Rates and Methods of Application of Nitrogen and Phosphorus for Commercial Field Production of Head Lettuce in Southcentral Alaska

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Introduction

Head lettuce (*Lactuca sativa L.*) is one of the major agricultural crops grown in Alaska. In 1992, its wholesale value was approximately $314,000, second only to potatoes among Alaska's commercially field grown vegetables (Brown et al., 1992).

The quality of head lettuce is as important as yield, as lettuce heads that do not meet minimum size and weight standards are unmarketable. Head size and weight are strongly influenced by management practices, dictating a high level of management for successful commercial production. Among manageable cultural variables, rate of fertilizer application and the method of fertilizer placement are two of the most critical. Despite the value of the head lettuce crop to Alaska vegetable growers and the importance of fertilization as a management practice, little research has been published on rates of application and method of applying nitrogen and phosphorus to commercially grown head lettuce.

Most of the commercially produced head lettuce in Alaska is established in the field with transplants produced in a greenhouse. Prior to transplanting, producers traditionally have broadcast fertilizer in a uniform application applied to the field surface and tilled into the top 10 to 20 cm of soil. In recent years, however, some producers have applied some or all of the fertilizer in a concentrated band placed five cm to the side and five cm below the transplants.

Placement of the fertilizer in a band may improve the efficiency of nitrogen uptake from cold soils, because both ammonium and nitrate absorption by lettuce is reduced as soil temperatures decrease (Frota and Tucker, 1972). Absorption is reduced in part because root development is reduced in cold soils, reducing the volume of soil exploited by a plant. This particularly affects the uptake of immobile nutrients such as phosphorus (Barber, 1988). Not surprisingly, Zhurbitsky and Shtrausberg (1958) found that absorption of nitrogen and phosphorus is more adversely affected by low soil temperatures than is absorption of other nutrients. Placement of fertilizer in a band concentrates nutrients and can improve nutrient uptake under conditions of limited root growth (Barber, 1988). When fertilizer (particularly phosphorus) comes in contact with soil it can be tied-up, reducing its availability to the plant. Band placement of fertilizer minimizes soil contact, reduces nutrient tie-up, and often results in increased fertilizer use efficiency (Barber, 1988; Smith et al., 1990). Banding can also aid the crop in its competition with weeds and promote early crop maturity. Baker (1979) found that banding phosphorus fertilizer for head lettuce production on a low phosphorus soil (3.1 ppm available phosphorus) not only increased yield compared to broadcast treatments, but also reduced the number of immature heads at harvest.

High rates of banded nitrogen fertilizer can produce salt levels that are high enough to damage plants and reduce yields. Fertilizers containing either nitrate or ammonium can cause salt damage, although the nitrogen fertilizer with the greatest potential for causing crop damage is urea. Urea can produce ammonia gas which can be highly toxic to plants (Halvorson, 1989). Pew et al. (1983 and 1984) recorded reduced head lettuce yields when 168 kg N/ha as urea was placed 10 cm below the row. On the other hand, Welch et al. (1987) applied 200 kg N/ha as ammonium sulfate in a band without any apparent deleterious effects to the lettuce crop (the band depth and distance from the row was not reported). Baker (1979) observed a positive yield response by head lettuce to band-application of as much as 84 kg N/ha as ammonium-phosphate-sulfate (16-20-0).

It is known that climatic and soil conditions can have a strong influence on crop response to banded fertilizer. Laughlin (1971) found that band application of 130 to 180 kg N/ha reduced stand and vigor of non-irrigated potatoes grown under Alaska conditions. Subsequent research conducted in Southcentral Alaska under similar conditions, but with adequate water provided through irrigation, indicated that 130 kg N/ha applied in a band did not adversely affect potato growth or yield (Walworth, unpublished data). Cochran and Schlentner (1992) found that risk of injury to barley from banded urea (at the rate of 100 kg N/ha) decreased as soil temperature decreased from 25 to 5°C, although slight adverse effects were noted even at 5°C. Lewis et al. (1987) found that urea banded at the rate of 90 kg N/ha did not injure barley grown in Interior Alaska.

