Response of Fall Grown Head Lettuce to Nitrogen Fertilization

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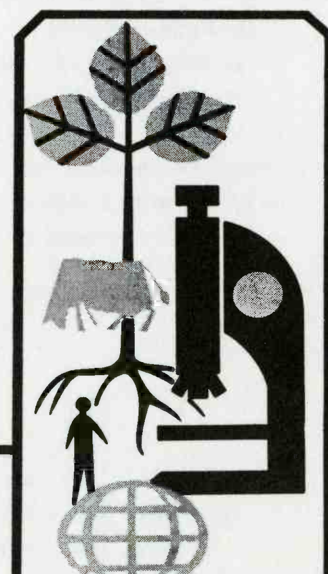

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RESPONSE OF FALL GROWN HEAD LETTUCE TO NITROGEN FERTILIZATION

By

B. R. Gardner and W. D. Pew[1]

INTRODUCTION

Nearly 55,000 acres of head lettuce (**Lactuca sativa** L.) are grown in Arizona each year. This does not, however, represent the use of as many acres since some of this acreage is double planted; a fall planting followed by a spring planting on the same land.

The production areas are widely scattered and a varying elevations, making it possible to utilize the climatic and temperature differences to extend the production season. Thus, lettuce is grown at some location in Arizona nearly every month of the year, although harvests occur from September through June.

The widely separated areas of production represent many fertilizer programs, soil types, irrigation water and management concepts. To achieve total success, specific guidelines relative to fertilization practices seem imperative and are the reason for these tests.

Although these experiments were conducted in the Yuma area, direct use has been made of these findings in other parts of the State, particularly in the Salt River Valley areas. Through the use of midrib NO_3-N analysis as a measuring process, these findings could be used in every lettuce producing area in the State.

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TABLE 1

Summary of N Treatments with Fall Lettuce

N Treatment	Preplant	Thinning	12 Leaves	Folding	Heading	Total
			Lbs. N/Acre			
			1966 - 1968†			
1	50	50	0	50	50	200
2	50	0	50	50	50	200
3	50	0	0	50	0	100
4	50	0	0	0	50	100
5	0	50	0	50	0	100
6	0	0	0	0	0	0
			1967‡			
1	50	50	0	0*	50	150
2	50	0	50	0	50	150
3	50	0	0	0	50	100
4	0	50	0	0	50	100
5	0	0	0	0	50	50

*In 1967 rain prevented an application at folding stage.
†12 replications
‡16 replications

MATERIALS AND METHODS

A series of N fertilization experiments, covering three successive fall growing seasons, was conducted in Yuma County, Arizona on a Gila silt loam soil which was cropped each preceding summer to Sudan for hay. No N fertilizer was added to the Sudan crop so that the soil N would be reduced and improve conditions for testing this element. A list of treatments is presented in Table 1. An application of 31 lbs of P per acre as treble superphosphate was broadcast each year over the entire experimental area prior to bedding. Liquid NH_4NO_3 as a preplant application was sprayed on the appropriate plots just prior to bedding. All other N, using prilled NH_4NO_3 was sidedressed on both sides of double-row beds.

"Merit 3186" seed was planted two rows per bed on standard 40-inch lettuce beds the last week of September. The plots were four beds wide and 100 feet long. Plants were thinned 12 inches apart during late October. One thinner or cutter was assigned individually to each replication to confound thinning variability with replication. The first harvest was made in late December. Yields were determined from 80 feet of bed within each plot and were recorded as number of heads per plot.

