayed from May 5 to May 24 in a N fertilization management study in Madras, Oregon.

Klamath Falls

Total tuber yields of 14.0, 14.2, 16.0 and 13.2 T/A were obtained with 0, 80, 160 and 240 lbs. N/A treatments, respectively (Table 2). The highest yield of U.S. No. 1 tubers, 68 percent, was obtained with the 160 lbs. N/A rate; 62, 63 and 64 percent U.S. No. 1 tuber yields were obtained with the 0, 80 and 240 lbs. N/A treatments, respectively (Table 2).

The first 80 lb. increment of N did not increase the yield but increasing the N rate from 80 to 160 lbs./A increased the total yield by 1.8 T/A. The third 80 lbs. N increment reduced the total yield by 2.2 T/A (Table 2). The first increment of N had little effect on grade but increasing N application from 80 to 160 lbs./A increased the U.S. No. 1 by 5 percent. An additional N increment tended to reduce the U.S. No. 1 tubers (Table 2). The highest N rate increased vine growth and reduced tuber dry matter at harvest (Appendix Table 2). Total tuber yield further declined at this location due to shorter length of growing season as compared with the other two

locations (Table 2).

In summary, increasing the N fertilizer rates did not increase the total and U. S. No. 1 yields. The length of growing season, the N status of soil prior to N fertilization and N treatments ultimately determined the total yields and grade of Russet Burbank potatoes at Hermiston, Madras and Klamath Falls.

SUMMARY AND CONCLUSION

The pattern of N uptake and accumulation by Russet Burbank potato plants during the growing season was studied at three different geographic locations of Oregon to provide data that could be used to improve N fertilizer recommendations. Yield and grade data were collected from all experiments.

Optimum yield of U. S. No. 1 tubers was obtained with 100, 80 and 160 lbs. N/A at Hermiston, Madras, and Klamath Falls, respectively. These treatments had 2.41, 1.99 and 2.60 percent nitrate-N, respectively, in the fourth petiole at the first sampling time indicating that these nitrate concentrations were adequate for optimum yield and grade.

Nitrogen taken up by the plants and accumulated in the vines was translocated to the tubers as the crop approached harvest. As the vines matured, the total amount of N in the tops decreased. In each experiment the total amount of N removed by the tubers at harvest had been taken up by the plants when the larger size tubers were 2.0-2.5 inches long.

In summary, sufficient N had been taken up by the plants at all three locations by the time the larger size tubers were 1.5-2.0 inches long and the vines had developed a complete ground cover to supply N removed by the tubers at harvest time. These results indicate

that N applied during the latter part of the growing season, after the larger tubers reach about two inches in diameter, might not be used in increasing yield or N content of the tubers.

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APPENDIX

Appendix Table 1. Concentration of petiole nitrate-N on dry weight basis as influenced by N fertilization treatments on Russet Burbank potatoes at different growth stages.

Location	N applied (lbs./A)	days after planting	percent nitrate-N
Hermiston	100	83	2.41
		97	0.87
	180	83	3.25
		97	1.88
	260	83	3.52
		97	2.46
	340	83	3.42
		97	2.52
Madras	0	55	1.08
		69	0.16
	80	55	1.99
		69	0.92
	160	55	2.60
		69	1.85
Klamath Falls	0	49	2.43
		64	1.66
	80	49	2.64
		64	1.55
	160	49	2.60
		64	1.85
	240	49	2.58
		64	1.84

Appendix Table 2. Dry matter of plant tops and tubers of Russet Burbank potato with different rates of N fertilization at three locations.

Location	Days after planting	Application rate - lbs. N/A							
		100		180		260		340	
		tops	tubers	tops	tubers	tops	tubers	tops	tubers
Hermiston	83	2269.86[a]	603.60[b]	2514.30	488.89	2514.30	535.45	2409.54	512.17
	97	2330.96	2051.60	2994.46	1815.88	3177.80	1763.50	3142.88	1999.22
	163	--	11849.10	--	11662.60	--	11772.90	--	11468.10
		0 lbs./A		80 lbs./A		160 lbs./A			
		tops	tubers	tops	tubers	tops	tubers		
Madras	55	1501.59[a]	754.00[b]	1798.42	861.03	1632.55	558.60		
	69	1807.16	2853.18	2575.41	3000.37	2584.14	2427.82		
	133	--	7927.92	--	8430.84	--	7642.11		
		0 lbs./A		80 lbs./A		160 lbs./A		240 lbs./A	
		tops	tubers	tops	tubers	tops	tubers	tops	tubers
Klamath Falls	64	2316.42[a]	1588.90[b]	2536.42	1429.82	2876.32	1767.77	2368.58	966.52
	99	--	5686.23	--	5812.77	--	6518.95	--	5612.75

[a] In pounds per acre

[b] In pounds per acre