In the past, field research determined that approximately 110 to 140 kg N/ha is an appropriate rate of application for nitrogen fertilizer applied by broadcast methods for Alaska production of either direct-seeded or transplanted head lettuce (Walworth et al., 1990). No information is available on band application of nitrogen to head lettuce in the cold soils typical in Alaska. Also, little information is available concerning rates and methods of application for phosphorus fertilizers. Therefore, a two-year field study was conducted to determine the most effective methods of nitrogen and phosphorus application, and to establish recommendations concerning appropriate rates of application of these two nutrients on head lettuce.

Procedures

Nitrogen

Field trials with nitrogen were conducted at the University of Alaska Fairbanks, Agricultural and Forestry Experiment Station's Palmer Research Center, Matanuska Research Farm, located six miles west of Palmer, Alaska. Preplant nutrient levels were measured on bulk samples collected from the top 15 cm of the soil. Inorganic nitrogen was extracted with 2N KCl and all other nutrients were extracted with the Mehlich 3 extractant solution. Climatic conditions were continuously monitored at a site approximately 250 m from the research location.

In 1992 four rates of nitrogen (45, 90, 135, or 180 kg N/ha) were applied as ammonium nitrate. In 1993, five rates of nitrogen (0, 22.5, 45, 90, or 135 kg N/ha) were used. The lower range of more closely spaced nitrogen treatments was used in 1993 to more precisely determine the effects of banded nitrogen in the critical range of application. Nitrogen fertilizer was either broadcast uniformly over the soil surface and incorporated to a depth of 12 to 15 cm immediately prior to transplanting head lettuce (cv Salinas in 1992, cv Alpha in 1993) or banded approximately five cm below and five cm to one side of the lettuce at the time of transplanting. Lettuce transplants, approximately four weeks old, were placed in the field with a tractor-mounted mechanical transplanter. Rows were 45 cm apart and there were 30 cm between plants in the row. Banded fertilizer treatments were applied with a V-belt type seeder mounted on the transplanter frame. Treatments were replicated four times in a randomized complete block design. Each plot consisted of four rows of lettuce 4.6 m long. Triple superphosphate and potassium chloride were broadcast at rates 225 kg P_2O_5/ha and 225 kg K_2O/ha and incorporated prior to transplanting to ensure that these nutrients were not limiting to growth and yield.

Phosphorus

A similar experiment was conducted with phosphorus in 1992 with four rates (112, 224, 336, or 448 kg P_2O_5/ha) and in 1993 with five rates (0, 112, 224, 336, or 448 kg P_2O_5/ha). The phosphorus source was triple superphosphate. As with nitrogen, phosphorus was either broadcast over the soil surface and incorporated or banded to one side and below the lettuce transplants. Ammonium nitrate (112 kg N/ha) and potassium chloride (225 kg K_2O/ha) were broadcast and incorporated prior to transplanting to ensure that nitrogen and potassium were not limiting to growth and yield. All other parameters were as described above with nitrogen.

General

Lettuce was transplanted June 8, 1992 and June 15, 1993. In both trials soil moisture was measured with tensiometers and water was applied through overhead sprinklers when soil water potential reached approximately 35 mP. Twenty lettuce heads were harvested by hand from the center two rows of each plot at maturity. Harvest date, head weight, and head diameter were recorded at harvest.

Results and Discussion

General

The results of preplant soil tests are shown in Table 1. Inorganic soil nitrogen levels were moderate, whereas phosphorus and potassium levels were considered low.

Climatic conditions at the research location for 1992 and 1993 are presented in Table 2. 1992 was colder than average in May, but slightly above average for the remainder of the growing season. Rainfall was close to the long-term average for most of 1992. Air tempera-

Table 1. Selected soil property values prior to applying fertilizer.

