Correct Project Number: 97-PB-o0

Project Number: 97-PB-00

Project Title: Boron deficiency in Almonds

FINAL REPORT

Summary

In nut crops including almond, the maximum number of fruits at harvest is as important as the total fruit weight and size in maximizing productivity. Maximum pollination up to 100% should be the target for optimal productivity which may require overcoming pollen, ovule, pollination and or fertilization limitations. Boron (B) nutrition is well known to affect pollination and fertilization in a number of crop species. The need for B however, is transitory and very high during floral development and fruit set such that trees growing in low B soils may suffer incipient deficiency during this peak time. This transient B demand has been one of the reasons that plant requirement for B cannnot be diagnosed by the traditional analysis of mid-summer leaves nor can it be reliably provided by soil B application. In California, locations with low soil B include the Upper Sacramento valley-north of Yolo County to Chico and eastern regions of the San Joaquin valley. The magnitude of almond acreage within these areas is large and economic losses due to B nutrition are potentially high.

Until 1991/1992 little work had been done to establish the B requirements in almond. We have investigated B requirement in almond orchards over the past 5 years in Stanislaus, Glen, and

Fresno Counties. Boron rates from 0 to 3 lb solubor (wettable powder) or Borosol (liquid) equivalent to these rates (0, 0.7, 1.41, 1.76 L/100 gal) were tried and found to linearly increase tissue B concentration, fruit set and sometimes yield. In most cases the medium 1 to 2 lb solubor or 0.7-1.41 L borosol/100 gal was most effective. Application in September or February resulted in the greatest final fruit set in all years and yield in 1996. February applications effectively increased the initial fruit set in all years at all sites but were less effective than September applications at increasing yield.

As a result of this research we have established the following recommendations: Boron at the rate of 2 lb solubor or 1.41 L borosol/100 gallon water is recommended to use in almond orchards showing a hull B concentration of less than 100 ppm or leaf B concentration of less than 30 ppm towards the end of the season. Foliar application of B should be made immediately postharvest (September) for optimal effect on tissue B concentration, fruit set and yield.

Experimental

Preliminary experiments were undertaken in 1991/92 in an almond orchard (initial leaf B was 19 ppm) in Hughson, Modesto in cooperation with the Cooperative Extension-Stanislaus County. Foliar (1 lb Solubor/100 gallons water) and soil application of B (8 oz solubor/tree) were applied postharvest and compared to

untreated trees and trees which received other foliar nutrients (N, P, K, Zn and Cu) in addition to foliar B. Although the overall fruit set was very low in this study, Soil and postharvest foliar application of B increased nut set and yield of almond cv'Padre' (Figure 1).

Replicated experiments were conducted in Fresno in 1992-1993, 1993 and 1994 to study the effect of foliar B application on almond fruit set and yield in low B orchards. Solubor, a commercial product containing 20.5% B was foliar applied in October and September of 1992 and 1993 respectively at a rate of 0, 1, 2 and 3 lb solubor/100 gal B using a hand gun operated sprayer mounted to a tractor to 2 compatible almond cultivars Butte (pollinizer) and Mono (pistil donor). Each tree was sprayed to run off (4 gallons/tree). Each treatment was replicated 5 times using a Randomised Complete Block Design (RCDBD). The results showed that Postharvest foliar application of B significantly ($p=0.026$) increased nut set of almond (Figure 2, open pollination, cv 'Butte' and Fig 3 hand pollination, cv 'Mono').

During 1992-1993 laboratory analyses on pollen development and quality were also performed. This established that foliar B application enhances in-vivo pollen germination and tube growth (Figure 4a). Foliar applied B also significantly reduced tube bursting of the in vitro germinated pollen (Figure 4b) although

the presence of B in germinating media was still required.

During the 1993/94 season a preliminary trial to determine the time of application of B to optimize production was conducted. Solubor (Sodium tetraborate) a commercial product containing 20.5% B was applied either in September, December or February at rates of 0, 1, and 2 lb solubor/100 gal to almond cv Butte at site one (Parlier, Fresno county - California), and 0, 1, 1.5, 2 and 2.5 lb solubor/100 gal on the same cultivar in August, September and February at site 2 (Orland, Glen county -California). The results from Fresno (Figure 5) indicated that **Postharvest** foliar application increased nutset and yield more than Preharvest and application at Bloom.

