Nitrogen and Phosphorus Fertilizer Requirements for Young, Bearing Microsprinkler-Irrigated Citrus, 2005 Report

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Abstract

Higher nutrient and water use efficiency are possible with microsprinkler-irrigated citrus compared to flood-irrigated citrus. Therefore, new N and P fertilizer recommendations are needed for microsprinkler-irrigated citrus. The objectives of these experiments were to i) determine the effects of N applications on tree growth, fruit yield, fruit and juice quality, and N and P removal in fruit for microsprinkler-irrigated navel oranges; ii) determine the effects of P applications on tree growth, fruit yield, fruit and juice quality, and N and P removal in fruit, and iii) develop Best Management Practices for N and P fertigation of microsprinkler-irrigated citrus. Field experiments were conducted at the University of Arizona Citrus Agricultural Center in separate blocks of 'Newhall' and 'Fukumoto' navel oranges, both on 'Carrizo' rootstock. In each block, ten treatments, consisting of all possible combinations of 5 N rates (0, 0.2, 0.4, 0.6, and 0.8 lb N/tree/yr) and 2 P rates (0, 0.2 lb P/tree/year) were applied to five replicate trees per treatment. Maximum yields of the 'Newhall' trees were 132 lb fruit/tree at a N rate of 0.5 lb N/tree/yr. Maximum yield of the 'Fukumoto' trees was119 lb fruit/tree at 0.5 lb N/tree/yr. Both varieties maintained appropriate leaf N and P concentrations at the yield-maximizing N rates. Total N in the fruit accounted for about 60 % of the N applied at the yield-maximizing N rates in both varieties. The results confirmed that microsprinklers effectively reduced the amounts of N fertilizer needed while maintaining adequate N status in the trees, with excellent N use efficiency.

Introduction

Nitrogen is the nutrient most likely to limit yield and quality of citrus, and is the nutrient used in largest amounts for citrus production. Adequate supplies of N are necessary to optimize yield of young citrus trees. Optimal growth and yield requires optimal levels of N and irrigation, but an excess of either is nonproductive, costly, and may result in loss of N by leaching and/or runoff.

Escalating water costs and declining water availability are causing growers to adopt production practices which allow them to significantly improve water use efficiency and decrease labor costs. One such practice is the installation of under-tree microsprinklers in place of conventional surface flood irrigation. In addition to allowing precise control of irrigation water applications, microsprinkler systems offer the ability to use fertigation with fluid fertilizer materials throughout the 9-month growing season.

Existing guidelines for fertilization of Arizona citrus crops were developed for flood irrigation. Previous research that we have conducted has demonstrated that the N rates recommended for young, non-bearing flood-irrigated citrus can be substantially reduced for microsprinkler-irrigated citrus. The lower N requirement is directly related to the higher water- and nutrient-use efficiency of microsprinkler irrigation compared to flood irrigation. We hypothesize that optimum N rates for fruit-bearing microsprinkler-irrigated citrus will also be lower than for flood-irrigated citrus. Field experiments are needed to test this hypothesis.

Arizona citrus crops are normally not fertilized with P. However, because of the altered pattern of root distribution and water and nutrient extraction in microsprinkler-irrigated citrus, compared to conventional irrigation methods,

and the capability for P fertigation, current P fertilizer practices should be re-examined. Therefore, research is needed to define appropriate rates of fluid P inputs for microsprinkler irrigated citrus in the desert Southwest.

Increasing water costs and environmental concerns create a need for more efficient management practices for citrus production. Microsprinkler irrigation and fertigation have the potential to significantly increase production efficiency. However, there is evidence that existing N and P fertilization guidelines need to be revised for microsprinkler production systems. There is a particular lack of good information on young fruit-bearing citrus. The objective of this project is to investigate the effects of two important management variables, N rate and P rate, on tree growth, nutrition, and fruit yield and quality. From these results we intend to develop recommended Best Management Practices for microsprinkler-irrigated citrus. Development of more up-to-date fertilizer recommendations will help Arizona citrus growers optimize fertilizer management practices.