					Total Extractable				
Year	pH	Organic matter	NH_4-N	NO_3-N	Inorganic N	P	K	Ca	Mg
		%	parts per million						
1992	5.8	5.09	<1	19	19	77	52	1458	176
1993	5.9	5.06	4	12	16	72	61	1423	174

Table 2. Climatic conditions during the 1992 and 1993 growing seasons at the University of Alaska Fairbanks Agricultural and Forestry Experiment Station, Matanuska Farm.								
	1992							
	MAY		JUNE		JULY		AUGUST	
Air Temperature (°C)								
Daily Max.	13.4	(14.3)[1]	18.8	(18.5)	19.4	(19.7)	17.2	(18.3)
Daily Min.	1.5	(2.3)	7.4	(6.8)	10.3	(8.8)	9.0	(7.7)
Daily Mean	7.4	(8.3)	13.1	(12.6)	14.8	(14.2)	13.1	(13.0)
Soil Temperature[2]								
Fallow	7.8		14.0		17.9		15.1	
Sod	9.9		13.0		18.4		15.0	
Precip. (cm)	1.85	(1.93)	3.84	(3.79)	5.79	(5.94)	2.5	(6.30)
	1993							
	MAY		JUNE		JULY		AUGUST	
Air Temperature								
Daily Max.	16.9	(14.3)	19.7	(18.5)	21.8	(19.7)	18.9	(18.3)
Daily Min.	4.5	(2.3)	7.7	(6.8)	10.3	(8.8)	9.9	(7.7)
Daily Mean	10.7	(8.3)	13.7	(12.6)	16.1	(14.3)	14.4	(13.0)
Soil Temperature								
Fallow	12.5		17.8		19.6		16.1	
Sod	14.1		18.9		20.2		16.6	
Precip. (cm)	2.64	(1.93)	2.18	(3.79)	1.96	(5.94)	6.55	(6.30)

[1] Values in parentheses represent a 58-year average.
[2] Soil temperatures were measured at a depth of 10 cm.

Table 3. Effect of fertilizer application method on days from transplanting to harvest (values averaged over all fertilizer rates).

	Nitrogen		Phosphorus	
Application method	**1992**	**1993**	**1992**	**1993**
Broadcast	62.9	63.2	63.3	64.0
Band	64.3	64.7	67.8	65.8
$LSD_{0.05}$	NS	1.4	2.3	1.6

$LSD_{0.05}$ = Least significant difference (5% confidence level).
NS=Not significant at the 5% level.

tures were well above average for the entire 1993 growing season. Rainfall was slightly greater than average in May, however precipitation for the remainder of the 1993 growing season was well below average. Soil moisture should not have been limiting because the plots were watered as necessary.

The effects of different rates and methods of placement of nitrogen and phosphorus on lettuce head weight are presented in Figures 1 and 2, respectively. Vertical bars represent the standard error associated with each plotted data point.

Table 4. Effect of nitrogen application method on lettuce head weight and diameter (values are averaged over all nitrogen rates).

	Head weight (g/head)		Head diameter (cm)	
Application method	**1992**	**1993**	**1992**	**1993**
Broadcast	808.3	724.6	13.8	13.0
Band	667.0	624.3	13.0	12.6
$LSD_{0.05}$	87.2	63.9	0.4	NS

$LSD_{0.05}$ = Least significant difference (5% confidence level).
NS=Not significant at the 5% level.

Nitrogen

In 1992, the rate at which broadcast nitrogen was applied had no statistically significant impact on head weight, and neither did lower rates of banded nitrogen fertilizer (Figure 1). However, when nitrogen was banded at the highest rate (180 kg N/ha) yields were reduced.

The response to broadcast nitrogen in 1993 was nearly linear. With the exception of an anomalous decrease in head weight obtained with 22.5 kg N/ha, lettuce responded positively to banded nitrogen when applied at rates up to 90 kg N/ha. Banded nitrogen appeared to reduce yields when 135 kg N/ha was applied.

