The Response of Leaf Lettuce to Phosphorus Fertilizer Placement and Rate

Kevin H. Pritchard, Thomas A. Doerge and Ted W. McCreary

Abstract

A one-year field study was conducted at the Maricopa Agricultural Center in the winter and spring of 1991-92 with the purpose of comparing the response of leaf lettuce grown with subsurface drip irrigation to various broadcast and banded phosphorus (P) fertilizer applications and rates. Two rates of banded treble superphosphate, 250 lbs.(1X) and 125 lbs.(1/2X) of P_2O_5 per acre, were applied immediately before planting in a concentrated strip 1 inch directly below the row to be seeded. One broadcast rate, 250 lbs. (1X) of P_2O_5 per acre of the same material, was applied and folded into the planting beds during listing. Control plots, in which zero P fertilizer was applied, were also maintained. Whole plant total P concentrations were higher in the first one-third of the growing season for the band treatments, though the differences in responses between band and broadcast applications were not statistically significant in the final third of the season. The 1X band treatment exhibited both greater plant heights and diameters than all other treatments during the first one-half of the growing season, and maintained greater height dimensions in the second half. The 1X broadcast and 1/2X band treatments exhibited similar growth throughout the season. By harvest there were not significant differences in head or plant size or in marketable yield among the three P treatments.

Introduction

Guidelines for the use of phosphorus (P) fertilizers in head lettuce production in Arizona are well established. Doerge et al. (1989) stated that an adequate supply of P is needed throughout the growing season to insure optimum yields, head size and marketability. This supply is particularly important if heads are formed during periods of cold weather when the availability of soil P to plant roots is low. Application techniques which incorporate P directly into the root zone, such as the placement of a concentrated band of fertilizer 2 to 3 inches below the planted seed, may significantly enhance P availability. Sanchez et al. (1990) reported that optimum head lettuce yields were obtained with a rate of banded P that was one-third of that required with a broadcast fertilizer placement.

Studies of crops other than head lettuce have also shown favorable responses to banded P. Randall and Hoeft (1988) concluded that small grains generally benefit from band applications, especially when preplant soil fertility tests are low, or soil moisture is limited. The placement of P in a concentrated band resulted in reduced amounts of P fertilizer required for a specified yield of sweet corn grown on Florida Histosols (Sanchez et al., 1991). Sleight et al. (1984) determined from greenhouse studies with oats that early beneficial effects from banded P result from a positional advantage obtained by plant roots with close, concentrated amounts of P rather than a reduced amount of

P "fixation" associated with soil-fertilizer contact. This implies that plants with a relatively weak rooting potential may benefit greatly from banded P, which provides for a much higher probability of root-P contact.

Leaf lettuce develops in a very similar manner to head lettuce, exhibiting slow, early growth and limited initial rooting. Interest in the production of high-value specialty crops such as leaf lettuce has also been steadily increasing in Arizona. These unique characteristics of the crop contribute to a dilemma involving the management of soil nitrogen (N) and P. A common procedure for applying phosphorus fertilizer in Arizona is to broadcast substantial amounts of P in the form of dry monoammonium phosphate (11-53-0) prior to bed formation. Leaf lettuce does not exhibit significant N uptake early in the growing season, so this method may contribute to a considerable loss of soil N by leaching or denitrification. An alternative technique such as banding treble superphosphate (0-45-0) may potentially reduce the quantities of P fertilizer required for optimum yields, and subsequently minimize the amount of soil N that is subject to loss. The objective of this study was to compare the response of leaf lettuce to various broadcast and banded P fertilizer application methods and rates.

Materials and Methods

A one-year study to examine interactions between different application methods and rates of P in the production of a leading variety of leaf lettuce (Waldmann's Green) was initiated in the fall of 1991 at the Maricopa Agricultural Center (MAC). The experimental design was a randomized complete block with three replications. Application techniques involving band, broadcast, and control treatments were used, consisting of two rates of applied P for the band method, one rate for broadcast, and zero applied P as a control. Banding of P fertilizer was accomplished by placing a concentrated strip of treble superphosphate (0-45-0) by hand approximately 1 inch below the anticipated seed row immediately before planting. Totals of 250 lbs. of P_2O_5 (1X) per acre, which is a common rate of P used in the commercial production of leaf lettuce in Arizona, and 125 lbs. P_2O_5 (1/2X) per acre were applied in the band treatments. Broadcasting of P fertilizer was distributed by hand prior to bed formation on 18 November at the 1X rate of 250 lbs. P_2O_5 per acre.The soil type in the experimental area was a Casa Grande sandy loam with a preplant soil test P level of 10.5 ppm (0.5M HCO_3 extraction, 1:20 soil to solution ratio), which is considered to be a moderately low value.