Recommended N rates for young, fruit-bearing citrus are generally based upon leaf N analysis or N removal in harvested fruit. The generally recommended critical leaf N concentration is 2.4-2.6%; within this concentration range tree N status is considered "optimum". Current Arizona recommendations call for 1-2 lb N/tree/yr to young bearing citrus with optimum leaf N (Doerge et al., 1991). However, these recommendations were derived for flood-irrigated citrus. The International Fertilizer Association (2002) summarized N recommendations worldwide for 6-year-old (bearing) citrus. Recommended rates were generally from 0.6 - 1.0 lb N/tree/yr. In Texas, N rates for 6-8 year-old citrus are 1 - 1.25 lb/tree/yr (Sauls, 2002). Florida recommendations call for similar rates of N application and are based upon leaf N concentration.

None of the recommendations cited in the previous paragraphs were developed for microsprinkler-irrigated citrus. Only the Texas recommendations explicitly recognize the higher efficiency of microsprinklers by recommending a 20% reduction in N rate with microsprinklers (Sauls, 2002). Previous research at the University of Arizona has demonstrated that optimum N rates for newly-planted microsprinkler-irrigated citrus are significantly lower than rates previously considered optimum for flood-irrigated citrus (Weinert et al., 2002). This is probably because of the higher water- and nutrient-use efficiency that is possible with microsprinkler irrigation. It is reasonable, therefore, to hypothesize that optimum N rates for young, bearing microsprinkler-irrigated citrus will also be lower than for flood-irrigated citrus. Because of the growing importance of microsprinklers in Arizona citrus production, there is an urgent need to determine optimum N rates.

Observed responses to P fertilization by citrus include increased juice content, increased soluble solids/acids in juice, increased yields, and decreased rind thickness (Hilgeman et al., 1938; Embleton et al., 1956; Smith, 1963; C.A. Sanchez, Yuma, AZ, unpublished data). Citrus crops in central Arizona are customarily not fertilized with P, and previous research in this area has generally shown a lack of response to P fertilization (Hilgeman and Dunlap, 1972). However, recent research in western Arizona on sandy soils showed that mature citrus converted from border flood to microsprinkler irrigation responded to granular P fertilization (C.A. Sanchez, Yuma AZ, unpublished data).

The objectives of this project are to i) determine the effects of N applications of 0 - 1.0 lb/tree/yr on tree growth, fruit yield, fruit and juice quality, and N and P removal in fruit for microsprinkler-irrigated navel oranges; ii) determine the effects of P applications of 0 - 0.2 lb/tree/yr on tree growth, fruit yield, fruit and juice quality, and N and P removal in fruit, and iii) develop Best Management Practices for N and P fertigation of microsprinkler-irrigated citrus.

Materials and Methods

Field studies have been conducted since March 1997 at the University of Arizona Citrus Agricultural Center in Waddell. The experiment is conducted on a Gilman loam soil, which has a pH of 8.0, Ec_e of 0.7 dS/m, extractable K of 702 ppm, exchangeable sodium <1%, and $CaCO_3$ <1%. 'Newhall' navel orange trees on 'Carrizo' citrange rootstock and 'Fukumoto' on 'Carrizo' were planted in March 1997.

Fifty trees of each scion-rootstock combination are planted in separate blocks on 20' x 20' centers within the same field. Each plot contains one tree. The experiment consisted of all possible combinations of five N rates (0, 0.2, 0.4,

0.6, 0.8 lb N/tree/yr), and two P rates (0, 0.2 lb P/tree/yr), arranged in a randomized complete block design. Each of the 10 treatments was replicated five times. Each tree was equipped with two 300 degree Maxijet (Maxijet, Inc., Dundee, FL) microsprinklers (10.5 gph each) under the canopy. In-line Dosatron injectors were used to apply the UN-32 and phosphoric acid (0-52-0) fertilizers. The N and P fertilizers were applied in nine fertigation events scheduled monthly from January to July. Irrigation was applied to maintain soil moisture above 70% available soil moisture, which is the optimum level for citrus tree. A foliar application of Zn-EDTA was applied during Mar. 2004.