Lettuce response to broadcast nitrogen was considerably greater in 1993 than in 1992. This may have been due to an inadequate supply of phosphorus in 1992. Although rates of phosphorus application were identical in both years, the apparent contradiction may be explained by considerably higher soil temperatures in 1993 (Table 2). It is well known that lower soil temperatures correspond to reduced phosphorus availability (Barber, 1984). This point is demonstrated by looking at the data points for the 225 kg P_2O_5/ha of broadcast phosphorus treatments for 1992 and 1993 in Figure 2 (this treatment is identical to that used for the blanket phosphorus treatment in the nitrogen studies). The blanket phosphorus application was adequate in 1993, but inadequate in 1992.

In the 1992 nitrogen studies, the number of days from transplant to harvest was not affected by method of application (Table 3). In 1993 lettuce receiving banded nitrogen required slightly more time to mature than lettuce receiving broadcast nitrogen. Nitrogen rate had no significant effect on the number of days from transplant to harvest (data not shown).

Overall, yields of lettuce from plots treated with banded nitrogen were never greater than those produced with broadcast nitrogen. At best, banded nitrogen produced yields comparable to broadcast but more often, head weight was greater where nitrogen had been broadcast, as illustrated by the direct comparison of application method presented in Table 4. These data are explained by damage to lettuce plant roots, and therefore reduced yields, when nitrogen is applied in bands. The risk of this type of damage is minimized when nitrogen is broadcast. Therefore, broadcasting seems to be the best method of nitrogen fertilizer application.

Phosphorus

Lettuce response to increasing rates of phosphorus is shown in Figure 2. In 1992, plots treated with banded phosphorus produced heavier heads except at the highest rate (448 kg P_2O_5/ha) where response to the two application methods was statistically the same. In 1993 broadcast phosphorus application generally resulted in heavier lettuce heads than did banded phosphorus application (Table 5). In that year, phosphorus banded at the rate of 336 kg P_2O_5/ha produced heads statistically identical in weight to those produced with the best broadcast treatments (Figure 2). At the highest application rate in 1993 (448 kgP_2O_{55}/ha) banded phosphorus reduced lettuce head weight. The combination of phosphorus rate and application method that produced the top yields was different for the 1992 and 1993, however in each year the best banded treatment was essentially the same as the best broadcast treatment.

The response to phosphorus fertilizer apparently was affected by environmental conditions, since soil test phosphorus levels were nearly identical each year (Table 1). Root proliferation and therefore phosphorus uptake is often reduced when soils are cool and consequently there is a greater likelihood of gaining benefit from band phosphorus placement when soils are cool (Barber, 1988). Soil temperatures in 1993 were higher than those in 1992 throughout the entire growing season (Table 2). Therefore one would expect to see a greater advantage from band placement in the data from 1992 than in 1993 and this is evident in Figure 2. The differences in soil temperatures may explain the contrasting responses to phosphorus application methods and rates obtained in 1992 and 1993.

Table 5. Effect of phosphorus application method on lettuce head weight and diameter (values averaged over all phosphorus rates).

	Head weight (g/head)		Head diameter (cm)	
Application method	**1992**	**1993**	**1992**	**1993**
Broadcast	796.5	838.2	13.7	13.4
Band	974.3	720.7	14.0	12.9
$LSD_{0.05}$	65.5	66.5	0.3	0.3

$LSD_{0.05}$ = Least significant difference (5% confidence level).

In both years of this study, lettuce grown with banded phosphorus required approximately two to four days longer to mature than lettuce with broadcast phosphorus (Table 3). Therefore banding phosphorus appears to lengthen the time from planting to harvesting slightly rather than shorten it as reported by Baker (1979). In neither year did phosphorus rate affect the number of days from transplanting to harvest.

