Title:
A Nutrient Budget Approach to Nutrient Management in Almond

Author:
Muhammad, Saiful, University of California Davis
Luedeling, Eike, University of California Davis
Brown, Patrick H, University of California Davis

Publication Date:
07-31-2009

Publication Info:
The Proceedings of the International Plant Nutrition Colloquium XVI, Department of Plant Sciences, UC Davis, UC Davis

Permalink:
http://escholarship.org/uc/item/70n6s7c3

Keywords:
Nutrient, budget, almond

Abstract:
A large scale multi-year experiment has been set up to develop a phenology and yield based nutrient model for Almond, to develop fertilizer response curves to relate nutrient demand with fertilizer rate and nutrient use efficiency and to determine nutrient use efficiency of various commercially important N and K fertilizer sources. The goal was to develop an integrated nutrient best management practice for almond. The treatments consists of four rates of nitrogen 140kg/ha, 224kg/ha, 308kg/ha and 392kg/ha and two commercially important sources of nitrogen, UAN 32 and CAN 17. There are three treatments for potassium rates: 112kg/ha, 224kg/ha and 336kg/ha and three sources of potassium: SOP, SOP+KTS and KCl. Leaf and nut samples were collected from the 768 individual trees in April, May, June, July, August and October and analyzed for N, P, K, Ca, S, Mg, B, Zn, Cu, Mn and Fe. A clear effect of N rate on the pattern and total quantity of annual nitrogen accumulation was observed. Changes in the pattern of total fruit N accumulation, leaf and fruit N concentrations suggest that fruit growth is the primary determinant of tree N accumulation and that resorption of N from fruit into perennial tree structures occurs as fruit matures. Similar patterns of resorption were observed for P but not for the other elements measured.

Introduction

Almond is grown on 0.74 million acres (0.3 million ha) in California and the production area is increasing (Almond Board of California, 2008). Currently nutrient management in almond is based on the Critical Value concept (Brown and Uriu, 1996). Critical Value (CV) represents the leaf nutrient concentration of a standard leaf sample at which yield is equal to 95% of maximum yield. (Ullrich and Hills, 1990). Ideally, CV's are established in carefully controlled experiments, in which the relationship between yield and nutrient concentration is closely monitored. In almond the majority of CV's have been determined on the basis of visual symptoms, not based on yield reduction (Beutel et al., 1978; Brown and Uriu, 1996). Yield-based CV's in Almond are only available for nitrogen (Uriu, 1976 and Weinbaum et al, 1990), potassium (Meyer, 1996; Reidel et al, 2004) and boron (Nyomora et al, 1999). Weinbaum (1990) suggested that a critical nitrogen leaf value of 2.3% in July non-fruiting spur leaves is likely adequate for Almond. Under the productivity levels in the experimental orchard in this study, 250 lbs of N per acre, applied during growth and nut formation in Almond appeared to be adequate.

The CV approach provides only an indication of adequacy or deficiency at a single point in time but does not provide any specific information on the appropriate rate or timing of fertilizer applications. The CV approach is thus inadequate for nutrient management in high value crops like almond. An alternative approach that has been widely used in high value crops, uses knowledge of crop growth and development to derive nutrient demand curves that guide the quantity and timing of fertilizer applications. Nutrient budgets have been developed for corn (Karlen et al 1988), cotton (Halevy et al 1977), tomato (Huett 1986) and others.

The goal of this research was to develop a phenology and yield based nutrient model for Almond. The trial also aims to develop fertilizer response curves to relate nutrient demand with fertilizer rate and nutrient use efficiency. Nutrient use efficiency of various commercially important N and K fertilizer sources will be determined, and integrated best nutrient management practices for almond will be developed. Since tree crops require a long term research approach, this experiment will be conducted for 3-5 years. Here we are presenting preliminary results from the first year.