In 1995/96 experiments were continued only in Orland, Glen county using Borosol a liquid polyboronated commercial product containing 10% B at rates of (0, 0.7, 1.41, 1.76 L/100 gal)(equivalent to those of Solubor in ppm). **Preharvest** and **Prebloom** foliar B application increased nut set and yield (Fig 6). Likewise in 1996/97 experiments were conducted in Orland, Glen county using a hand gun sprayer. The overall yield was generally high. No significant increase in nut set or yield was observed from single application in Orland, Glen County however, multiple application **Preharvest**, **postharvest** and **prebloom**, significantly increased nut set and yield of 'Butte' (Table 1).

Time and rate of application had a significant effect on almond plant tissue (leaf, bud, and hull) B concentration (Fig 7 a-d). Similar results were obtained in 1996 and 1997, so only

data for 1997 are presented. No significant differences in B concentration were observed in immature and mature fruit samples as a result of any treatment (data not shown). Leaf B concentration in leaves harvested in June and September was highest (from 35 to over 45 ppm) when trees were sprayed in February than September or August in that decreasing order (Fig 7a). Boron applied in August 1996 significantly increased B levels in leaves sampled in June 1997 (Fig 7a) or September 1997 (Fig 7b) over the controls only when it was applied at the highest rates. Similar results were found in the 1995/96 season. Bud B concentration increased significantly from 80 ppm in non-treated to over 150 ppm with increasing rates of foliar applied B. Applications made in February resulted in significantly higher B concentrations than August and September application (Fig 7c). Hull B concentration increased from 100 ppm in non-treated to over 300 ppm in trees treated with 2lb solubor or 1.41 L borosol/100gal when trees were sprayed in August 1996 and 1997 and sampled the following month (Fig 7d). Hull B concentration in 1997 from trees sprayed in September (1996) did not increase significantly and were comparable to hull B concentration from the control trees.

In all previous experiments, 1-2 lb solubor/100 gallon or 0.7-1.4 L borosol/100 gal increased fruit set and in most years, yield. This recommendation was based on hand gun sprayer (w/v) with 400 gallons of water applied per acre (i.e 4 gallons water/tree X 100 trees). This rates was repeated using a commercial speed sprayer at 100 gallons per acre. 0 to 5 lb

solubor/acre were applied postharvest at a site in Stanslaus County. Nut set and yield of 'Nonpareil'were significantly increased in 1997 with an optimum yield obtained at the rate of 2 to 3 lb solubor/100 gal/acre (Figure 8). The rate of 3lb solubor/100 gal was most effective.

Conclusion

To date, our investigations in Modesto, Fresno and Glen County have shown that applying 2lb solubor/100 gallons water results in optimum increase in tissue B and frequently results in significant yield increases. Based on these results, a rate of 2 lb solubor/100 gallon water or 1.41 borosol/100 gal is recommended to use in almond orchards showing a hull B concentration of less than 100 ppm or leaf B concentration of less than 30 ppm. The results using a speed sprayer showed 2-3 lb solubor/100 gal/acre was the most effective rate. This suggests that it is the concentration of B in solution that is important in determining B response. Thus, B application rates should be based on concentration (2 lbs solubor/100 gallons/acre and not on total B application per acre.

Year to year variation in response to the rate and time of B application was observed throughout the duration of the project. This is likely a result of changes in B availability and other environmental factors that influence yield. Application of B postharvest resulted in the most consistent yield increase though

prebloom B application was also effective in some years and sites. Additional adaptation of these results to local conditions and spray application technique is required. In addition, further basic research is required to determine why B has such an important effect on flowering and yield.

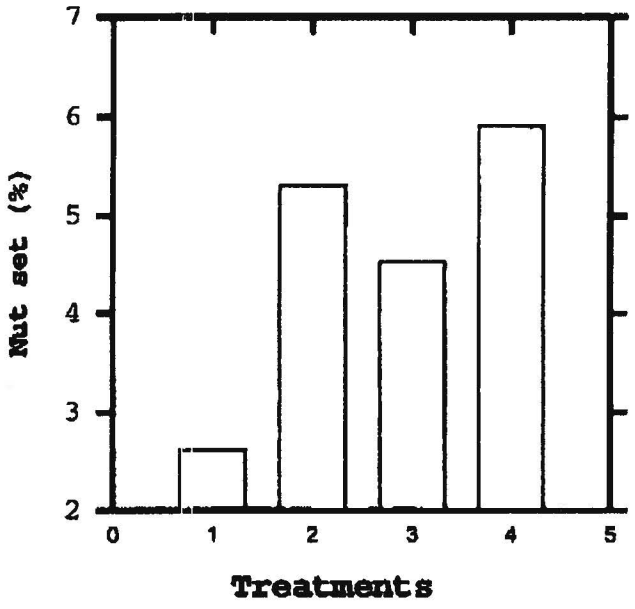

Figure 1: Effect of foliar and soil applied B on almond cv Padre nut set (Hughson, Modesto). (1) Check, (2) Soil B ½ oz/tree, (3) Foliar B, 1 lb solubor/100 gal, (4) Foliar nutrients NPK + Zn, Cu.