Leaf tissue was collected in August 2004 and analyzed for N and P to determine nutrient status of the trees as affected by N and P rates. Fruit was harvested on December 13, 2004. All fruit were processed through an automated fruit sizer, and eight fruit from each plot were collected, individually weighed, and juiced for determination of fruit and juice quality, including percent juice, peel thickness, brix, and titratable acidity. Selected fruit from each plot were oven-dried, ground, and analyzed for N and P concentration, to determine the mass of N and P removed in harvested fruit.

Results and Discussion

Yield and Quality. During the 8th growing season of these trees, considerably lower amounts of fertilizer N were applied to the 'Newhall' and 'Fukumoto' navel orange trees under microsprinkler irrigation, compared to rates recommended for flood-irrigated citrus (Doerge et al., 1991). Fertilizer N rates recommended for flood-irrigated citrus in AZ are 450-910 g N tree^{-1} yr^{-1} (1-2 lb N/tree/year) for trees more than five years after planting (Doerge et al, 1991).

Maximum predicted fruit yield from the response equation in the 'Newhall' trees with no fertilizer P application (P=0) was 59.9 kg tree^{-1} (132 lb/tree) in 2004 (Fig. 1A). The response of yield to N rate with fertilizer P application (P=91), however, did not follow a quadratic model (Fig. 1A). The reason for the response is unclear. The maximum yield of 'Newhall' trees was at 214 g N tree^{-1} yr^{-1} (0.5 lb N/tree/yr) during 2004 (P=0) (Figure 1A). The maximum predicted yield of the 'Fukumoto' trees was 53.8 kg tree^{-1} (P=0) (119 lb/tree) and 48.0 kg tree^{-1} (P=91)(106 lb/tree) during 2004 (Fig. 1B). Maximum yield of the 'Fukumoto' trees was at 233 g N tree^{-1} yr^{-1} (P=0) (0.5 lb N/tree/yr) and 173 g N tree^{-1} yr^{-1} (P=91) (0.4 lb N/tree/yr) during 2004 (Fig. 1B).

During this harvest, differences in fertilizer N rate and P rate did not affect fruit and juice quality, including brix, acids, TSS:TA ratio, fruit weight, and rind thickness (data not shown). In both varieties, the mean brix contents were 11.3 to 11.9%, total acidity was 0.41 to 0.48%, and the TSS:TA ratios were 24.9 to 28.2 (data not shown). Koo (1980) reported that fertigation resulted in lower total acidity in juice and higher TSS:TA ratio. Our results showed similar brix contents, lower acidity, and higher TSS:TA ratio compared with mature 'Valencia' orange trees under trickle irrigation (Koo, 1984). The mean fruit weights in the 'Newhall' trees were 296 g fruit^{-1}; in the 'Fukumoto' trees the average fruit weight was 296 g fruit^{-1}. Feigenbaum et al. (1987) reported on mature 'Shamouti' orange trees in Israel, that higher amounts of fruit yield reflected larger number of fruits on the trees, which resulted in lowering the fruit weight. Interestingly, the 'Newhall' trees characterized higher yield and larger fruit weights, leading to smaller number of fruits. It appears that reduction of fruit yield in the 'Fukumoto' trees could be partly attributed by production of larger fruits.

