ANNUAL REPORT TO THE ALMOND BOARD OF CALIFORNIA

March 31, 1997

Potassium Fertilization Regimes and Foliar N, P, K, B Studies on Almonds
(Project No. 96-RM1)

by

Roland D. Meyer

Cooperating Personnel: J. P. Edstrom, L. J. Schwankl, W. O. Reil & Nickels Soil Laboratory (trustees Michael Murray, Raymond Charter and Greg Ramos)

Objectives:

Potassium fertilization regimes study: (1) To evaluate the effects of different placement, source and rate of applied potassium under micro-sprinkler, single and double line drip irrigation systems on growth, nutrient concentrations in leaves and nut yields of almonds. (2) To assess the extent of potassium movement in soil under different placement, source and rate of application treatments.

Foliar application study: (1) To evaluate the effect of foliar applications of several nitrogen, phosphorus, potassium and boron treatments on growth, nutrient concentrations in leaves and nut yields. (2) To evaluate the effect of several timings of foliar treatments on yields and leaf nutrient levels.

Problem and its Significance:

Potassium fertilization regimes study: High yielding almond orchards with declining leaf potassium levels on the West side of the Sacramento Valley and other areas of the state have given growers cause for concern regarding how best to apply potassium. The irrigation of almonds is accomplished with a number of different systems that may apply the necessary water to a very limited soil volume or wetted area up to flooding the entire soil surface and wetting all of the soil. Fertilizers may be applied to the soil surface in a band or broadcast before irrigation or winter rains, or through the irrigation system to help move the materials into the soil. If added through a low volume or smaller wetted area system, even potassium fertilizers which are not easily moved in soils have been taken up readily by trees. Some fertilizers are not dissolved easily or water quality characteristics prohibit trouble free injection and growers choose to use application on the soil surface as an alternative. The availability of several new formulations of potassium sulfate, phosphate and thiosulfate make it easier to inject into irrigation systems. Given the different types of application now being utilized, it seems prudent to evaluate the relative efficiency of potassium uptake from several sources and methods of placement.

Foliar application study: Recent research with foliar application of nutrients on citrus, avocado, peach and almond has shown some potential for increasing yields and improved efficiency of fertilizer use, particularly nitrogen. The primary benefits seem to point to improved set and strength of newly developing fruit/nuts. It is also uncertain what, if any, additional benefit may accrue from phosphorus, potassium, and boron applications along with the nitrogen. The availability of a new material, mono potassium phosphate, along with good nitrogen sources-urea and potassium nitrate provide additional motivation for a more in depth investigation and reevaluation of this topic.

Experimental Procedures:

Potassium fertilization regimes study: The Butte and NonPareil rows of the irrigation system comparison trial on the Marine Avenue location of Nickels Soil Laboratory are being used for this study. The potassium sources: potassium sulfate, mono-potassium phosphate, potassium chloride, and potassium thiosulfate are compared at several rates injected through three irrigation systems (micro sprinkler, single line drip and double line drip) versus higher rates applied on the soil surface as bands 3-4 inches wide approximately 4 feet from the tree on both sides of the tree row. Several higher rates are also included in the micro-sprinkler treatments because the wetted soil area is larger. The trial was initiated with the band applications being made the fall of 1995 which is a practice often used by growers. Injection treatments were applied beginning the summer of 1996 and will normally begin in the spring and continue throughout the growing season. The orchard was planted in the spring of 1990 to 4 varieties: Butte (B), NonPareil (N), Carmel (C), and Monterey (M) in a B-N-C-B-N-M sequence. The soil at the site is an Arbuckle gravely loam (Fine-loamy, mixed, thermic Typic Haploxeralf) having a pH of just below neutral (~6.7). Tree spacing is a "diamond" 16' x 22' (145 trees/A) with individual plots having 5 trees each. There are a total of 72-five tree plots. Tree circumference measurements were recorded for each tree and the five tree plot totals were ranked from lowest to highest to establish the "blocks" or replications. Treatments listed below were then randomly assigned to the four replications of the single line drip irrigation system, two replications of the micro irrigation system and two replications of the double drip irrigation system. Liquid fertilizer injection systems were designed, built and installed the summer of 1996 to inject fertilizer for each 5 tree plot. The main irrigation system valves, one for the drip (both single and double line) and one for the micro sprinkler, are turned on approximately 3 hours before any fertilizer is injected to improve the uniformity of application. Dry granular potassium sulfate (0-0-52) is used to apply the fall banded applications. Liquid K_2SO_4 is applied as Great Salt Lake ESP (1-0-8), potassium thiosulfate (KTS) is a liquid 0-0-25, mono potassium phosphate (MKP) is a dry granular material (0-51.5-34) we add to water, and we also dissolve KCl (0-0-60) in water to apply it as a liquid. All liquid treatments will be split and applied as two injected applications on approximately May 15 and June 15.