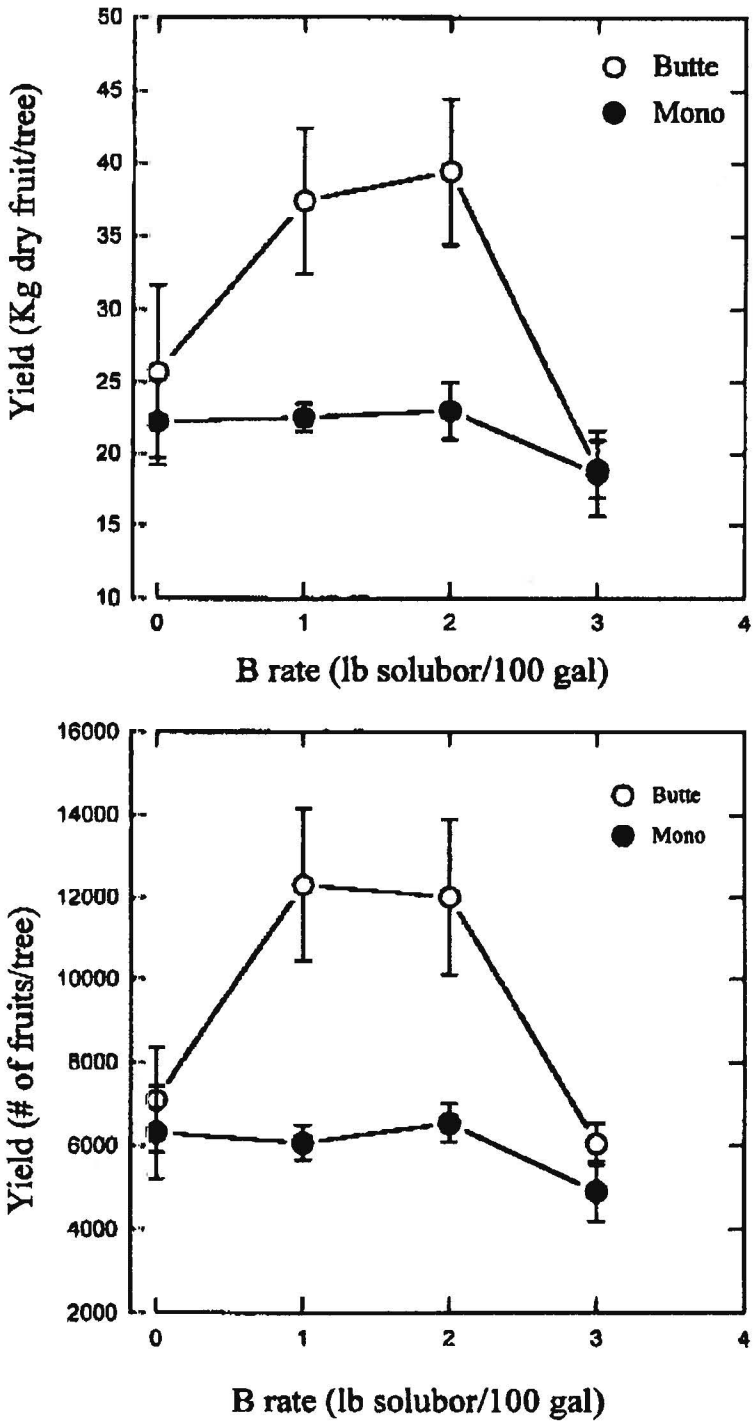

Figure 2 : Effect of B application on almond nut set and yield (error bars if not visible are smaller than the symbol)(open polination).

