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EFFECTS OF RESIDUAL SOIL NITROGEN AND APPLIED NITROGEN ON YIELDS OF HEAD LETTUCE

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INTRODUCTION

Field studies previously conducted in the Matanuska Valley have determined that head lettuce production can be optimized by applying approximately 100 lbs per acre of nitrogen (N) as a fertilizer supplement when residual soil N levels are low (Carling et al., 1987 and 1988). However, conditions in grower's fields often are such that significant quantities of residual N fertilizer may remain in the soil from one growing season to the next. Maximizing the utilization of residual N makes sense both economically as this N has substantial value as a plant nutrient, and ecologically as N may contribute to groundwater contamination if permitted to leach from the soil profile.

A field study was conducted during the 1988 growing season to examine the effects of residual soil N in combination with various levels of spring-applied N fertilizer on head lettuce yields. Residual soil N is defined as N present in the soil and detected by a soil test prior to the application of fertilizer in the spring. This study had two primary objectives: to promote maximum utilization of N through accurate interpretation of soil test results and to evaluate interactions between residual and spring-applied N. The results of the first year of this study were reported by Michaelson et al. (1989). The experiment was repeated during the 1989 growing season and the results of that study are contained in this report.

MATERIALS AND METHODS

Field plots were established in the summer of 1988 on a Knik silt loam, at the University of Alaska Agricultural and Forestry Experiment Station Matanuska Farm. Initial surface (0-6 inch) soil nutrients determined using Mehlich 3 extractant were 73 parts per million (ppm) phosphorus (P), 51 ppm potassium (K), 1560 ppm calcium (Ca), and 190 ppm magnesium (Mg). The pH of a 1:1 soil:water suspension was 6.02. Organic matter, measured by combustion, was 5.06% of dry soil weight.

Sixty-four plots, each measuring 6 by 15 feet, were arranged in a split-plot design, with four replications. The main treatments consisted of ammonium nitrate (NH_4NO_3) broadcast at four rates and tilled to a depth of about 6 inches on August 23, 1988. The purpose of these treatments was to establish a range of residual soil N levels for the next growing season. All plots were fallowed until the spring of 1989. On May 25, 1989 soil in all main plots was sampled in three-inch increments to the bottom of the soil profile (21 to 24 inches). Extractable soil N was measured in 2N KCl extracts of air-dried soil samples. Ammonium (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-) concentrations in the extracts were determined colorimetrically (Michaelson et al., 1987). On May 26, 1989 triple super phosphate and potassium chloride (KCl) were broadcast on all plots to supply 141 lbs per acre P and 133 lbs per acre K. Main plots were then randomly divided into four sub-plots, each of which received 0, 25, 50, or 100 lbs per acre of N as NH_4NO_3. The soil was tilled to a depth of about 6 inches, and 4-week-old greenhouse grown lettuce (Lactuca sativa L. var Salinas) seedlings were transplanted on May 31, 1989. Between plant spacing within each row was 12 inches; the between row spacing was 18 inches. Soil moisture status was monitored with tensiometers throughout the growing season, and water was supplied via sprinkler irrigation as needed.

Ten plants from each plot were collected on June 26, 1989, then were washed, oven-dried, and weighed as a measure of treatment effects on early plant development. Diameters and weights of 20 heads per plot were determined at maturity, approximately 70 days after planting, as measures of lettuce yield.

RESULTS AND DISCUSSION

Residual soil N values, expressed as the sum of extractable N in the NH_4^+ and NO_3^- forms, correspond closely to the levels of N applied in the fall of 1988 (Figure 1). Nitrogen in the NO_2^- form was not included in this figure because the levels measured in all soil samples were less than 0.1 ppm N. However, this assay may not have been accurate because drying the soil samples could have caused loss of NO_2^- which is relatively unstable. Nitrite (NO_2^-) is of interest because it is known to be toxic to plants, even at very low concentrations. In future studies, refined methods will be used to determine whether NO_2^- is present in levels which could adversely affect lettuce growth.

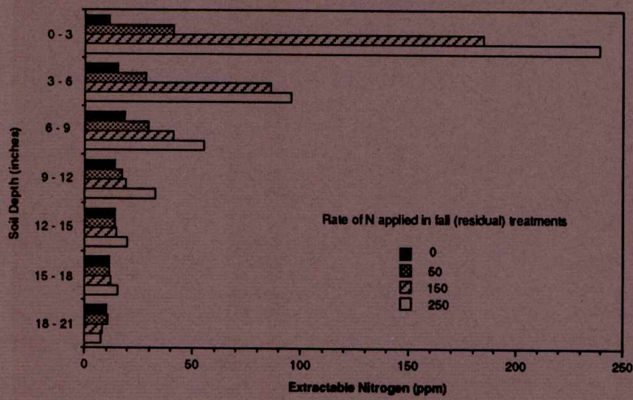

Figure 1. *Extractable soil N in three-inch increments. Samples were collected May 25, 1989 to determine residual N levels prior to application of N fertilizer in the spring.*