Leaf Nitrogen and Phosphorus Concentrations. Leaf N concentrations in both varieties increased linearly with N rate. At yield-maximizing N rates, leaf N concentrations were 25 to 27 mg g^{-1}, which is the generally accepted critical leaf tissue N concentration range (Tucker et al, 1995; Sauls, 2002; and Kallsen, 2003) (Figure 2).. The results indicate that tree N status was adequate at yield-maximizing N rates. These findings support the effectiveness of reducing N fertilizer application on microsprinkler production systems. These results suggest that optimum N fertilizer rates for microsprinkler irrigated citrus are substantially lower that the currently recommended for flood-irrigated citrus during the 8th growing season (Doerge at al., 1991).

During this growing season, leaf P concentrations in all treatments of both varieties were within or above the critical tissue P range of 12 to 16 mg g^{-1} (Tucker et. al., 1995; Sauls, 2002; Kallsen, 2003; and Obreza et. al., 2003) (Data

not shown). Leaf tissue P was negatively correlated with increasing fertilizer N rates except both varieties with P=0 in 2004. Leaf P concentration showed that the trees maintained adequate P throughout the experiment.

Nitrogen and Phosphorous removal in fruit. To estimate and evaluate fertilizer N and P uptake efficiencies, N and P concentrations in fruit were converted to a dry matter basis. Total fruit N content in the 'Newhall' trees at the yield-maximizing rate was 124.8 g tree^{-1} (0.3 lb N/tree) (Figure 3A), equivalent to about 60% (P=0) of the yield-maximizing N rate. Total fruit N accumulation in the 'Fukumoto' trees at the yield-maximizing N rate was 124.9 g tree^{-1} (P=0) (0.3 lb N/tree) and 115.3 g tree^{-1} (P=91)(0.25 lb N/tree) (Figure 3B).Thus, fruit N removal accounted for 52 to 66% of N applied at the yield-maximizing N rate. The percentage of applied N removed in fruit decreases as N rates increase beyond the yield-optimizing rate (Alva and Paramasivam, 1998; Lea-Cox et al, 2001; and Mattos Jr. et al, 2003a).

During this growing season, average total P removal in fruit accounted for 16% of P applied at the yield-maximizing N fertilizer rates in both varieties (data not shown). Lower P removal in fruit may be due to the low sink demand for absorbed P in the new organs (Mattos Jr. et. al., 2003b). The lack of fruit response to fertilizer P rate applied and the high P use efficiency in P=0 trees seen in our study confirmed that fertilizer P application was not needed.

Conclusions

During the 8th growing season of two varieties of microsprinkler-irrigated navel oranges, there was no effect of fertilizer P rate on fruit yield and quality, leaf N and P levels, and N and P removal in fruit. Fruit quality was also not affected by fertilizer N rate. Maximum yields of the 'Newhall' trees were 132 lb fruit/tree at a N rate of 0.5 lb N/tree/yr. Maximum yield of the 'Fukumoto' trees was119 lb fruit/tree at 0.5 lb N/tree/yr. Both varieties maintained appropriate leaf N and P concentrations at the yield-maximizing N rates. Total N in the fruit accounted for about 60 % of the N applied at the yield-maximizing N rates in both varieties. The results confirmed that microsprinkler production system effectively reduced optimum N rates, while maintaining adequate N status in the trees, with excellent N use efficiency. Therefore, optimum N fertilizer rates for microsprinkler irrigated citrus are lower than those currently recommended for flood-irrigated citrus during the 8th growing seasons.

Literature Cited

Alva, A.K. and S. Paramasivam. 1998. Nitrogen management for high yield and quality of citrus in sandy soils. Soil Sci. Soc. Am. J. 62: 1335-1342.

Doerge, T.A., R. L. Roth and B.R. Gardner. 1991. Nitrogen fertilizer management in Arizona. The Univ. of Arizona, College of Agriculture, Report No. 191025.

Embleton, T.W., J.D. Kirkpatrick, W.W. Jones, and C.B. Cree. 1956. Influence of applications of dolomite, potash, and phosphate on yield and size of fruit and on composition of leaves of valencia orange trees. Proc. Am. Soc. Hort. Sci., pp. 183-190.