Materials and methods

The experiment was established in a commercial almond orchard at Belridge, Kern County, California under fan jet and drip irrigation systems. Each of the 12 treatments were applied to five or six blocks with 15 trees per block. The treatments consist of four rates of nitrogen (140 kg N ha^{-1}, 224 kg N ha^{-1}, 308 kg N ha^{-1} and 392 kg N ha^{-1}), supplied as two commercially important sources of nitrogen (Urea Ammonium Nitrate 32% [UAN 32] and Calcium Ammonium Nitrate

17% [CAN 17]). Potassium was applied in three rates (112 kg K ha^{-1}, 224 kg K ha^{-1} and 336 kg K ha^{-1}) and supplied by three sources of potassium (Sulphate of Potash [SOP], SOP + Potassium Thiosulphate [KTS] and Potassium Chloride [KCl]). 60% of the potassium in K rate treatments was applied as SOP in early February, while the remaining 40% was applied as KTS in four fertigation cycles. Nitrogen was also applied in four fertigation cycles with 20%, 30%, 30% and 20% of total nitrogen supplied in February, April, June and October, respectively. Fifteen trees and their immediate 30 neighbors, over three orchard rows, were treated as one experimental unit. All data were collected from six trees in the middle row. A total of 768 experimental trees were selected for this experiment. Leaf and nut samples were collected from individual trees in April, May, June, July, August and October. A total of 5400 leaf and nut samples were collected and analyzed for N, P, K, Ca, S, Mg, B, Zn, Cu, Mn and Fe at the Agriculture and Natural Resources (ANR) Laboratory at the University of California Davis. The crop was harvested in August and individual tree yields were determined for all data trees. Two kilogram samples were collected from each replicate to determine crack out percentage and oven dry weight. Twenty nuts were collected at harvest from each experimental tree to determine the ratio of kernel to shell/hull and the partitioning of nutrients.

Results

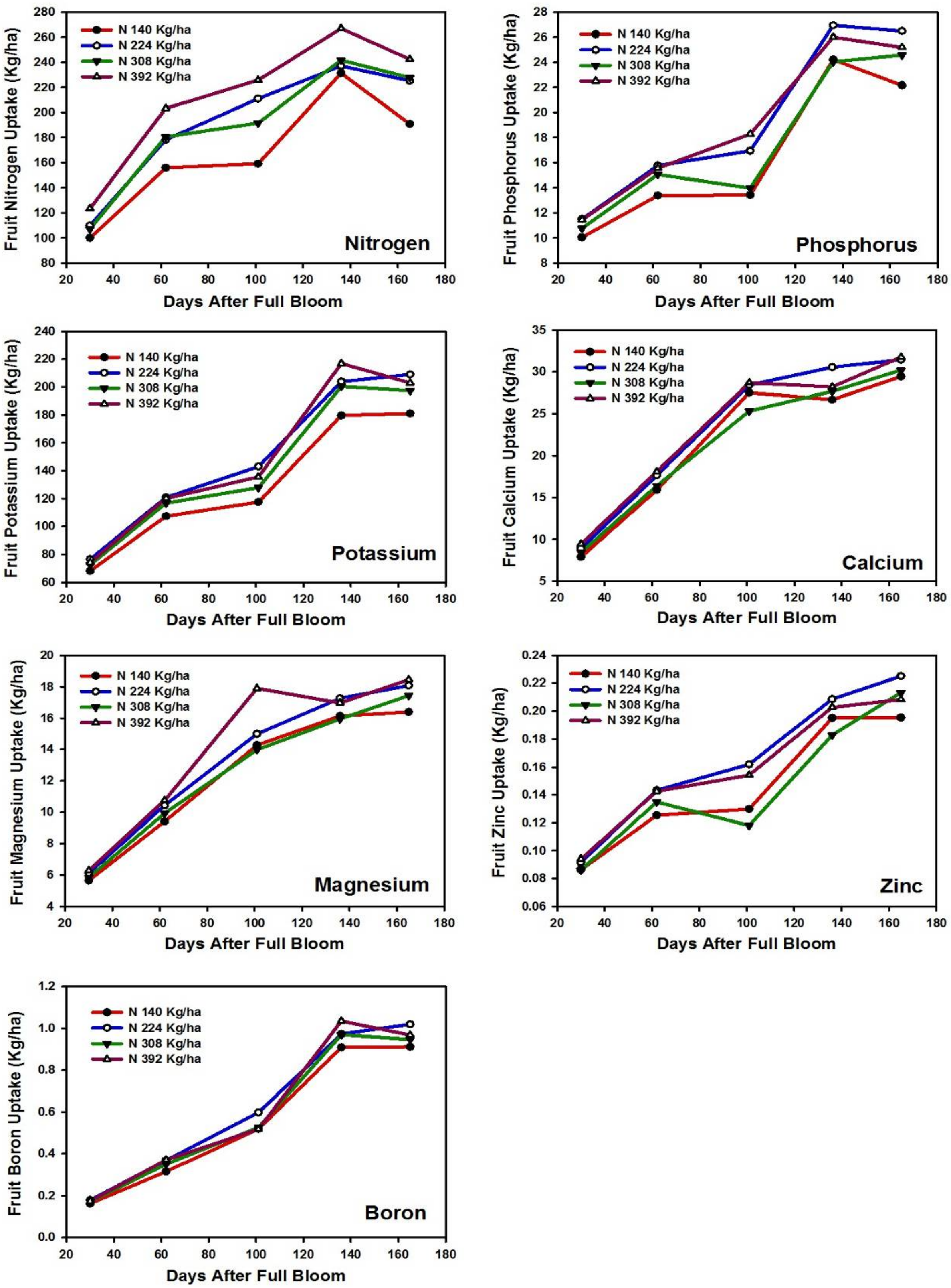
The accumulation of Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Zinc and Boron in the fruit for different rates of N increased over the season is shown in figure 1.