The amount of extractable N remaining in the soil profile in the spring of 1989 was generally about twice the level of the previous year (Michaelson et al., 1989) and was about equal to the amount of N applied in August, 1988. Additionally, the bulk of the extractable N was found in the surface 6 inches of the soil profile in 1989 indicating that fall, winter, and early spring movement of N was minimal. Although the N was applied as NH_4NO_3, most of the N had been oxidized to the NO_3^- form by spring. In the plots with the highest residual soil N levels, about 90% of the N was in the NO_3^- form, while in the check plots that received no N the NO_3^- fraction was 76%. The NH_4^+:NO_3^- ratio can have an impact on lettuce growth, although it is not expected that a difference of this magnitude would explain the yield results we observed.

Nitrogen soil test values from samples collected on May 25, 1989 were averaged over various sampling depths and are presented in Table 1. These sampling depths represent those potentially adaptable to a routine soil sampling program designed to predict N fertilizer needs of head lettuce. The relationship between residual N concentrations of soil samples averaged over different depths (from Table 1) and the head lettuce harvest weights from plots receiving no spring-applied N was examined to determine optimum sampling depth for use in a soil testing program. The relationship between residual soil N concentration and head weight improved as sampling depth increased from 6 to 9 inches (r^2=0.78 and 0.80, respectively), with no additional improvement as sampling depth increased further. These data indicate that the relatively shallow soil samples customarily used for determining the status of other plant nutrients might suffice for N analysis in the Matanuska Valley.

	Soil sampling depth (inches)			
	0-6	0-9	0-12	0-15
Fall-applied N rate (lbs/acre)	ppm			
0	13.5	15.3	15.0	14.8
50	34.5	32.8	28.9	26.0
150	135.3	103.8	82.6	69.1
250	167.0	129.8	105.4	88.4

Table 1. *Spring soil residual nitrogen levels averaged by soil depth.*

Lettuce plant dry weights from the June 26 harvest are presented in Figure 2. Plants responded positively to spring-applied N in the 0 lbs per acre residual N treatment. The plant weight increased when 25 lbs per acre of N was added in the spring, but no further increase occurred when higher rates were used. Plant weights tended to decrease with increasing rates of spring-applied N in the 50, 150, and 250 lbs per acre residual N treatments. Stunting of the young lettuce plants in the 50, 150, and 250 lbs per acre residual N plots was visually apparent. Also, the leaves of these plants appeared to be thicker and more rigid than those of plants in the 0 lbs per acre residual N plots.

Head weight at harvest followed a similar pattern (Figure 3). In the 0 lbs per acre residual N treatment, head weight increased with increasing rates of spring-applied N up to the highest rate used. This agrees with the data of Carling et al. (1987 and 1988) and Michaelson et al. (1989). As residual N levels increased, however, average head weight decreased, regardless of the level of spring-applied N. The head diameter followed a comparable pattern (Figure 4). The density of lettuce heads (calculated from the diameter and weight measurements, based on the assumption that head shape was spherical) also decreased when residual N levels were elevated (Figure 5). As a result, the weight of a 6-inch diameter lettuce head would have been decreased approximately 2.7 oz by the higher levels of residual N, even if head size had not been affected. This is equal to a decrease of about 4 lbs for a 24-head carton. Spring N applications, on the other hand, did not significantly affect head density.

The head weight data presented here compare quite closely with those from the previous year (Michaelson et al., 1989). All yields were greater in 1989, but the responses to residual and spring-applied N were very similar. In both years, the presence of residual N at levels above about 20 ppm in the surface 15 inches (or about 25 ppm in the surface 9 inches) suppressed any response to spring-applied N. This was true even though the percentage of identical residual N treatments, remaining in the soil profile until spring, varied by a factor of two between 1988 and 1989. The potential crop loss in 1989 associated with residual N above these levels was 16.6 oz per head, or approximately 38% of the top-yielding plots.

Data collected over two years indicate that there is a depression of head lettuce growth associated with levels of residual soil N comparable to those which may be found in commercial vegetable fields. Similar responses have not been reported for other crops here or elsewhere, and at this time we have not tested any crops other than lettuce at this location. The nature of the depressive mechanism is not clear at this point, but research is continuing to better explain the situation. It is clear that additional N fertilization can not overcome the observed yield reductions associated with residual soil N.