Conclusions

Broadcasting appears to be the superior method of applying nitrogen for head lettuce under Southcentral Alaska's growing conditions. There appears to be no advantage to using band application of nitrogen for head lettuce production under the soil and environmental conditions of Southcentral Alaska. Considerable crop damage may result from band applied nitrogen, particularly if the application rate exceeds approximately 90 kg N/ha. In these trials, yields with banded nitrogen never exceeded those obtained when nitrogen was broadcast.

Limited advantage was gained by banding phosphorus, even though the soils selected for this study are cold and have low soil test phosphorus levels, circumstances under which banding would be expected to afford the greatest advantage. In a cool year (1992), banded phosphorus was superior when phosphorus fertilization rates were low, although that advantage was eliminated when higher levels of phosphorus were applied. In other words, when soil temperatures were low (as in 1992), applying phosphorus in a band was more efficient than broadcast application. At very high application rates (400 kg P_2O_5/ha or more) however, there may be a possibility of yield reduction associated with banded phosphorus.

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Figure 1. Effect of rate and placement of nitrogen on lettuce head weight.

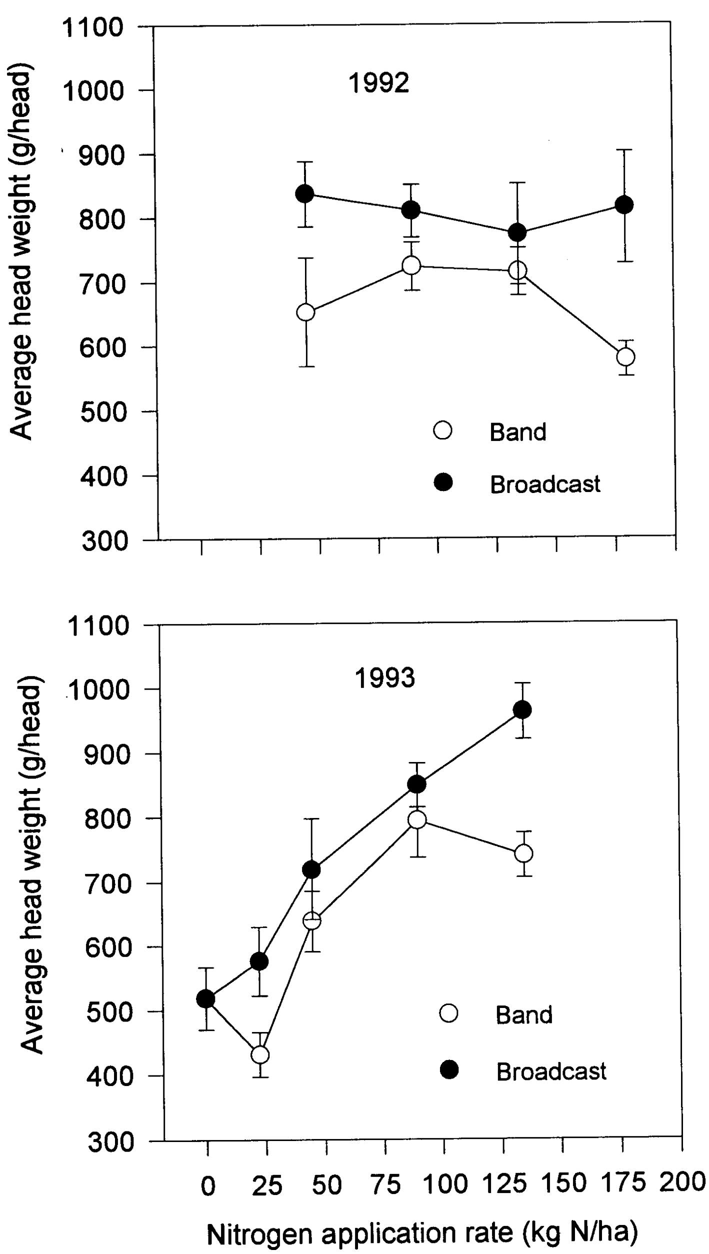
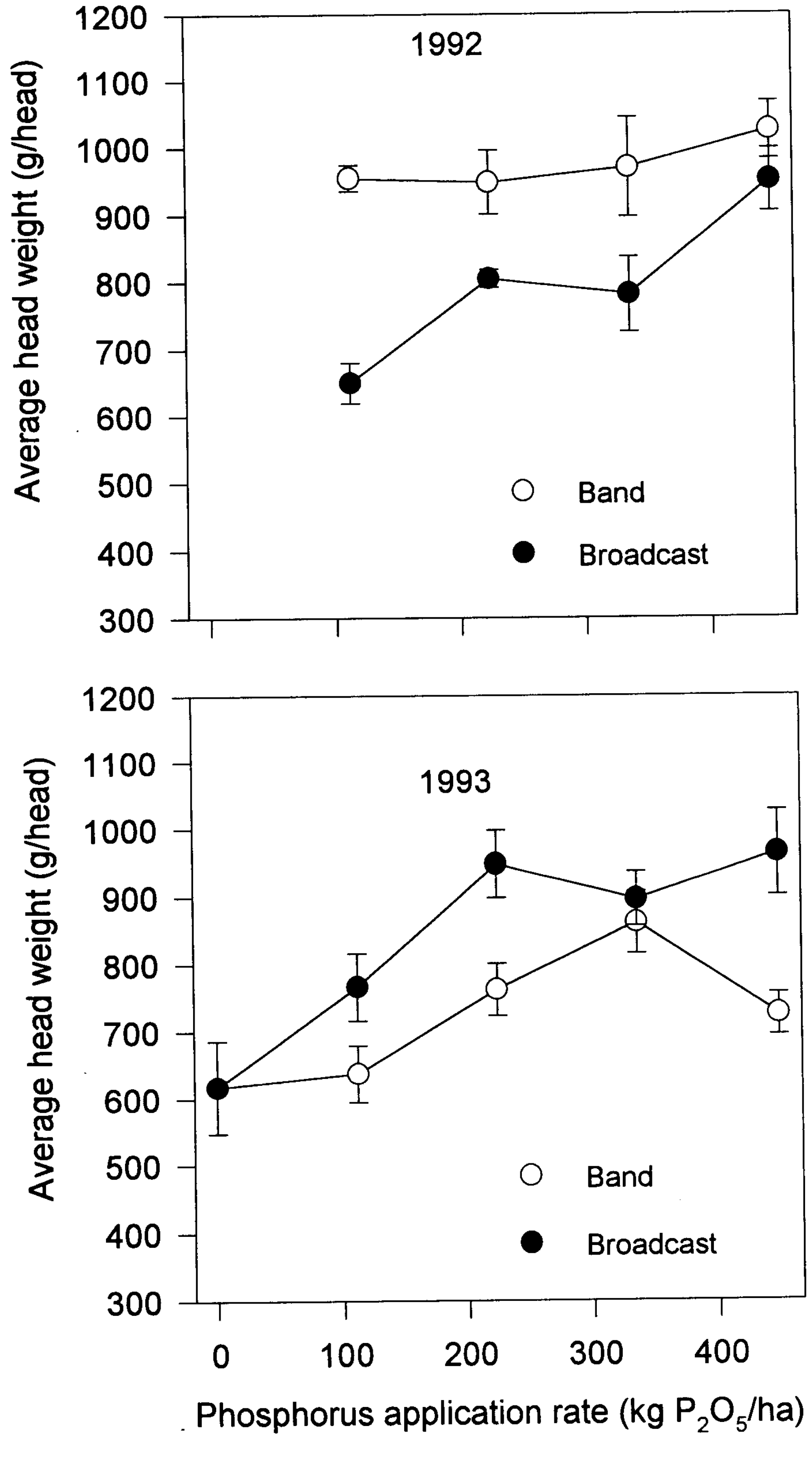


Figure 2. Effect of rate and method of placement of phosphorus on lettuce head weight.



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