Soil samples were taken from each plot after planting, but prior to the germination irrigation; at thinning, and after harvest. Samples were taken with an Oakfield probe inserted eight inches deep at about a 45° angle just below the corner of the bed under a lettuce plant. Six to eight cores were taken from two inside beds, composited, air dried, ground to pass a 2mm sieve. Nitrate-N was extracted with water at 1:5 soil-to-water ratio and the N was determined by the phenoldisulfonic acid method.[1]

For tissue analyses, 12 to 20 wrapper leaves, depending on plant size, were taken from each plot. The midribs were removed, oven dried at 150-160°F and ground to pass through a 40-mesh screen and the NO_3 content determined by the Johnson and Ulrich method.[1] The first samples were taken when plants were large enough to get a midrib sample, usually a week after thinning. Subsequent samples were taken at 10- to 14-day intervals with five or six sets of samples taken before harvest.

The mean air temperatures were obtained from a U.S. Weather Bureau substation adjacent to the experimental area.

Samples for quality evaluation were taken at two harvest dates in 1966 and 1967 from all treatments except the control. In 1968 only one harvest date was sampled. Samples were taken from only 10 of the replications each year for the quality studies because of limited refrigerated transportation equipment. The lettuce was vacuum cooled, transported by refrigerated trailer to the University of Arizona Research Laboratory facilities at Mesa, and stored at 34° F for eight to 10 days to simulate a commercial transit period.

The lettuce was then evaluated and measured for several quality factors. Head size was determined by averaging the diameter of six randomly selected heads from each treatment trimmed for retail sales. The other factors were judged by three knowledgeable persons using a scale of one to nine with nine being most desirable. A second evaluation was made on the remaining six trimmed heads for the same characteristics after a second storage period of seven days at a temperature of 40 to 45°F simulating retail outlet temperatures.

Data from the experiments were analyzed statistically as outlined by Snedecor[2] at the numerical analyses laboratory of the University of Arizona. The five percent level of significance was used in all cases unless otherwise indicated.