Single line drip (4 replications)

1. Control (No K)
2. 1 lb K_2O/tree K_2SO_4
3. 2 lbs K_2O/tree K_2SO_4
4. 1 lb K_2O/tree MKP
5. 2 lbs K_2O/tree MKP
6. 1 lb K_2O/tree KTS
7. 2 lbs K_2O/tree band K_2SO_4
8. 4 lbs K_2O/tree band K_2SO_4
9. 1 lb K_2O/tree KCl

Double line drip (2 replications)

1. Control (No K)
2. 1 lb K_2O/tree K_2SO_4
3. 2 lbs K_2O/tree K_2SO_4
4. 1 lb K_2O/tree MKP
5. 1 lb K_2O/tree KTS
6. 2 lbs K_2O/tree band K_2SO_4

Micro-sprinkler (2 replications)

1. Control (No K)
2. 1 lb K_2O/tree K_2SO_4
3. 2 lbs K_2O/tree K_2SO_4
4. 4 lbs K_2O/tree K_2SO_4
5. 1 lb K_2O/tree MKP
6. 2 lbs K_2O/tree MKP
7. 4 lbs K_2O/tree MKP
8. 1 lb K_2O/tree KTS
9. 2 lbs K_2O/tree KTS
10. 2 lbs K_2O/tree KCl
11. 2 lbs K_2O/tree band K_2SO_4
12. 4 lbs K_2O/tree band K_2SO_4

Leaf samples (25 leaves from each of the 5 trees per plot) will be taken three times each year (April 1, July 1 and October 1) to evaluate the nutrient status (Total N, P, K, Ca, Mg, S, Zn, Mn, B, Cl) and yield data will be collected in September (NonPareil variety) and October (Butte variety) to determine treatment effects. Eight to ten pound samples are collected from each plot for moisture and meat shellout percentages. One hundred twenty five nut samples are also collected for meat, shell and hull percentages as well as number of doubles, blanks and average kernel (meat) weights for each plot. Tree circumference measurements (one foot above soil surface) are recorded in January of each year to assess individual tree growth during the season. Soil samples will be taken at the end of 1998 to evaluate potassium and phosphorus movement.

Foliar application study: The experiment was established on a March 1989 planting of Butte variety with a 15 feet by 20 feet "diamond" tree spacing arrangement. Tree circumference measurements were recorded for each tree and the five tree plot totals were ranked from lowest to highest to establish the three "blocks" or replications. Treatments were then randomly assigned to the three blocks. The foliar nutrient treatments listed below are applied beginning with the prebloom (A timing) application when the tip of the bloom is pink. The second (B timing) foliar nutrient treatments are applied 30 days after the prebloom treatments and the third (C timing) foliar nutrient treatments are applied 60 days after prebloom. Rates of applied nutrients were chosen to minimize any possible damage with increasing amounts being applied as the leaf area increases 30 and 60 days after the prebloom application. Almond leaves are observed after each foliar application for any phytotoxicity. Leaf samples are taken the first week in July and October. Almond meat yields are collected in late September or early October. Eight to ten pound samples are collected from each plot for moisture and meat shellout percentages. One hundred twenty five nut samples are also collected for meat, shell and hull percentages as well as number of doubles, blanks and average kernel (meat) weights for each plot. Tree circumference measurements (one foot above soil surface) are recorded in January of each year to assess individual tree growth during the season.

Fall foliar application study: Since some of the more recent research with foliar application of nutrients on citrus and peach has involved applying fertilizers in the fall just prior to leaf drop, another small trial was initiated in November 1995 to study the effect on almonds. The objective was to investigate the potential for increasing nutrient storage in the wood if the leaves were sprayed with rather high nutrient concentrations just prior to leaf drop and affect a meat yield increase. Treatments included foliar applications of mono-potassium phosphate alone at 1, 2 and 3% solution concentrations and in combination with urea at 20 lbs N/A. These applications were made on November 10, 1995, and October 23, 1996, approximately 3-6 weeks before leaf fall to provide adequate uptake of applied nutrients.