Nitrogen

Nitrogen accumulation in the fruit was positively correlated with nitrogen supply at all sampling dates. At 30 DAFB 100 kg ha^{-1} N was accumulated for N rate 140 kg ha^{-1}, 109 kg ha^{-1} for N rate 224 kg ha^{-1} and 308 kg ha^{-1}, while 124 kg ha^{-1} N was accumulated for N rate 392 kg ha^{-1}. Nitrogen accumulation increased in all treatments and was maximal at 136DAFB. Between 136 and 165 DAFB (harvest), however, total fruit N accumulation declined for all N rate treatments suggesting that N in fruit had been remobilized back to the tree.

Phosphorus

Phosphorus exhibited an annual trend that resembled nitrogen and increasing nitrogen supply also increased phosphorus uptake. All treatments also exhibited a small but significant decline in P concentrations between 136 and 165 DAFB (harvest). This pattern of pre-harvest decline was observed with N and P but not with any other element.



Fruit Nitrogen Uptake (Kg/ha)
N 140 Kg/ha
N 224 Kg/ha
N 308 Kg/ha
N 392 Kg/ha
Nitrogen
Days After Full Bloom
Fruit Phosphorus Uptake (Kg/ha)
Phosphorus
Fruit Potassium Uptake (Kg/ha)
Potassium
Fruit Calcium Uptake (Kg/ha)
Calcium
Fruit Magnesium Uptake (Kg/ha)
Magnesium
Fruit Zinc Uptake (Kg/ha)
Zinc
Fruit Boron Uptake (Kg/ha)
Boron

Fig 1. Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Zinc and Boron uptake by almond fruit from nitrogen rate treatments

Potassium

Potassium accumulation in the fruit increased with growth (fig 2). K uptake from K rate 224 kg ha^{-1} and 336 kg ha^{-1} was similar during the season except at 165DAFB (harvest). Fruit K accumulation increased from 70.5 kg ha^{-1} at 30DAFB to 184 kg ha^{-1} at 165DAFB for K rate 112 kg ha^{-1}, while for K rate 336 kg ha^{-1} K accumulation increased from 77 kg ha^{-1} at 30DAFB, to 208 kg ha^{-1} at 165DAFB.