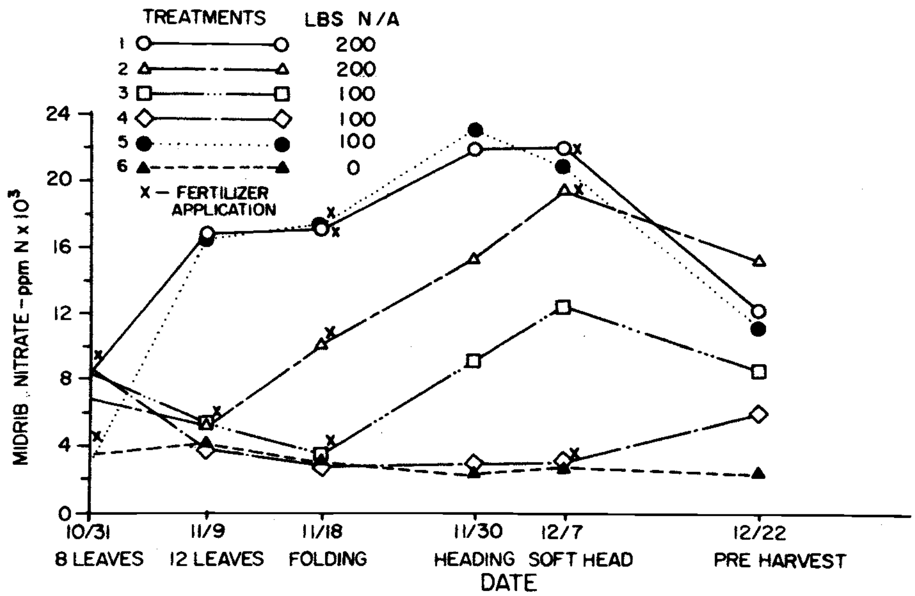

Fig. 1. Nitrate in Lettuce Midribs - Fall 1966

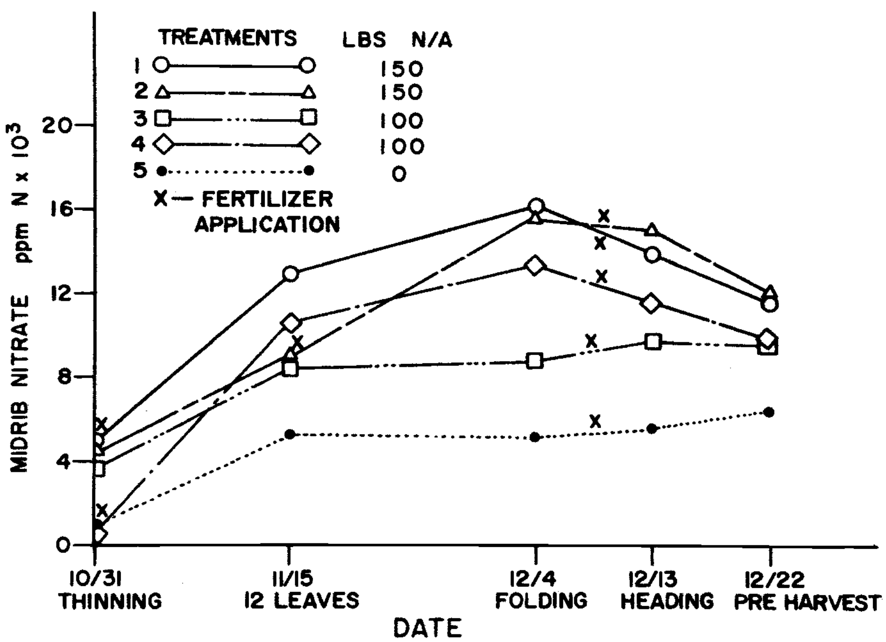

Fig. 2 Nitrate in Lettuce Midribs - Fall 1967

RESULTS AND DISCUSSION

The rate and timing of N fertilizer applications to soil affected the N supply available to the lettuce plant. The NO_3 content of the midribs of the outer wrapper leaves was determined to be a reliable measure of the N variations in soil and the influence of temperature on its availability to the plants (Fig. 1, 2 and 3).

The low N level in the control plants for all three years related closely to the limited supply of soil N during the test (Table 2). The plants in the control plots were considered N deficient most of the season. Midrib NO_3-N ranged from 1000 to 6000 ppm (Fig. 1, 2 and 3). Visual comparisons indicated that the general yellowing of the plants normally associated with an N deficiency became noticeable when the NO_3-N level dropped to 5000 ppm or below.

The NO_3-N levels in the first plant samples show the uptake and influence of the preplant N. These plants had about 4000 ppm more NO_3-N than those without the preplant application. In 1968 the thinning application, made on October 14, is reflected in treatments N_1 and N_5 (Fig. 3). In 1966 and 1967 a sidedress application on October 31 increased the NO_3-N very sharply.

The influence of a sidedress application made at the 12-leaf stage is shown in treatment N_2 each year. The application of N at folding stage was not made in 1967 because of rain (Table 1).

In 1966 the NO_3-N levels of plants receiving N at the folding stage increased 6000 to 8000 ppm over their previous level. But in 1968 treatment N_3 was the only one in which the NO_3-N level was increased by this application. The difference in response to this added N related closely with the temperature variations as illustrated in Fig. 4.

The weekly mean air temperatures (Fig. 4) were calculated by adding the high and low each day of the week and dividing by 14. Even though the air and soil temperatures affect the rate of plant growth[3] it was found that day to day fluctuations in air temperature had little effect on soil temperatures until a cooling or warming trend existed for a week or more.

As the mean temperatures decreased to about 55°F the growth rate became very slow. This temperature relationship is consistent with the fact that winter grown lettuce requires 120-130 days compared to the 80 to 90 days for summer and early fall grown lettuce. The uptake and/or storage of N by lettuce plants when the mean air temperature falls below 55°F is markedly reduced regardless of the N level in the soil and/or its source and probably represents a compensatory or maintenance level.* This information is in agreement with findings reported by Frota and Tucker[4] in which they found the absorption of both nitrate and ammonium ions was promoted by increasing the air temperature from 45 to 73°F. They also