Feigenbaum, S., H. Bielorai, Y. Erner, and S. Dasberg. 1987. The fate of 15N labeled nitrogen applied to mature citrus trees. Plant Soil 97:179-187.

Hilgeman, R.H. and J.A. Dunlap III. 1972. 30th Anniversary Report and Citrus Field Day. Univ. of Arizona Coop. Ext. Serv. Series P-29, 24 pp.

Hilgeman, R.H., C.W. Van Horn, and W.E. Martin. 1938. A preliminary report on the effects of fertilizing practices upon maturity and quality of Marsh Grapefruit in Arizona. Proc. Am. Soc. Hort. Sci. pp. 352-355.

International Fertilizer Association. 2002. Citrus. In World Fertilizer Use Manual. Internet: posted at http://www.fertilizer.org/ifa/publicat/html/pubman/citrus.htm.

Kallsen, C. 2003. Fall leaf tissue samples important for maintaining citrus growth, fruit quality and yields. University of California cooperative extension. Internet: posted at http://cetulare.ucdavis.edu/pub/Subtropics%20Fall%2003.pdf

Koo, C.J. 1980. Results of citrus fertigation studies. Proc. Fla. State Hort. Soc. 93:33-36.

Koo, C.J. 1984. Effect of trickle irrigation and fertigation on fruit production and juice quality of 'Valencia' orange. Proc. Fla. State Hort. Soc. 93:33-36.

Lea-Cox, J.D., J.P. Syvertsen, and D.A. Graetz. 2001. Springtime 15 Nitrogen uptake, partitioning, and leaching losses from young bearing Citrus trees of differing nitrogen status. J.Am. Soc. Hortic. 126:242-251.

Mattos Jr., D., J.A. Quaggio, H, Cantarella, and A.K. Alva. 2003a. Nutrient content of biomass components of hamilin sweet orange trees. Scientia Agricola. 60:155-160.

Obreza, T.A. 2003. Prioritizing citrus nutrient management decisions. University of Florida Coop. Ext. Serv. UF/IFAS Bulletin. SL 199.

Sauls, J.W. 2002. Texas Citrus and Subtropical Fruits: Nutrition and fertilization. Internet: posted at http://aggie-horticulture.tamu.edu/citrus/nutrition/L2288.htm.

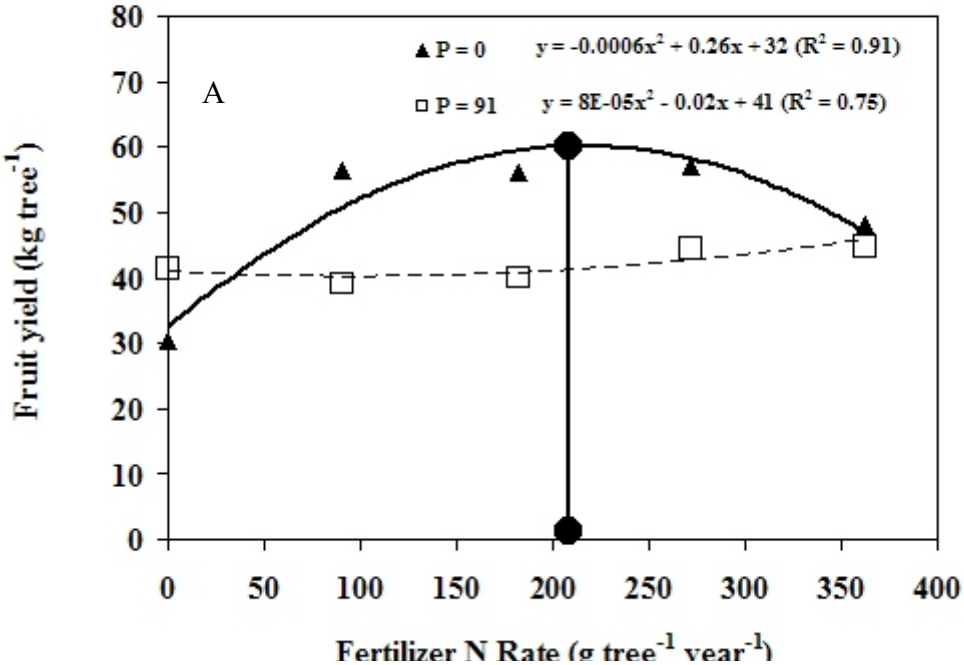
Smith, P.F. 1963. Effect of fertilization on quality of citrus fruits: In Hansen et al. (ed.) Proceedings of the 39th Annual Meeting of the Council on Fertilizer Application. National Plant Food Institute, Washington, D.C. pp. 16-25.