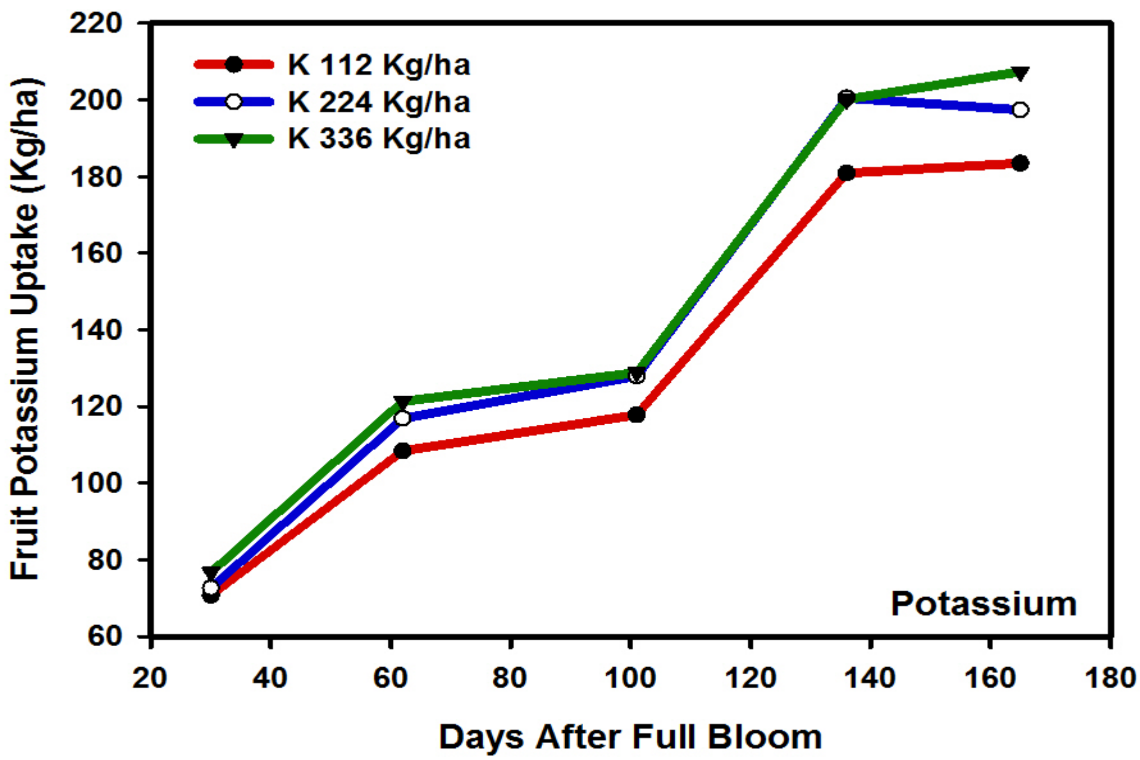


Fig 2. Potassium uptake by almond fruit from potassium rate treatments

Fruit Nitrogen Concentration

Fruit nitrogen concentration declined overtime for all N rate treatments (Fig 3). Maximum fruit N concentration was observed at 30DAFB and minimum N concentration at 165DAFB (harvest) for all N rate treatments.