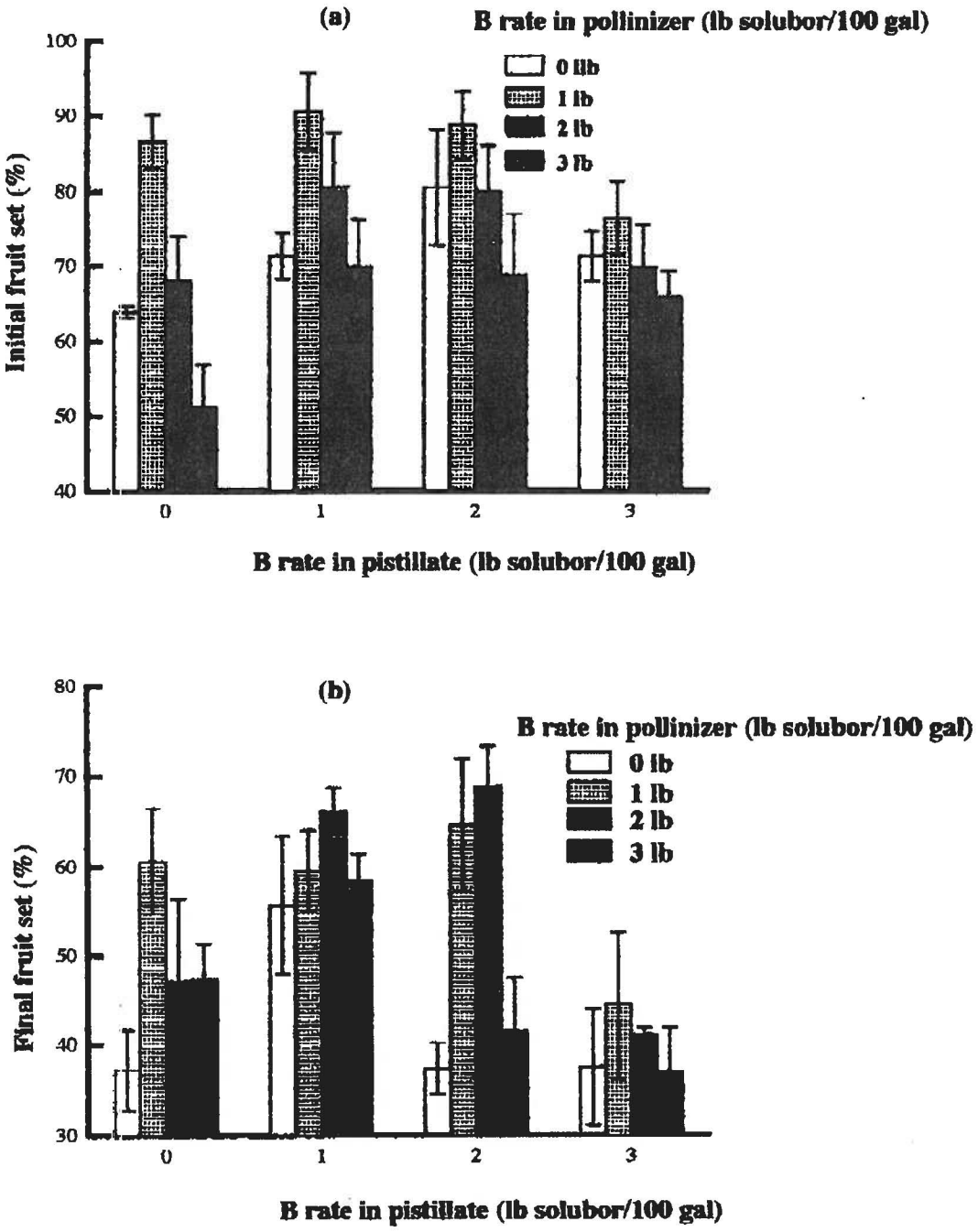

Fig 3: Effect of foliar applied B to pistil donor and pollinizer trees on almond cv 'Mono' fruit set (hand pollination)

(a) Initial set (b) Final set.