A Stanhay precision planter was used to place two lines of coated leaf lettuce seed separated by 13 inches on the surface of raised 40 inch beds on 6 November. The effective planting date was determined to be 14 November, since this was the date that irrigation water reached the dry seeds. After thinning at the 4- to 5- leaf stage on 8 January, the final plant population was 32,400 plants per acre, which is an interplant spacing of approximately (10 inches) in both seed lines on each bed.

A subsurface drip irrigation system was used to subirrigate all plots for 14 consecutive days during the establishment period. The system consisted of one line of Chapin Twin-wall IV@ drip irrigation tubing buried eight to ten inches below the soil surface of each north-south oriented bed. The flow rating for this tubing is 0.5 gpm/100 ft. and the outlet spacing is 9 inches. The amount of water delivered during establishment (13-27 November) was 33.2 inches, which is somewhat excessive, but was necessary because of the unanticipated deep placement of the drip tubing. Irrigation was conducted once daily throughout the growing season except when unnecessary because of recent rainfall or cold temperatures. After the establishment period, the total cumulative amount of irrigation water applied to all plots was 8.8 inches. Tensiometers installed at 12 and 24 inch depths were used to guide irrigation scheduling. Water was applied to maintain a soil moisture tension of 70 mbars just prior to an irrigation event, which represents a total soil water depletion of about 50%.

Nitrogen requirements of the crop were met by injecting urea, ammonium nitrate solution (32-0-0) through the irrigation system at scheduled intervals. All plots received equal amounts of N, resulting in cumulative total of 170 lbs. N per acre. The irrigation water contained 3.0 lbs. N per acre of NO_3-N + NH_4-N. No other nutrient solutions were applied throughout the growing season. No pesticides were used and weeds were controlled by hand hoeing.

Plant diameter and height measurements were taken four times during the growing season (3 January, 17 January, 14 February, and 6 March) at the 3-4, 4-6, 8-11, and 18-23 leaf stages. Whole plant tissue samples, which consisted of the entire above-ground portion of the plant, were collected on 3 January, 14 February, and 31 March. Leaf samples, which included petiole + midrib and leaf blade tissues from the youngest fully expanded leaf, were taken on 31 March. All samples were dried at 60° C and ground to pass a 40 mesh screen. Tissues were tested for total PO_4-P concentration using microwave digestion with ascorbic acid colorimetry. Lettuce plants were harvested for fresh weight yields from 2 m^2 of row (16 plants) on 31 March by horizontally severing the main tap root at the soil surface. Heads were then trimmed according to "U.S. Fancy" grade specifications for Leaf Lettuce. The vertical dimension (length) and average fresh trimmed weights of four heads from each plot were then determined. Statistical analysis was conducted with routine ANOVA techniques, and separation of treatment means was done using Duncan's Multiple Range Test.

Results and Discussion

Phosphorus Accumulation in Plant Tissues

The patterns of season-long accumulation of total P are illustrated in Figure 1. During the first one-third of the growing season, whole plant total P concentrations were significantly higher in both the band treatments than the control, and the 1X band exceeded the 1X broadcast application. The trend toward greater total P levels in the band treatments during the early growth stages may have been influenced by cool temperatures and inhibited root development. Fertilizer concentrated in bands could have had a positional advantage at this time in supplying P to slowly developing root systems.

In general, total P concentrations tended to decrease toward mid-season, then increase as the plants matured in both band treatments, while the control and 1X broadcast applications rose fairly steadily throughout the growing season. Plants in the banded fertilizer plots appeared to be visibly larger than the other treatments before mid-season, so the apparent decrease may be attributed to the dilution effect of P in greater quantities of vegetative matter. Dry matter accumulation rates were not recorded throughout the growing season because of limited plot area and the need for non-destructive measurement techniques, so this phenomenon could not be verified.