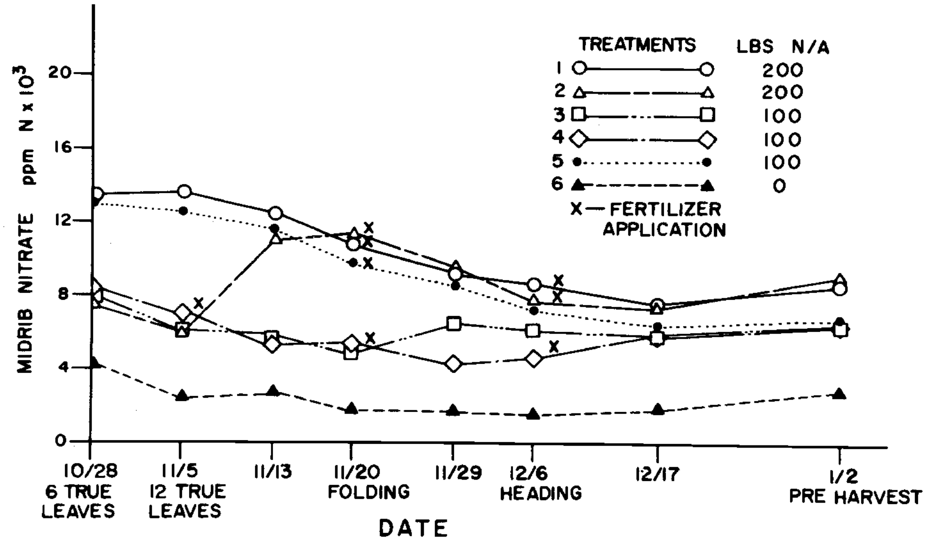

Fig. 3. Nitrate in Lettuce Midribs - Fall 1968

TABLE 2

Effect of N Treatment on Soil Nitrate Found in Lettuce Beds for a Fall Grown Crop

Treatment	Preplant Irrigation	Thinning	Post Harvest
	PPM NO_3		
	1966		
N_1	111 a[1]	42 a	58 a
N_2	110 a	39 a	44 abc
N_3	112 a	43 a	38 bcd
N_4	106 a	38 a	28 cd
N_5	51 b	36 a	48 ab
N_6	53 b	37 a	21 d
	1967		
N_1	67 a	29 b	66 b
N_2	61 a	37 a	101 a
N_3	64 a	25 b	47 bc
N_4	37 b	23 b	37 cd
N_5	38 b	22 b	18 d
	1968		
N_1	139 a	74 a	83 a
N_2	147 a	69 a	90 a
N_3	139 a	75 a	51 b
N_4	163 a	80 a	60 b
N_5	75 b	46 b	51 b
N_6	71 b	43 b	40 c

[1]Number followed by the same letter belong to the same population within each year at the 5% level of probability.