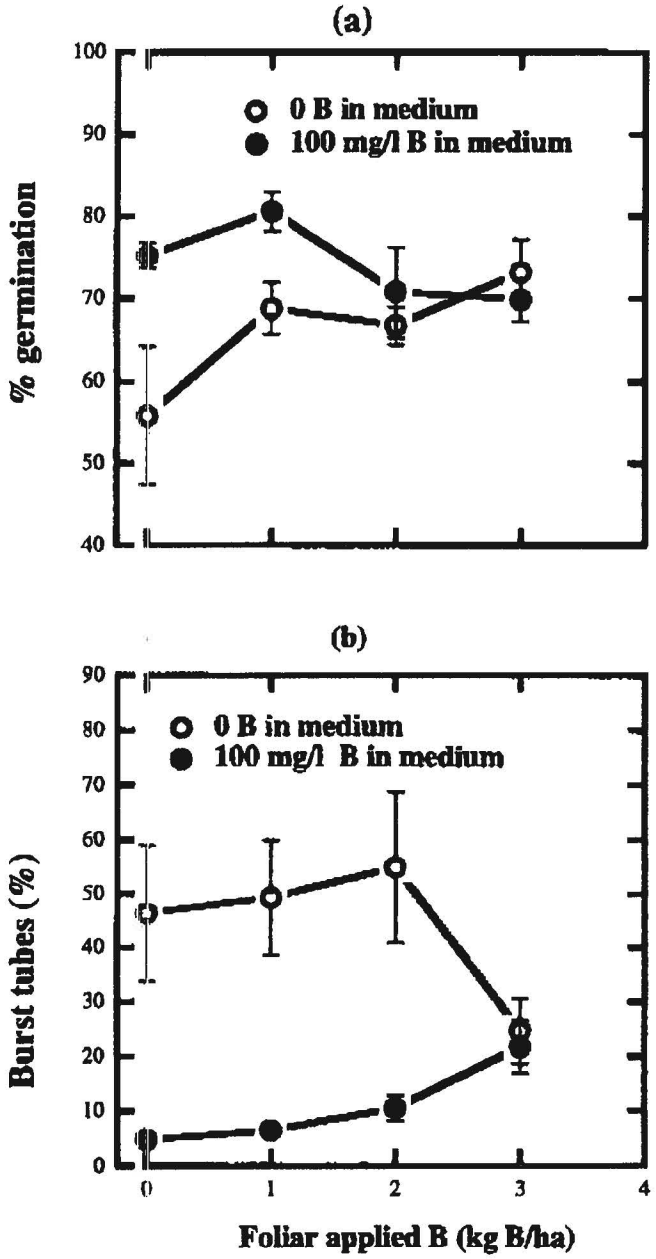

Fig. 4: Effect of foliar and media applied B on almond in vitro pollen germination and quality. (a) Germination percentage (b) percentage burst tubes. Each value with respective standard error is a mean of 10 replications