Differences in total P concentrations seen during the early growth stages between the band and broadcast methods were virtually absent in the final one-third of the season, although P levels of plants in the control plots remained significantly below those in the 1X band and broadcast treatments. The common procedure in lettuce production in which fertilizer is broadcast across a level surface and then incorporated by bed-forming tillage may contribute to this effect. This practice concentrates nearly all of the broadcast fertilizer in the surface 6 to 8 inches of the bed, but it is less positionally available to newly developing roots than banded fertilizer. As the root systems expand both downward and laterally, they eventually contact equivalent amounts of P fertilizer in both the broadcast and the band applications.

Plant Diameter and Height Measurements

Figures 2 and 3 depict plant diameter and height responses to the various rates and methods of P fertilizer application. Results for both plant diameter and height were very similar during the first half of the growing season. The 1X band measurements were greater than any other treatment and the plants in the control plots were smaller than those in all other plots in both diameter and height during this period. The 1X broadcast and 1/2X band results were very similar throughout the entire growing season. In the second half of the season, the control plots lagged behind all other treatments in plant dimensions, while the 1X band application exhibited a greater plant height than all the others near the end of the season. Both plant diameter and height measurements increased dramatically after the 4-6 leaf stage (64 days after planting), which also coincided with warmer growing conditions.

Harvest Data

Table 1 displays fresh weight yields, head dimensions, and total leaf P concentrations at harvest. There were no significant differences in head weight, marketable yield or head length among the three P treatments at harvest. Harvest was delayed because of wet weather, and as a result most of the lettuce heads had matured beyond the point normally preferred in commercial production. Because of the late harvest, most of the plants throughout all plots had become fairly uniform in size, which is reflected in the data. A difference is noted in total leaf P concentrations, where the 1X band treatment was significantly greater than the control.

Conclusions

Applications of treble superphosphate fertilizer in a concentrated band appeared to have a greater influence on the accumulation of total P in leaf lettuce than broadcast treatments during the first one-third of the growing season. This may be particularly true under conditions of stress, such as cool temperatures. The effect of enhanced P uptake exhibited by band applications during the early developmental stages of lettuce tended to be equalled by broadcast applications in the final one-third of the season. P fertilizer banded at the fully recommended rate (1X) resulted in greater plant size during the first half of the growing season, and a greater plant height approaching the end of the second half than all other application methods and rates. The 1X broadcast and 1/2X band treatments were very similar in all aspects of growth throughout the season. Harvest measurements, which were collected at a time which was considered to be later than optimum, showed no significant differences between the individual treatments. Because of earlier visual indications, it is hypothesized that a more timely harvest would have resulted in significant differences in size and yield. The early beneficial effects of banding P fertilizers are apparent, though, and the overall results at least equal and possibly exceed those exhibited by more conventional broadcast applications.

Literature Cited

Doerge, T.A., B.R. Gardner, and R.L. Roth. 1989. Fertilizing Head Lettuce in Arizona. Univ. of Arizona Coop. Ext. Bul. 8922.

Randall, G.W., and R.G. Hoeft. 1988. Placement methods for improved efficiency of P and K fertilizers: A review. J. Prod. Agric. 1:70-78.

Sanchez, C.A., P.S. Porter, and M.F. Ulloa. 1991. Relative efficiency of broadcast and banded phosphorus for sweet corn produced on Histosols. Soil Sci. Soc. Am. J. 55:871-875.

Sanchez, C.A., S. Swanson, and P.S. Porter. 1990. Banding P to improve fertilizer use efficiency in lettuce. J. Am. Soc. Hort. Sci. 115:581-584.

Sleight, D.M., D.H. Sander, and G.A. Peterson. 1984. Effect of fertilizer phosphorous placement on the availability of phosphorus. Soil Sci. Soc. Am. J. 48:336-340.

Table 1. Fresh weight yields, head dimensions, and leaf total P concentrations recorded at harvest for leaf lettuce in response to different rates and applications of treble superphosphate fertilizer.