Thompson, T.L., S.A. White, J. Walworth, and G.S. Sower. 2002. Development of best management practices for fertigation of young citrus trees, 2002 report. University of Arizona Citrus and Deciduous Fruit and Nut Report.

Tucker, D.P., A.K. Alva, L.K. Jackson, and T.A.Wheaton. 1995. Nutrition of Florida citrus trees. University of Florida Coop. Ext. Serv. UF/IFAS Bulletin. SP169.

Weinert, T.A., T.L. Thompson, S.A. White, and M.A. Maurer. 2002. Nitrogen fertigation of young navel oranges: Growth, N status, and uptake of fertilizer N. HortScience 37:334-337.

Figure 1 (A) Yield of 'Newhall' navel oranges, and (B) 'Fukumoto' navel oranges harvested on December 13, 2004. The x-intercepts indicate the N rate associated with maximum predicted yield.



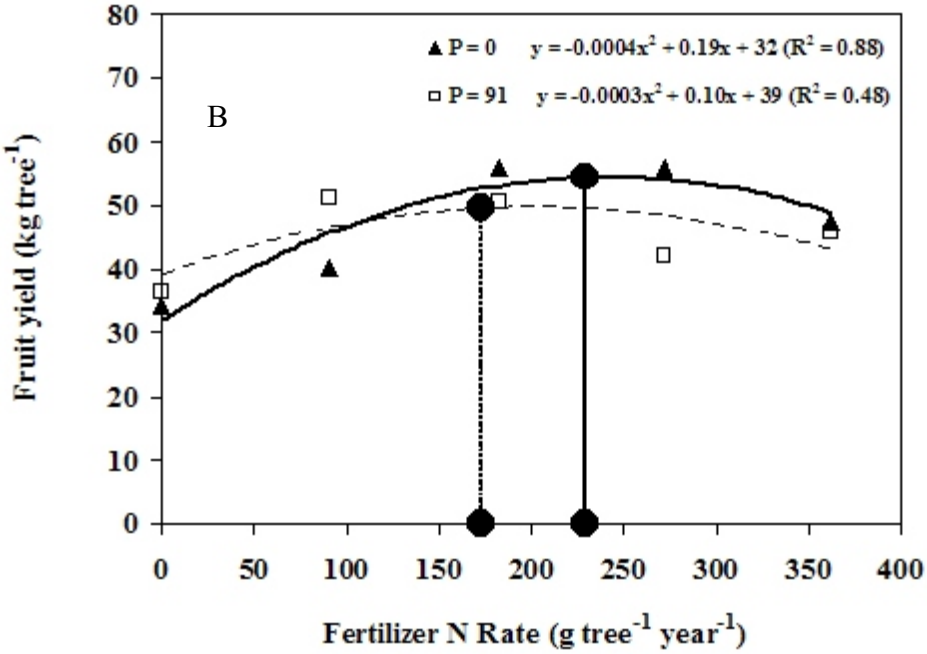


Figure 2. Leaf N in (A) 'Newhall' navel oranges and (B) 'Fukumoto' navel oranges, in samples collected in August, 2004. The x-intercepts indicate the N rate associated with maximum predicted yield.