*Unpublished data of B. R. Gardner and W. D. Pew

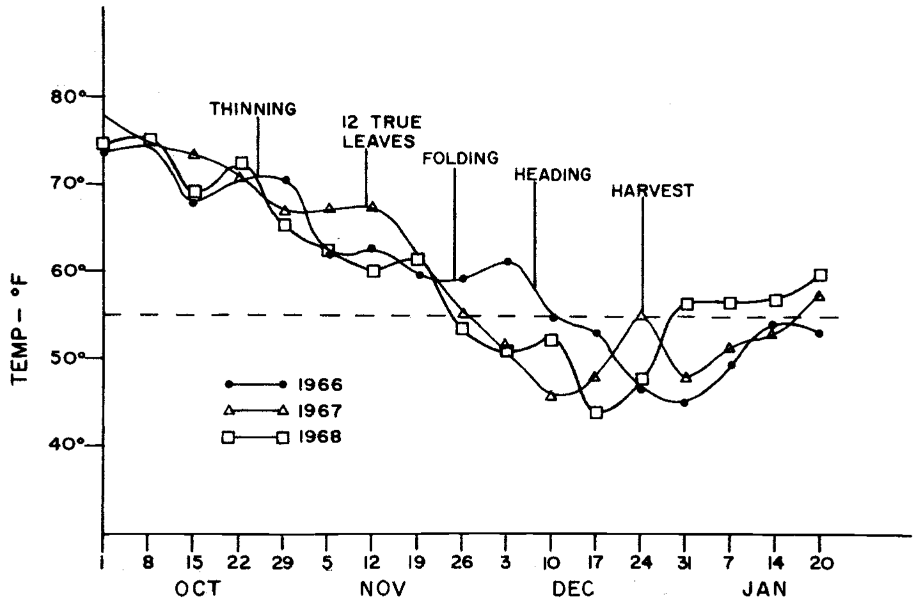

Fig. 4. Weekly mean temperature at Experiment Site, Yuma, AZ.

TABLE 3

Effect of N Treatment on Yield of Fall Grown Head Lettuce

Treatment	First	Harvests Second	Third	Total	Cartons Per Acre
		No. Heads/Plot			
		1966			
N_1	112 a[1]	23 a		135 a	919
N_2	106 a	29 a		135 a	919
N_3	90 b	33 a		124 a	842
N_4	65 c	39 a		104 b	703
N_5	97 b	33 a		129 a	881
N_6	7 d	0 b		7 c	50
		1967			
N_1	49 a	36 a	10 b*	95 a	648
N_2	40 ab	36 a	12 b	88 a	597
N_3	46 ab	29 b	14 b	89 a	614
N_4	37 b	40 a	13 b	90 a	616
N_5	18 c	28 b	21 a	67 b	435
		1968			
N_1	82 a*	38 b		120 a	708
N_2	80 a	45 b		125 a	742
N_3	51 bc	69 a		120 a	749
N_4	42 c	73 a		115 a	729
N_5	63 ab	60 ab		123 a	749
N_6	. . .	. . .		. . .	. . .

*First harvest 1968 and third harvest 1967 consisted of lettuce heads of the 2½ dozen size per carton.

[1]Numbers followed by the same letter belong to the same population within each year at the 5% level of probability.

reported a decrease in the amount of ammonium and nitrate ions absorbed as the temperature in the root zone decreased.

In 1966 the weekly mean air temperature remained at or above the 55° F level for a period of two weeks following the application of N at folding time. In contrast, the weekly mean air temperature in 1968 dropped below the 55°F level and remained there until after the first harvest. The difference in yield because of temperature can be seen in both earliness (Table 3) and N content by comparing these data with information in Fig. 1 and 3. Regardless of year, N applications made at heading stage did not increase the midrib NO_3-N levels, except in those treatments where the concentration was below 8000 ppm. In those cases an application of N at heading time tended only to delay the loss of midrib N. The weekly mean air temperatures during this period were mostly below the 55°F level. This is an important consideration since at this stage nearly 80% of the dry weight is produced.[3]

The effect on yield of an extended period of warmer temperatures following the folding stage in the 1966 crop is shown in Fig. 4 and Table 3. About 80% of the marketable heads were cut in the first harvest of 1966 whereas in 1967 and 1968 only 50 and 65%, respectively, were cut. The data in Table 3 illustrate the effect of rate and timing of N on yield.

In 1966, N had little effect except in treatment N, and the control on total number of heads harvested, but maturity was markedly affected as measured by the number of heads cut at first harvest. Both showed N deficiency most of the season. The higher rates of N generally produced earlier lettuce. The longer the plants were allowed to be N deficient, the fewer the heads cut at first harvest. While N did not affect the total number of heads harvested, it did have considerable effect on their size and maturity and thus upon yield. Also, the plants receiving higher rates of N (N_1 and N_2) resulted in midrib NO_3-N values above 8000 ppm during most of the season and larger, heavier heads were produced (Table 3 and 4). This is contrary to findings by Lorenz et al indicating 5000 ppm NO_3-N is adequate.[5]