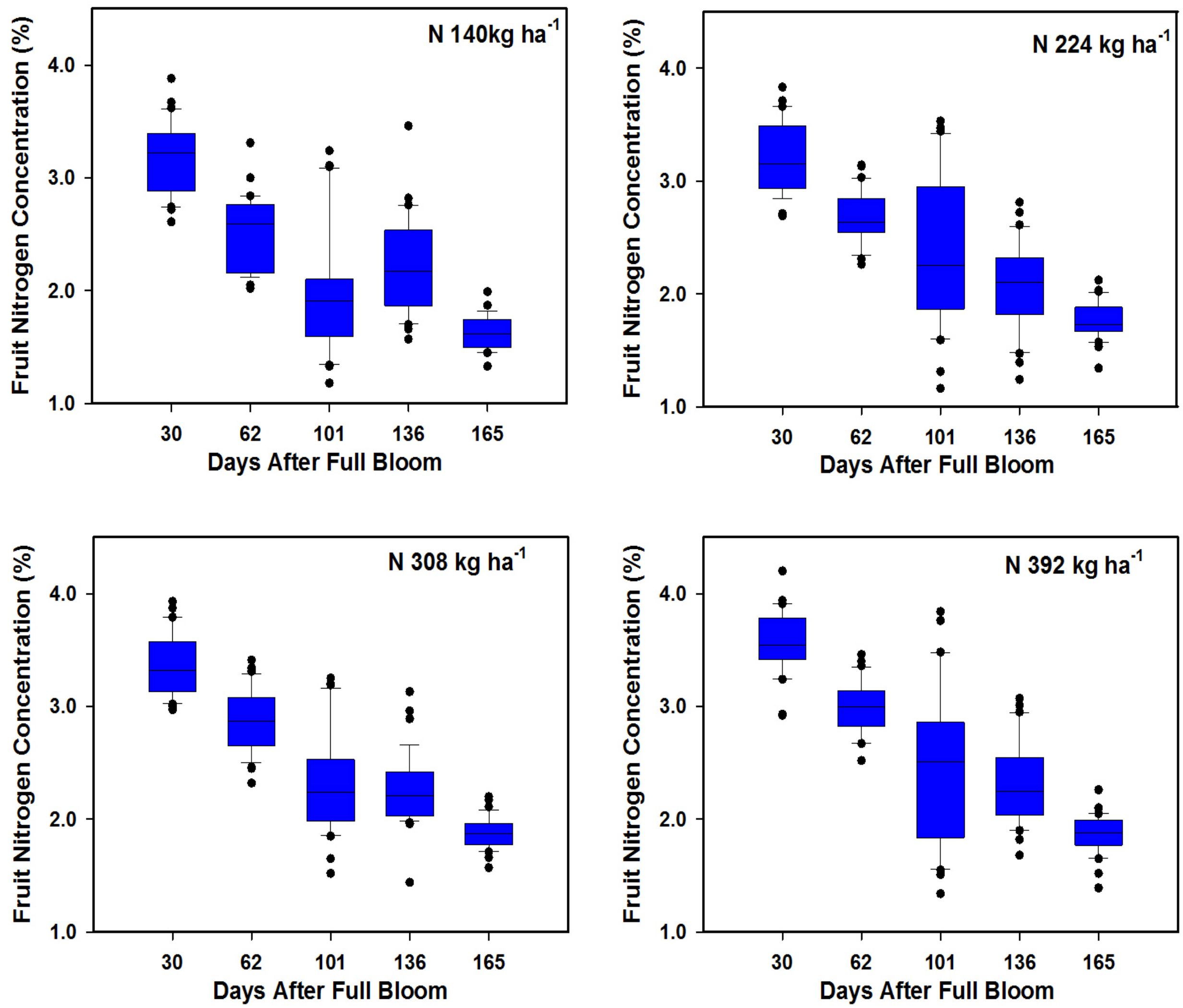


Fig. 3. Nitrogen concentration of Almond overtime for N rate treatments. In box plots, the central line is the median of the distribution, the edges of the boxes are the 25% and 75% quantiles, error bars, represent the 10% and 90% quantiles, and all points are outliers.

Yield

Crop yield varied substantially throughout the orchard. Even though this experiment was only established in spring 2008, nitrogen treatments had a significant effect on crop yields in year 1 of the experiment (Fig. 4). Maximum fruit yield (12,800 kg ha^{-1}– total dry fruit weight) was obtained from the highest N treatment (392 kg ha^{-1}), while minimum yield (11,500 kg ha^{-1}) was obtained from the lowest nitrogen treatment (140 kg ha^{-1}). The effect of the K rate treatments on fruit yield was not statistically significant.