Phosphorus Treatment	Trimmed Head Weight (lbs)	Marketable Yield (tons/acre)	Head Length (in)	Total Leaf P (ppm)
Control	1.1	9.3	8.0	1205
1X Broadcast	1.4	14.6	8.3	1543
1/2X Band	1.0	7.9	7.9	1721
1X Band	1.1	10.4	8.1	2015
LSD 0.05	NS	NS	NS	528

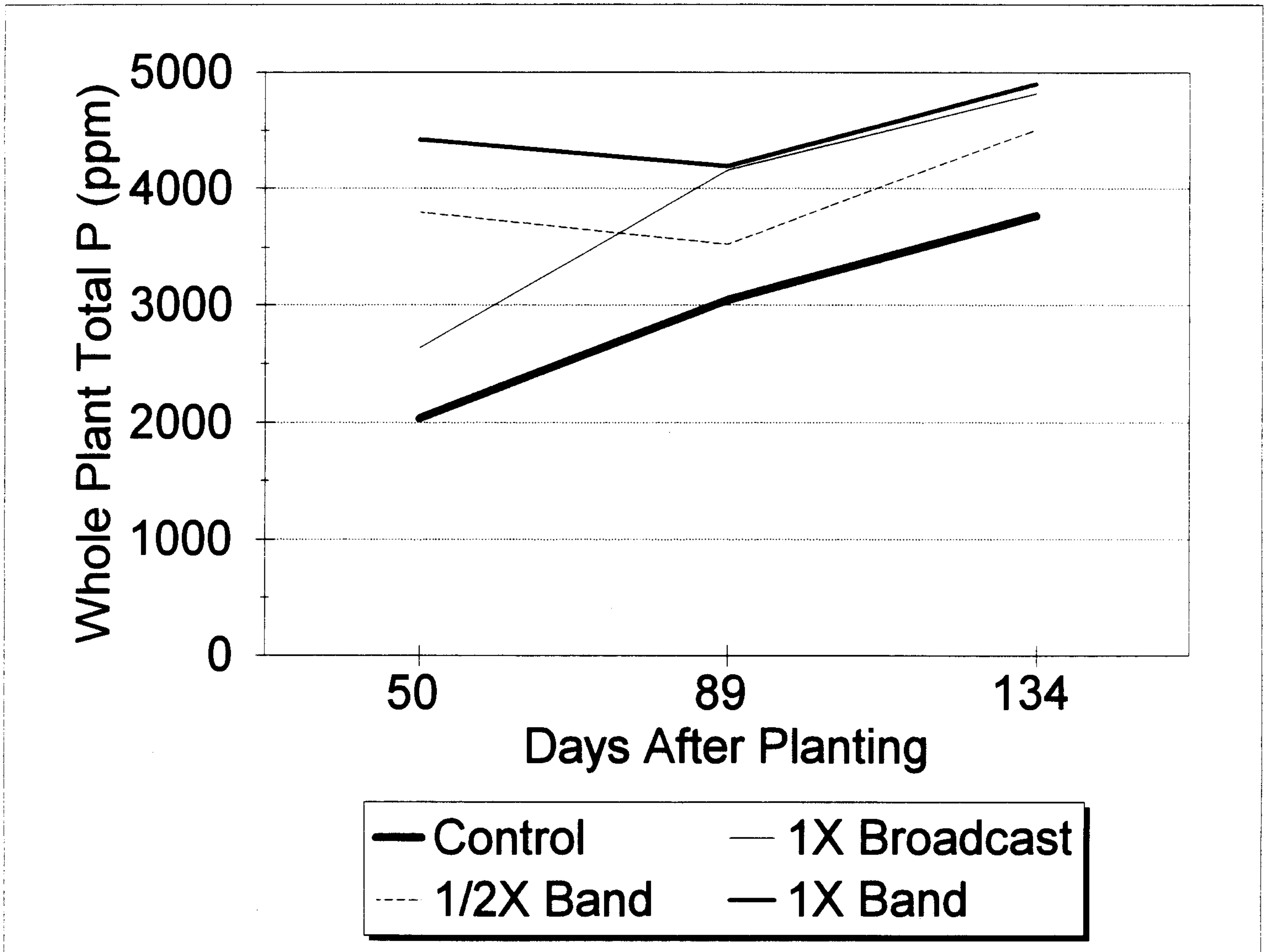

Figure 1. Seasonal patterns of whole plant total P concentrations for leaf lettuce in response to different rates and applications of treble superphosphate fertilizer. LSD (0.05) values for the 50, 89, and 134 days after planting levels are 1583.7, 907.5, and 920.4, respectively.