When N deficiencies occurred early in the season, as with treatment N_5 in 1966 and 1968 and N_4 in 1967· the net result was a delay of the har-

TABLE 4

Effects of N Treatment on Selected Physical Measurements of Fall Grown Head Lettuce. (Average for First and Second Harvests)

Treatment	24 Heads Expressed in Pounds Untrimmed Weight	Trimmed Weight	Percent Trimmed Weight	Head Size Inches
		1966		
N_1	42.2 c[1]	24.8 b	58.7 a	4.6 d
N_2	40.0 b	24.0 b	60.0 a	4.4 c
N_3	38.8 ab	21.7 a	55.9 a	4.3 b
N_4	37.6 a	21.1 a	56.1 a	4.1 a
N_5	39.2 b	23.4 b	59.7 a	4.4 c
First Harvest Mean	40.6 b[2]	26.4 b	65.0 b	4.5 b
Second Harvest Mean	38.5 a	19.6 a	50.9 a	4.2 a
		1967		
N_1	41.7 d	26.9 c	64.2 a	4.4 b
N_2	41.0 cd	26.2 bc	63.6 a	4.4 b
N_3	40.5 c	26.3 bc	64.9 a	4.4 b
N_4	39.1 b	25.1 b	64.2 a	4.3 b
N_5	36.6 a	23.2 a	63.3 a	4.1 a
First Harvest Mean	41.4 b	27.8 b	67.0 b	4.6 b
Second Harvest Mean	38.1 a	23.3 a	61.0 a	4.1 a
		1968		
N_1	43.2 b	28.0 b	64.7 c	4.2 b
N_2	43.4 b	28.0 b	64.3 bc	4.2 b
N_3	41.5 a	25.5 a	61.3 ab	4.1 a
N_4	41.8 a	25.7 a	60.7 a	4.0 a
N_5	41.9 a	26.2 a	62.2 abc	4.1 a
First Mean Harvest	38.3 a	22.7 a	59.0 a	3.8 a
Second Mean Harvest	46.5 b	30.7 b	66.2 b	4.4 b

[1, 2] Numbers followed by the same letter for treatment and harvest mean groups respectively belong to the same population at the 5% level of probability.

vest and some reduction in head size. The same association occurred when a preplant N application was made, but permitted to result in N deficiency during the folding stage as in Treatment N_3. When the N deficiencies were allowed to develop during the heading stage (N_4, 1966 and 1968) size was even more markedly reduced (Fig. 1, 2 and 3); (Table 4).

It is interesting to compare the head size for the first and second harvests in 1966 and 1967 with those of 1968. In 1966 and 1967 there were significant statistical differences between all factors evaluated in favor of the first harvest, whereas in 1968, the difference was reversed (Table 4). Treatment means were separated by Duncan's Multiple Range Test.[6]

The influence of temperature is an important factor in understanding N nutrition. The weekly mean air temperatures (Fig. 4) for 1966 and 1967 remained below the 55°F level throughout the harvesting period. The smaller heads, those cut at second harvest, had previously been exposed to cooler weather as they were forming and proper size was not achieved. In 1968 the weekly mean air temperature warmed to 55°F and above from first harvest until after the second harvest, and these heads were larger.

The midrib NO_3-N levels of plants in all treatments prior to the first harvest in 1968 were at or below the adequate level of 8000 ppm. This low level of N combined with the low temperatures during head formation, resulted in small, 2½ dozen size heads (Tables 3 and 4). However, when the temperature increased following the first harvest, plants that had enough NO_3-N (8000 ppm or more) developed larger two-dozen size heads.