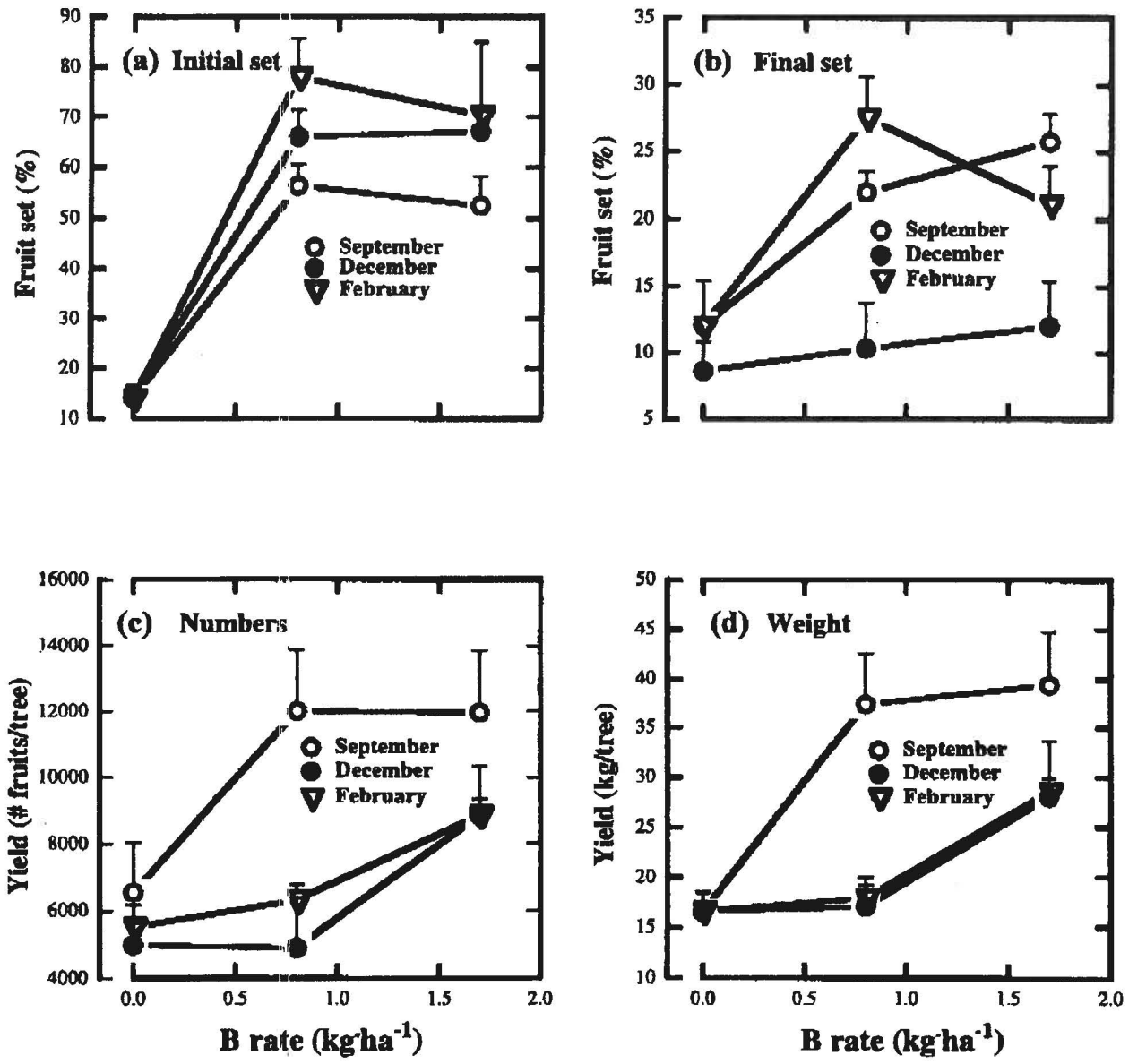

Fig 5: Effects of rates and times of foliar B application on almond cv 'Butte' nut set and yield (Fresno site). (a) initial set (b) final set (c) number of nuts (d) inshell nut weight.

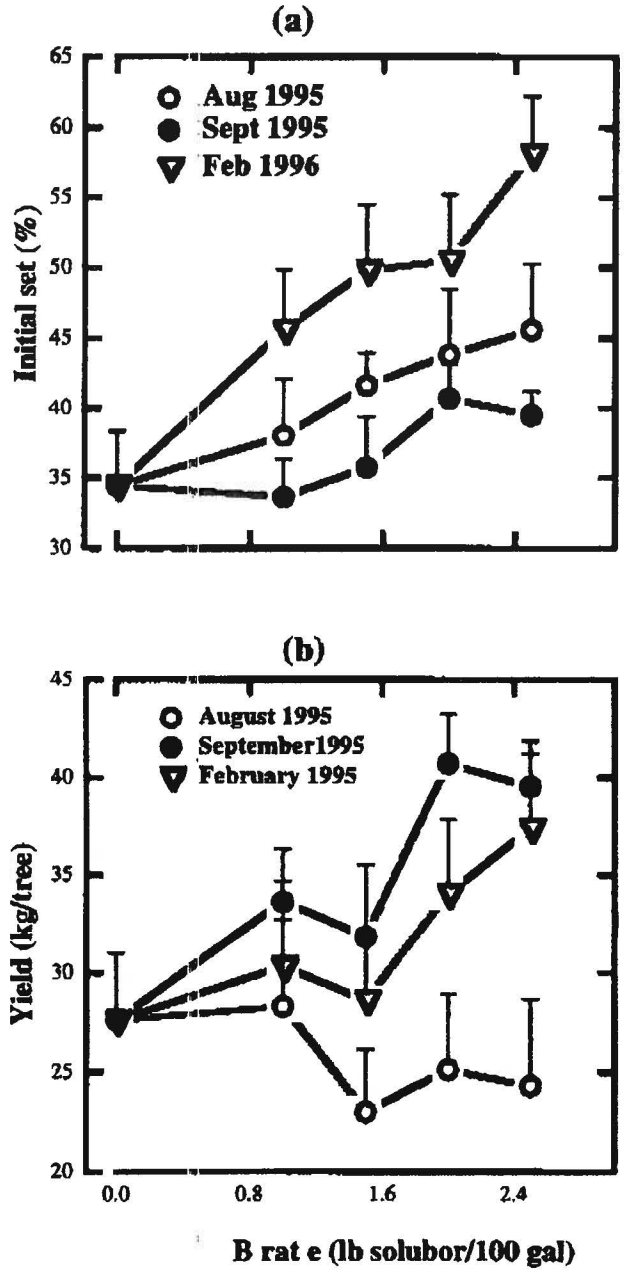

Fig. 6: Effect of rates and time of foliar B application on almond cv "Butte" fruit set (a) and yield (b) in 1996 (Glen County).