Results:

Potassium fertilization regimes study: A preliminary experiment to evaluate the effectiveness and potential detrimental effect of injecting potassium chloride (0-0-60) was initiated on two almond varieties: NonPareil and Butte with two irrigation levels: 0.6 and 1.0 ET_c each with nine rates of potassium chloride: 0, 0.125, 0.25, 0.375, 0.5, 0.625, 0.75, 0.875, and 1.0 lbs K_2O/tree. The potassium chloride treatments were applied every 30 days beginning May 29, 1996 for four applications. This resulted in a season total application of 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0 lbs K_2O/tree or 0, 0.83, 1.67, 2.5, 3.3, 4.2, 5.0, 5.8, and 6.7 lbs potassium chloride (0-0-60) per tree. Leaf samples were taken every two weeks (8 times) after the first application of fertilizer with the last sample date being October 3, 1996. Visual observation of the trees beginning a week after the first fertilizer application and for the remainder of the season indicated no leaf burning from any of the rates applied. Figure 1 illustrates the leaf potassium

concentrations for four of the eight sample dates. It can be noted that there is a small increase in leaf potassium of about 0.3% for most of the rates applied with the July 2nd sample date showing the higher K levels at the 0.25 to 0.625 lb K_2O/tree rates. Figure 2 illustrates the leaf chloride concentrations for the same leaf sample dates. The chloride concentrations show a consistent and gradual increase on each sample date and increasingly higher concentrations with the later sample dates. The information obtained in this experiment has indicated that the 1.0 lb K_2O/tree/season rate for the single line drip system would be in the beneficial region and pose a minimal if any detrimental effect. It is also interesting to note that the NonPareil variety had higher concentrations of K (0.3-0.4%), Mg (0.1%), and early season N (0.1-0.15%) than did the Butte variety. The Butte variety had a small but significantly higher Cl level on 3 of 6 sample dates tested and a significantly higher Mn level (ave. of 75 ppm) on the 3 sample dates tested. The higher water treatment (1.0 ET_c) resulted in higher leaf N, Ca, and Mg but lower K levels than the 0.6 ET_c water treatment.

The Butte and NonPareil rows of the irrigation system comparison trial on the Marine Avenue location of Nickels Soil Laboratory were used for the larger potassium by irrigation system study. The potassium sources: potassium sulfate, chloride, thiosulfate and mono-potassium phosphate are compared at several rates injected through three irrigation systems (single and double line drip and micro-sprinkler) versus higher rates applied on the soil surface as bands 3-4 feet from the tree on both sides of the tree row. The treatments and the number of replications are listed under the experimental procedures. The band applications were made in January 1996 and November 22, 1996. Injection treatments were made on July 30-31 and August 19-20, 1996. Leaf samples were taken on April 4, July 3 and October 16, 1996 to evaluate nutrient concentrations for total N, P, K, S, Zn, Mn, B, Cl. Yield data was collected on September 11, (NonPareil) and 26, 1996 (Butte) to determine treatment effects. Eight to ten pound samples were taken from each plot for moisture and meat shellout percentages. One hundred twenty five nut samples were also collected for meat, shell and hull percentages as well as number of doubles, blanks and average kernel (meat) weights for each plot. Tree circumference measurements (one foot above soil surface) are recorded on December 6, 1995 and February 3, 1997 to assess individual tree growth during the season.

Since the fertilizers were applied during the current growing season it is unlikely that they would have any effect on the 1996 yields so this year's yield data are being considered more of a baseline against which future yields can be compared. Average yields for the three irrigation systems were as follows: single-line drip-1906 meat lbs/A, micro-sprinkler-2283 meat lbs/A, and double-line drip-1854 meat lbs/A. The average yield for the NonPareil variety was 2315 meat lbs/A and for the Butte variety was 1686 meat lbs/A. The average meat weight of 1.19 grams for NonPareil was significantly greater than the 1.01 grams per meat for the Butte variety. There were no significant differences between varieties or irrigation systems with respect to meat shellout percentage. The 125 nut samples indicated no difference in meat percent but the NonPareil variety had a significantly higher hull percentage (55 versus 47%) and a significantly lower shell percentage (16 versus 24%) than the Butte variety. Leaf nutrient concentrations of N, P, K, S, Zn, Mn, B, and Cl were not significantly different consistently for the season as measured on the early April, July and October dates. There was a trend for higher leaf potassium levels for all the potassium treatments in samples taken on October 16, 1996. Tree size as measured by the average circumference of 5 trees on December 5, 1995, was significantly larger for the Butte variety (55.1 cms) than the NonPareil variety (51.8 cms). This same pattern was the case on February 3, 1997 when the Butte variety averaged 62.5 cms in circumference while the NonPareil averaged 57.7 cms. There was a significantly greater increase in growth for the Butte variety as measured by tree trunk circumference and cross-sectional area than for the NonPareil variety (7.37 cms versus 5.92 cms for circumference and 69.1 sq. cms versus 51.6 sq. cms for cross-sectional area). There was also a significantly larger increase in average tree circumference for the micro-sprinkler (6.94 cms) versus the single line drip (6.61 cms) versus the double line drip irrigation

system (6.38 cms). A trend was apparent for the band application treatment of potassium sulfate to have the highest increase in tree trunk circumference.