The data presented in Table 5 show the effect of N on selected quality factors. No significant difference in any year was associated with N levels and incidence of tipburn· pinkrib, slime mold, russet spot, ribbiness, or pithiness. However, significant differences in butt color and solidity were obtained; but these were more directly related to maturity and plant size than were the others. There was an inverse relationship between butt color and size. N treatments that developed the larger heads also produced heads with a lighter butt color. This observation seems contradictory to common belief. However, color was found related to the amount of foliage that shaded the base of the plant and the number of wrapper leaves trimmed prior to packing.

Maturity was closely associated with N supply. Nitrogen deficiencies early in the growing season (N_5 in 1966 and 1968, N_4 in 1967) delayed the maturity as shown by the solidity factor. The smaller more solid heads came from treatments N_4 in 1966 and 1968 and N_3 in 1967 and these were N deficient during head formation stage. These heads had a relatively good butt color (Table 5). From these data, the head formation period was found to be the most critical time for N deficiencies to occur. In these cases, later applications of N had no influence on increasing head size. In contrast, when N deficiencies occurred during the early growing season, they could be corrected by N fertilizer with no apparent defects, except a delay of three to 10 days in maturity.

The influence of midrib NO_3·N levels made at more than one sampling date on yield at first harvest was

TABLE 5

Effects of N Treatment on Selected Quality Factors in Fall Grown Lettuce

Treatment	Tipburn No. Heads	Pinkrib	Slime	Ribbiness	Pith	Russet Spot	Color	Solidity
				1966				
N_1	0.0	8.4 a[1]	8.9 a	7.1 a	5.8 a	8.7 a	7.4 ab	7.2 ab
N_2	0.0	8.5 a	8.9 a	7.2 a	6.1 a	8.8 a	7.1 a	7.2 ab
N_3	0.0	8.4 a	8.7 a	7.1 a	5.8 a	8.7 a	7.2 a	7.2 ab
N_4	0.0	8.6 a	9.0 a	7.5 a	6.2 a	8.9 a	7.6 b	7.7 c
N_5	0.0	8.4 a	8.9 a	7.2 a	6.0 a	8.8 a	7.6 b	6.9 a
First Harvest	0.0	8.2 a[2]	8.8 a	7.5 b	7.1 b	8.6 a	7.5 a	7.3 a
Second Harvest	0.0	8.7 b	8.9 a	6.9 a	4.8 a	8.9 b	7.3 a	7.2 a
First Evaluation	0.0	8.5 a[3]	9.0 a	7.3 b	6.1 a	8.7 a	7.5 b	7.3 a
Second Evaluation	0.0	8.5 a	8.8 a	7.1 a	5.9 a	8.9 b	7.2 a	7.1 a
				1967				
N_1	1.0 a	8.9 a	9.0 a	6.7 a	6.7 a	9.0 a	6.4 a	6.6 a
N_2	0.9 a	8.9 a	9.0 a	7.0 a	7.0 a	9.0 a	6.7 ab	6.6 a
N_3	1.0 a	8.9 a	9.0 a	6.9 a	6.9 a	9.0 a	6.7 ab	7.0 ab
N_4	1.0 a	8.7 a	9.0 a	7.0 a	6.8 a	9.0 a	6.9 b	6.6 a
N_5	1.0 a	8.9 a	9.0 a	7.5 a	7.0 a	9.0 a	7.3 c	7.1 b
First Harvest	1.3 b	8.8 a	9.0 a	7.0 a	7.0 b	9.0 a	6.8 a	6.5 a
Second Harvest	0.6 a	8.9 b	9.0 a	7.0 a	6.8 a	9.0 a	6.8 a	7.0 b
First Evaluation	0.7 a	8.9 b	9.0 a	6.9 a	6.5 a	9.0 a	7.1 b	6.6 a
Second Evaluation	1.2 b	8.7 a	9.0 a	7.2 b	7.2 b	9.0 a	6.5 a	6.9 b
				1968				
N_1	1.2 a	8.9 a	8.9 a	6.6 a	6.0 a	9.0 a	6.4 a	7.1 ab
N_2	1.1 a	8.9 a	8.8 a	7.0 a	6.2 a	8.9 a	6.6 a	7.2 a
N_3	0.8 a	8.9 a	8.9 a	7.1 a	6.4 a	8.9 a	6.8 a	7.4 a
N_4	0.8 a	8.9 a	8.9 a	7.0 a	6.6 a	9.0 a	6.9 a	7.3 a
N_5	1.2 a	8.9 a	8.9 a	6.8 a	6.8 a	8.9 a	6.6 a	6.8 b
First Evaluation	. . .	8.9 a	8.9 a	7.3 a	5.6 b	9.0 a	7.0 a	6.9 b
Second Evaluation	. . .	8.9 a	8.9 a	6.5 b	7.2 a	8.9 a	6.4 b	7.4 a