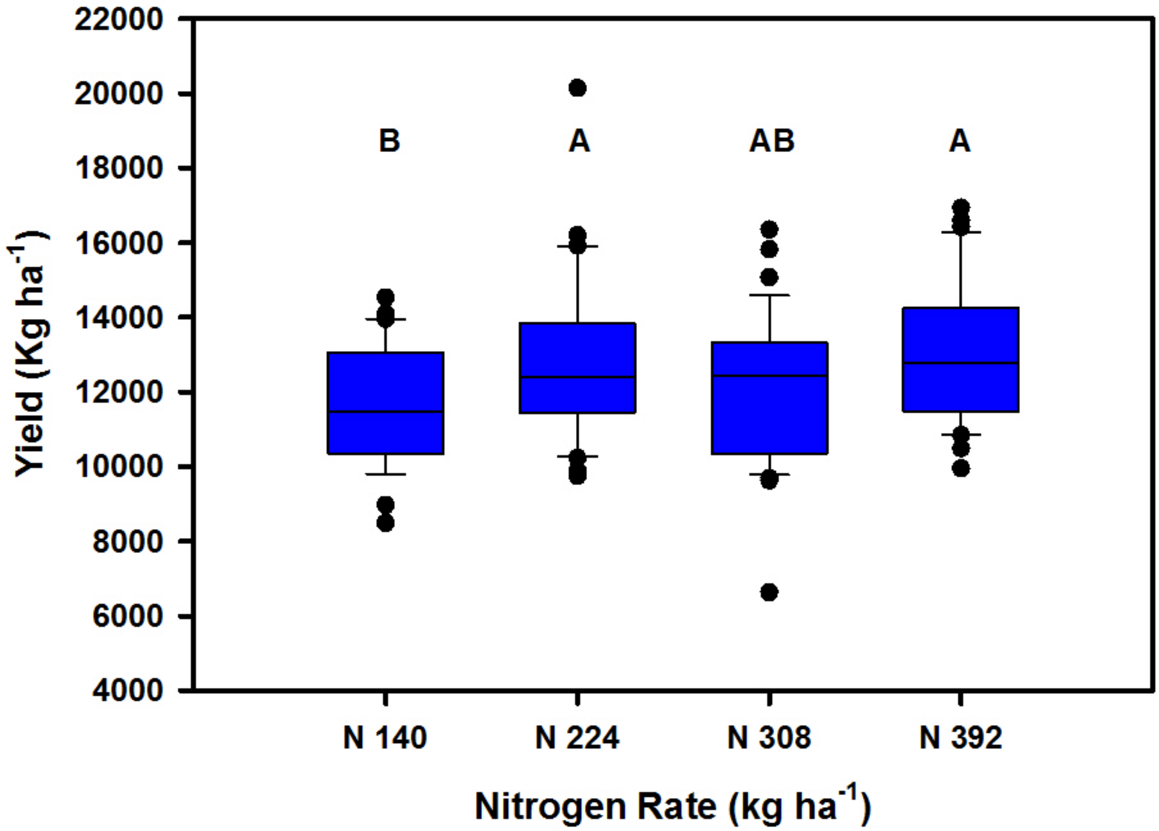


Fig 4. Effect of different nitrogen rates on almond yields at Belridge, CA in 2008. In box plots, the central line is the median of the distribution, the edges of the boxes are the 25% and 75% quantiles, error bars, represent the 10% and 90% quantiles, and all points are outliers.

Discussion

Results from a single year of experimentation should be interpreted with care as treatment effects may not be fully established and multi-year effects cannot be discerned. Increasing nitrogen supply, however, significantly increased fruit yield and nitrogen concentration in the plant tissues and these differences existed between treatments at all sample dates. Trends in nutrient concentrations and fruit accumulation were evident early in the season and persisted throughout the year and may imply that early season sampling may be useful in monitoring of tree nitrogen demand. Nitrogen and phosphorus accumulation was highest at 136 DAFB and then decreased at harvest suggesting that N and P moved from the fruit to the shoot during nut maturation. The resorption of N and P was high for the lowest N rate (140 kg ha^{-1}) suggesting that relative tree demand can influence N resorption. Resorption of phloem mobile nutrients from fruit back toward tree woody structures has not, to our knowledge, been previously recorded, this effect was not seen with K, Ca, Mg and Zn.

References

Almond Board of California 2008. 2007 Almond Acreage Report. www.almond-board.com

Almond Board of California. 1972-2003. Years of discovery. pp. 285-296.

Beutel J, Uriu K, Lilleland O. 1978. Leaf analysis for California deciduous fruits. In: Reisenauer HM (ed.) soil and plant-tissue testing in California. Pp 11-14.

Brown P. H, and Uriu K. 1996. Nutrition deficiencies and toxicities: diagnosing and correcting imbalances. In: Almond production manual. University of California, Division of Agriculture and Natural Resources. Publication 3364.

Halevy J. Marani A. Markovitz T. 1987. Growth and NPK uptake of high yielding cotton grown at different nitrogen levels in a permanent-plot experiment. Plant and Soil 103, 39-44

Huett DO 1986. Response to nitrogen and potassium of tomatoes grown in sand culture. *Aust.* J. *Exp.* Agric., 1986, 26, 133-138

Karlen, D.L; Flannery, R. L and Sadler E. J. 1988. Aerial Accumulation and Partitioning of Nutrients by Corn. Agron. J. 80:232-242

Meyer RD. 1996. Potassium fertilization/foliar N/P/K/B studies. In: Almond Board of California. 1972-2003. Years of discovery. pp 291-292.

Nyomora AMS, Brown PH, Krueger B. 1999. Rate and time of boron application increase almond productivity and tissue boron concentration. HortScience 34: 242-245.

Reidel EF, Brown PH, Duncan RA, Heerema RF, Weinbaum SA. 2004. Sensitivity of yield determinants to potassium deficiency in 'Nonpareil' almond (Prunus dulcis (Mill.) DA Webb). J Hort. Sci Biotech. 79: 906-910.

Uriu K. 1976. Nitrogen rate study. In: Almond Board of California. 1972-2003. Years of discovery. p 287.

Weinbaum SA, Carlson RM, Brown PH, Goldhamer DA, Micke WC, Asai W, Viveros M, Muraoka TT, Katcher J, Teviotdale B 1990. Optimization of nitrogen use. In: Almond Board of California. 1972-2003. Years of discovery. pp 289-290.