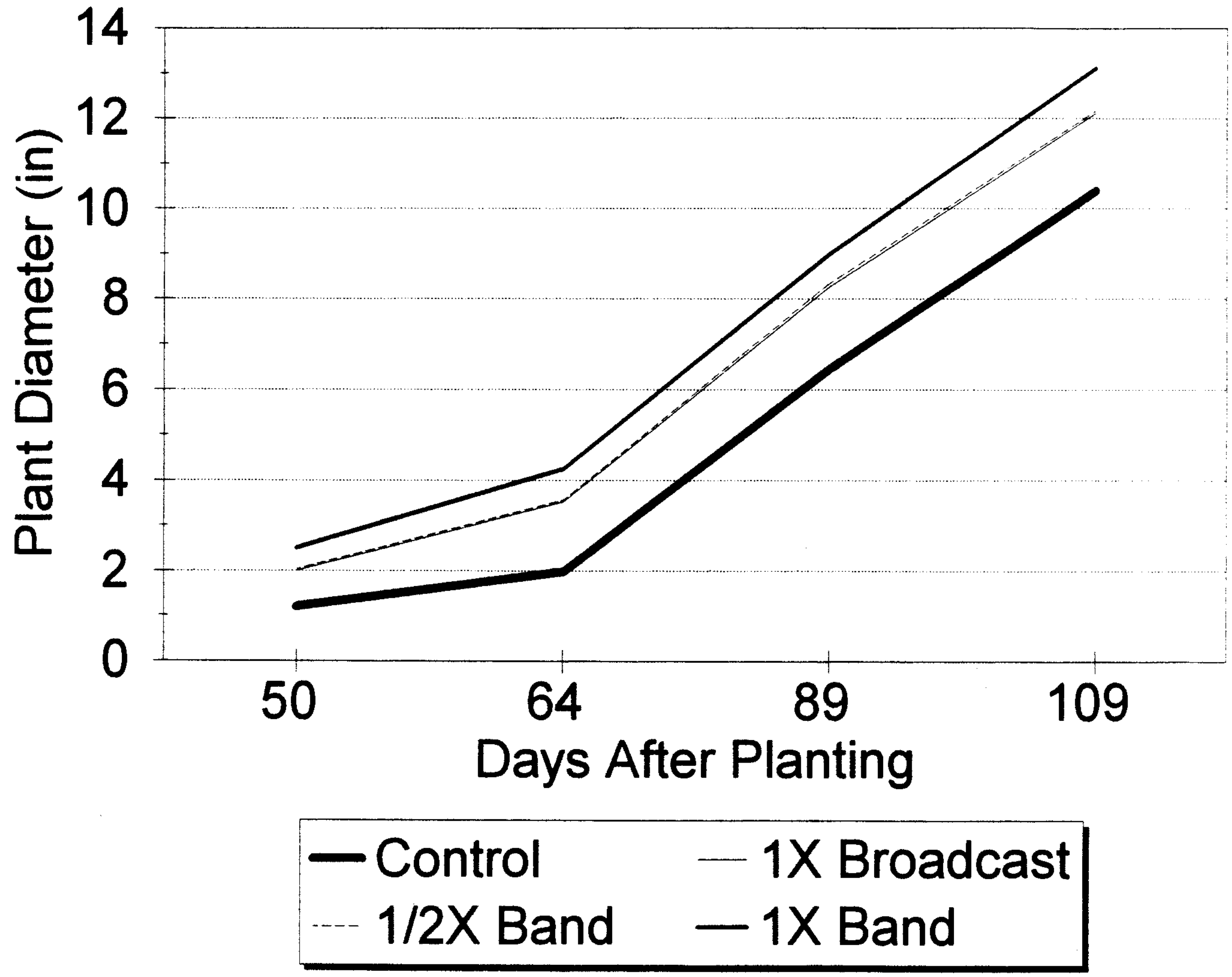

Figure 2. Plant diameter measurements of leaf lettuce in response to different rates and applications of treble superphospahte fertilizer. LSD (0.05) values for the 50, 64, 89, and 109 days after planting levels are 0.26, 0.49, 0.72, and 0.94, respectively.