[1, 2, 3]Numbers followed by the same letter for treatment, harvest mean and evaluation groups respectively belong to the same population at the 5% level of probability.

analyzed by the multiple regression analyses as shown in Table 6. Because a stepwise multiple regression analysis was used, only the sampling dates that made a significant contribution to the correlations were included in the table. It is important to note that each year the midrib NO_3-N levels at the early vegetative stage and at the end of the head formation were the only ones that contributed significantly to the correlation. This explains, in part, the observation previously given regarding the size, maturity, and butt color associated with N deficiencies during these two periods.

TABLE 6

Multiple Regression of the Number of Heads at First Harvest on the Nitrate Content of Fall Grown Lettuce Midribs at Selected Dates

Date and Stage at Sampling		B	S_B	F	Multiple R
		1966			
December 7	Soft Head	0.365	0.034	113:30**	.719
October 31	8 Leaves	0.419	0.080	84.70**	.786
December 22	Preharvest	0.262	0.076	66.15**	.810
		1967			
November 15	12 Leaves	0.253	0.067	30.24**	.622
December 22	Preharvest	0.315	0.084	25.16**	.719
		1968			
January 2	Preharvest	1.677	0.317	27.92**	.571
November 5	12 Leaves	0.351	0.135	18.75**	.630

**Significant at 1% level.

SUMMARY

Midrib NO_3-N can indicate the N status of lettuce plants. The levels must be above 8000 ppm throughout the season to insure desired head size at harvest time.

Observable N deficiency symptoms appear as the midrib NO_3-N level drops below 5000 ppm. If midrib NO_3-N falls below 8000 ppm in the early vegetative stage the deficency can be corrected by applying N fertilizer, but a three to 10 day delay in harvest will result. If the N deficiency occurs during head formation, adding N fertilizer will not change this situation and small head size and reduced yields cannot be avoided.

Mean air temperature of 55°F or lower for a week or longer sharply reduces the growth rate of lettuce plants. The midrib NO_3-N content should be over 8000 ppm before cold weather begins to insure adequate levels during head formation to obtain good head size. The N supply had no effect on quality factors other than size and color, but brought about earlier maturity.

REFERENCES

1. Johnson, C. M. and A. Ulrich. Determination of nitrate in plant materials. Anal. Chem. 22, 1950, pp. 1526-1529.
2. Snedecor, G. W. Statistical Methods. 5th Ed.· Iowa State College Press, Ames, Iowa, 1957, p. 534.
3. Zink, F. W. and M. Yamaguchi. Studies on the growth rate and nutrient absorption of head lettuce. Hilgardia 32, No. 11 1962, pp. 471-500.
4. Frota, J. N. E. and T. C. Tucker. Temperature influence on ammonium and nitrate absorption by lettuce. Soil Sci. Soc. Amer. Proc. 36, 1972, pp. 97-99.
5. Lorenz, O. A., F. W. Zink, and F. D. Howard. Nutrient survey of lettuce fields in Salinas Valley. V. C. Series 87. Univ. of Calif. Veg. Crops· Davis, Calif. 1954, pp. 1-12.
6. Duncan, D. B. Biometrics 11, 1955, pp. 1-42.