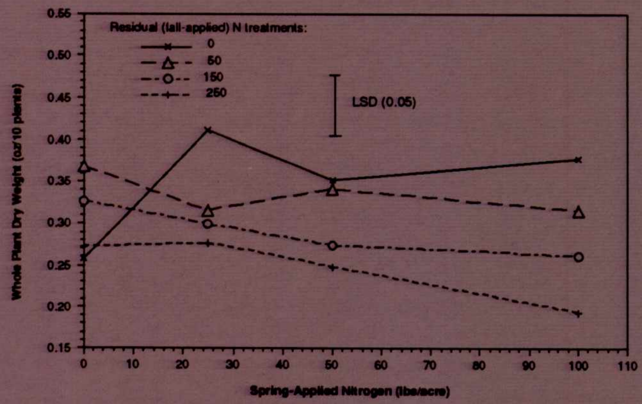

Figure 2. *The effect of residual and spring-applied N on whole plant weight 26 days after transplanting. LSD = Least Significant Difference. If two points differ more than the amount shown by the LSD bar, they are considered significantly different.*

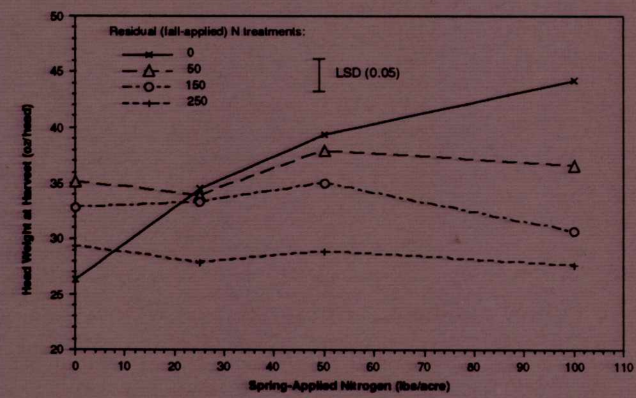

Figure 3. *The effect of residual and spring-applied N on head weight at harvest. LSD = Least Significant Difference. If two points differ more than the amount shown by the LSD bar, they are considered significantly different.*

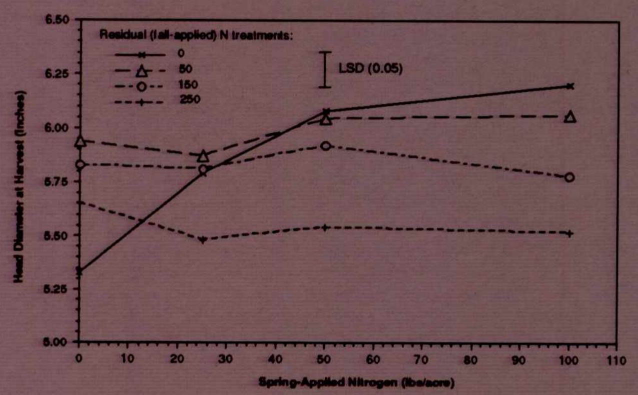

Figure 4. *The effect of residual and spring-applied N on head diameter at harvest. LSD = Least Significant Difference. If two points differ more than the amount shown by the LSD bar, they are considered significantly different.*

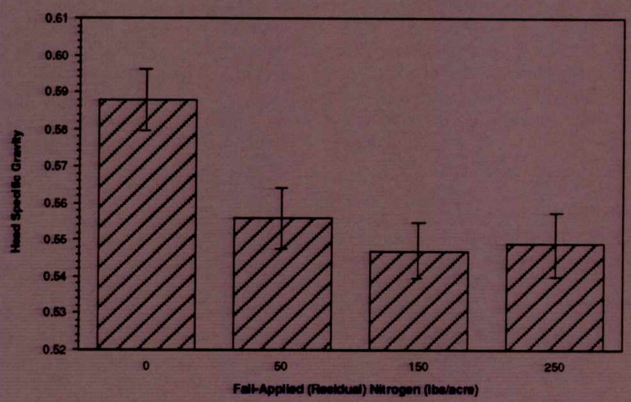

Figure 5. *The effects of residual N treatment levels on specific gravity of lettuce heads at harvest. Specific gravity is head density (weight/volume) relative to that of water. Statistical symbols indicate standard error.*

SUMMARY

This study has now been conducted for two years. The following summary statements apply to the first year's data (Michaelson et al., 1989), as well as to the second year of experimentation described in this report.

1. The levels of N extractable with 2N KCl were proportional to the amount of fall-applied (residual) N in a given year. However, the amount of N retained in the soil profile from one growing season to the next may vary considerably. This indicates that soil samples collected for determination of residual N should be collected in the spring rather than in the fall.

2. Soil samples should be collected to a depth of at least 9 inches for a reliable determination of residual soil N.

3. Early plant growth, and the size, weight, and density of mature heads were all adversely affected by the presence of more than about 20 ppm N in the surface 15 inches or about 25 ppm N in the surface 9 inches of the soil. Spring-applied N had no effect on head size and weight when residual soil N exceeded these levels. Growers should probably avoid planting lettuce in fields where spring soil tests indicate that N is at or above these levels.

4. Spring applications of up to 100 lbs per acre of N had no effect on head density, but positively affected head size and weight in the absence of high levels of residual soil N.

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