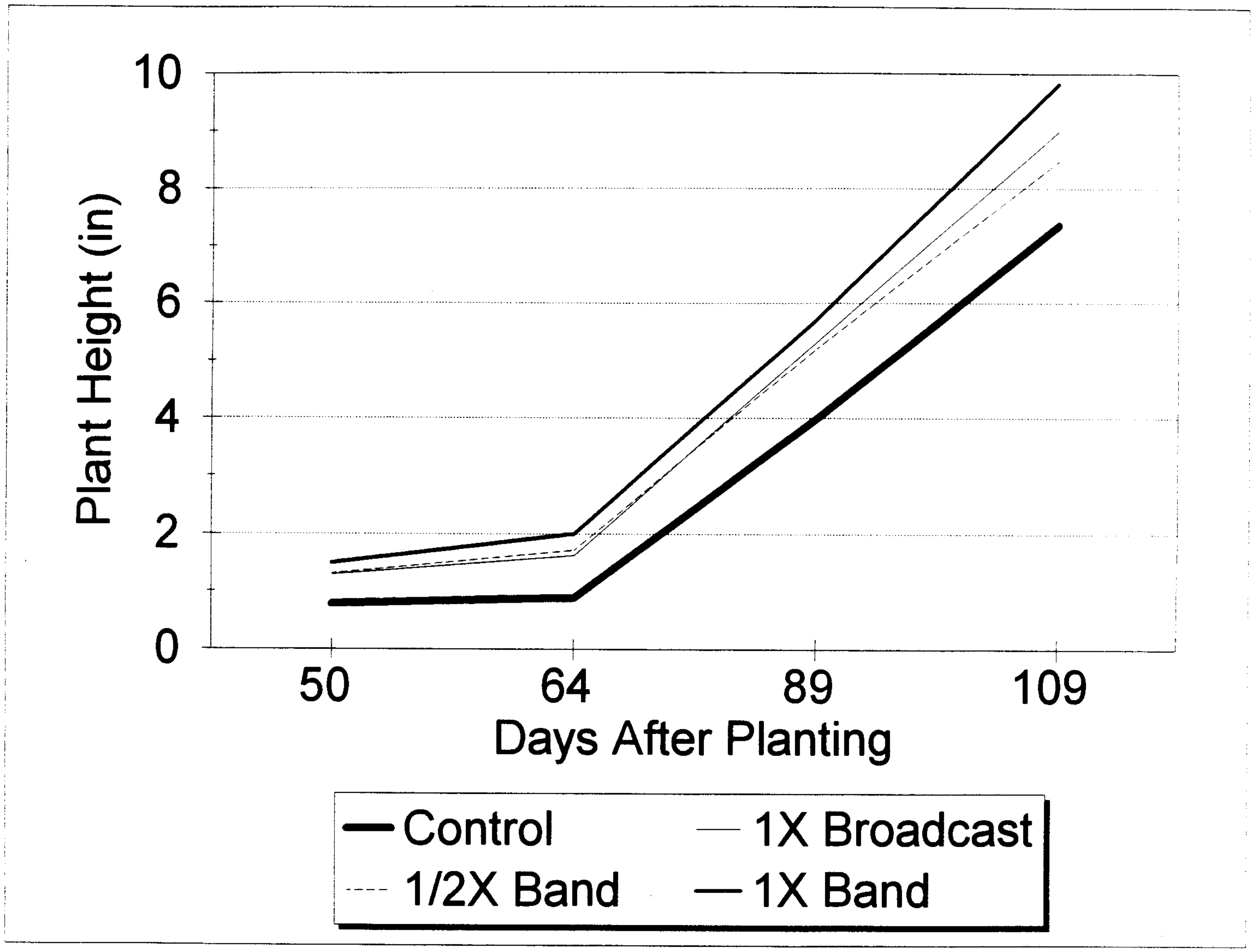

Figure 3. Plant height measurements of leaf lettuce in response to different rates and applications of treble superphosphate fertilizer. LSD (0.05) values for the 50, 64, 89, and 109 days after planting levels are 0.17, 0.16, 0.49, and 0.66 respectively.