Table 1: Comparison of the time of B application (2lb/100gal) on almond cv Butte bud B concentration, fruit set and yield.

Parameter	August		September		February		All times	
	1996	1997	1996	1997	1996	1997	1996	1997
Bud B (ppm)	89±8	119±2	99±7	95±2	89±3	89±3	143±7	150±7
Initial fruit set (%)	42±2	72±3	41±2	74±3	50±5	71±1	40±3	78±2
Final fruit set (%)	25±5	28±1	20±3	25±1	34±4	23±1	27±3	33±1
Nut wt (Kg/tree)	23±2	52±12	28±1.5	38±1	27±1	35±1	27±1	34±4
No fruits ('000s')	6.8±.5	27±2	8.2±.6	34±3	7.1±.3	26±2	7.5±.2	26±6

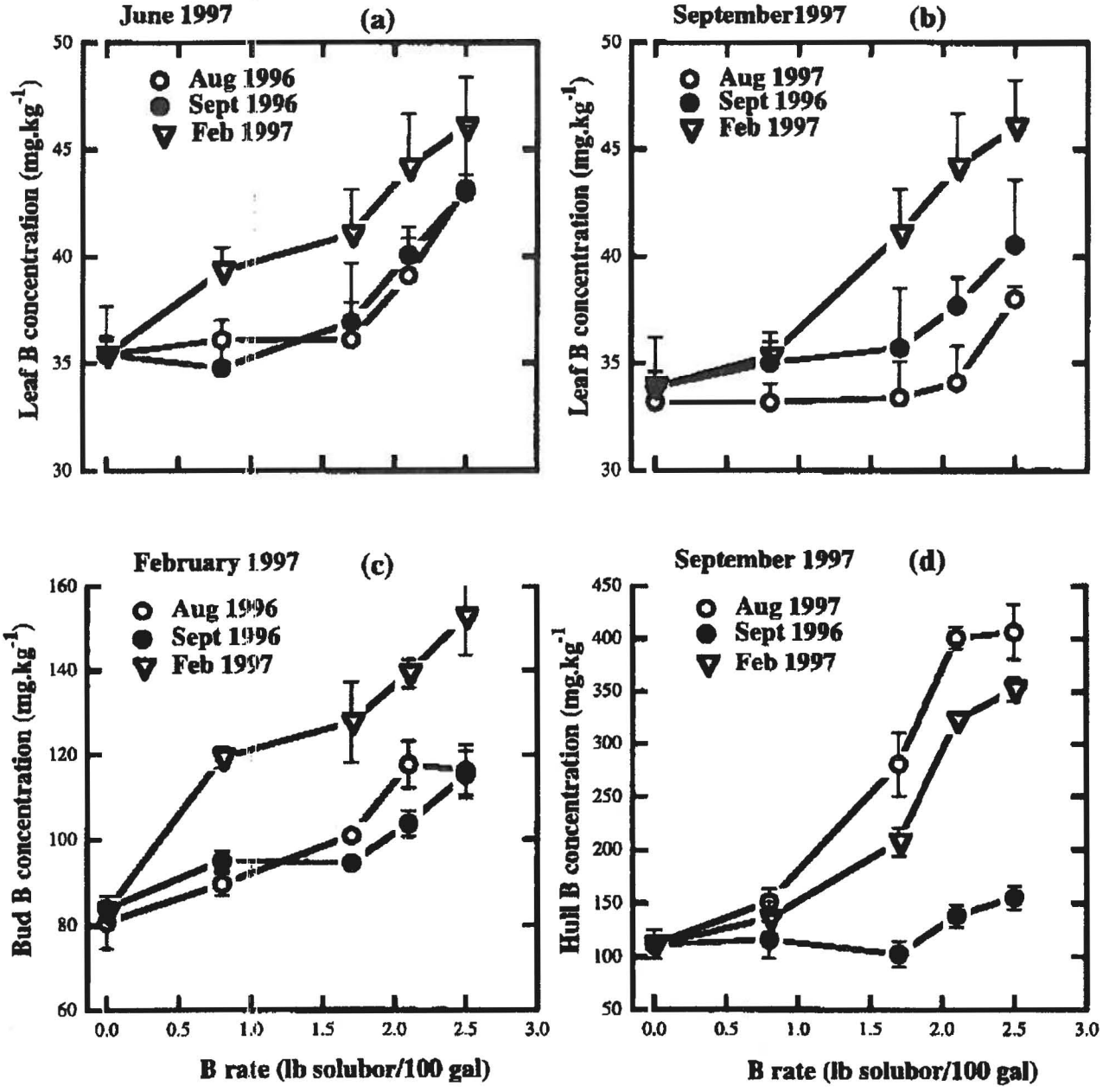

Figure 7: Tissue B concentration in response to foliar B sprays at indicated dates (August, September and February) in Glen County. (a) leaf B in June (b) leaf B in September (c) bud B in February (d) hull B in September