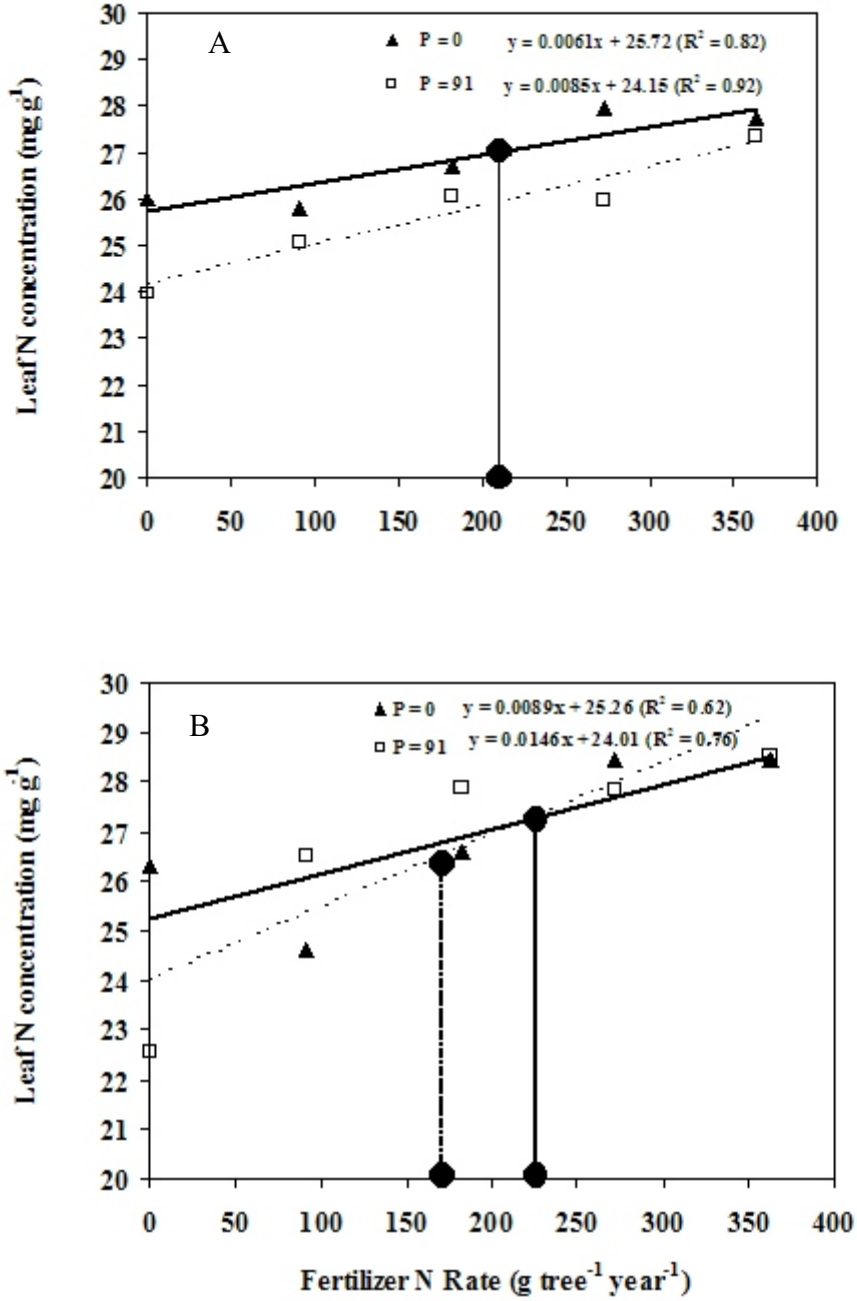


Figure 3. Nitrogen removal by (A) 'Newhall' navel oranges, and (B)'Fukumoto' navel oranges harvested on December 13, 2004. The x-intercepts indicate the N rate associated with maximum predicted yield.