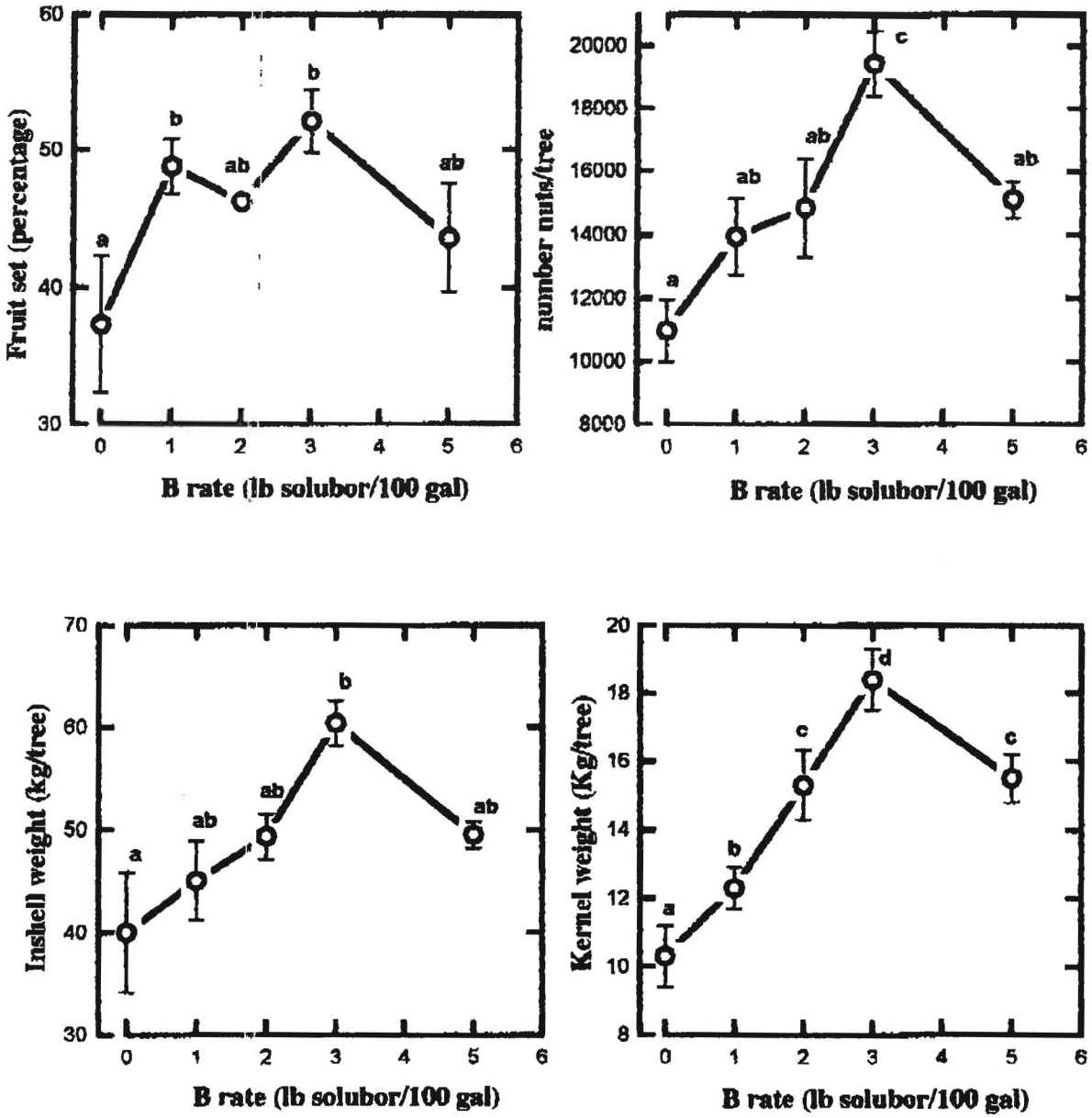

Figure 8: Effect of foliar applied B on almond cv Nonpareil fruit set and yield. Points sharing the same letter in the same graph are not significantly different (p=0.05). Application rate of 100 gal/acre was used.