Foliar application study: The experiment was established on a March 1989 planting of Butte variety with a 15 feet by 20 feet "diamond" tree spacing arrangement. Tree circumference measurements were recorded for each tree and the five tree plot totals were used to establish the three blocks or replications. Treatments were then randomly assigned to the three blocks. The foliar nutrient treatments listed below were applied beginning with the fall application of boron (Trt #14 on 11-10-95), the prebloom application (A timing) on February 13 (Trt #2-8) and 14, 1996 (Trt #9-13 & 15-22). The second (B timing-30 days after prebloom) foliar nutrient treatments (4-8, 10-13, 16-17, & 19-22) were applied on March 19, 1996, and the third (C timing-60 days after prebloom) foliar nutrient treatments (6-8, 12-13, 17, & 21-22) were applied on April 30, 1996. All materials were applied in a spray volume of 3 gal/tree on individual plots having 5 trees each. Almond tree leaves were observed for any phytotoxicity but none was

Treatments No. Fertilizer	Rate of Application, lbs N, P_2O_5, K_2O/A A*		B*		C*	Yield, meat lbs/A 1995**	1996**
1. Control	0-0-0	+	0-0-0	+	0-0-0	1985 (11)	1827 (12)
2. Urea (low biuret)	5-0-0					2259 (1)	1871 (8)
3. Urea (low biuret) plus MKP***	5-3-2					1879 (15)	1799 (15)
4. Urea (low biuret)	5-0-0	+	10-0-0			2089 (6)	1851 (10)
5. Urea (low biuret) plus MKP***	5-3-2	+	10-6-4			1813 (18)	1868 (9)
6. Urea (low biuret)	5-0-0	+	10-0-0	+	10-0-0	1777 (20)	1694 (20)
7. Urea (low biuret) plus MKP***	5-3-2	+	10-6-4	+	10-6-4	1886 (14)	1784 (16)
8. Urea (low biuret) plus MKP***	5-3-2	+	10-6-4	+	20-12-8	2063 (7)	1943 (3)
9. CoRoN	5-0-0					1777 (19)	1602 (21)
10. CoRoN	5-0-0	+	5-0-0			2054 (8)	1810 (14)
11. CoRoN	5-0-0	+	10-0-0			1691 (21)	1751 (19)
12. CoRoN	5-0-0	+	10-0-0	+	10-0-0	2131 (4)	1820 (13)
13. CoRoN	5-0-0	+	10-0-0	+	20-0-0	1597 (22)	1487 (22)
14. Boron-Solubor 20% B (3 lbs/A)	0.6 lb B/A					2144 (3)	2166 (1)
15. Urea (low biuret) plus KNO_3	5-0-2					1868 (16)	1754 (18)
16. Urea (low biuret) plus KNO_3	5-0-2	+	10-0-4			2099 (5)	1925 (4)
17. Urea (low biuret) plus KNO_3	5-0-2	+	10-0-4	+	10-0-4	1887 (13)	1845 (11)
18. Fulcrum	5-3-2					2239 (2)	1909 (6)
19. Fulcrum	5-3-2	+	5-3-2			2043 (9)	1886 (7)
20. Fulcrum	5-3-2	+	10-6-4			2013 (10)	1780 (17)
21. Fulcrum	5-3-2	+	10-6-4	+	10-6-4	1823 (17)	1924 (5)
22. Fulcrum	5-3-2	+	10-6-4	+	20-12-8	1952 (12)	2106 (2)
$LSD_{0.05}$						496	321

* Timing of treatment applications: (A). Prebloom - 2/3-4/95; 2/13/96-trts 2-8 and 2/14/96 trts 9-13 & 15-22, (B). 30 days after prebloom application - 3/6/95-trts 4, 5, 6, 7, 8 and 3/30/95-trts 10, 11; 3/19/96, and (C). 60 days after prebloom application - 4/4/95-trts 6, 7, 8 and 5/2/95-trt 11; 4/30/96. The fall application of treatment #14 was made on 11/10/95 and 10/23/96. All materials were applied in a spray volume of 3 gal/tree on individual plots having 5 trees each. Unfortunately the entire trial received a foliar boron application of 0.82 lb B/A on 10/30/96.

** Rank of yield for each year follows the yield in ( ).

*** MKP=Mono Potassium Phosphate (0-51.5-34).

found. Rates of applied nutrients were chosen to minimize any possible damage with increasing amounts being applied as the leaf area increased 30 and 60 days after the prebloom application. Leaf samples were taken on July 5, and October 11, 1996. Almond meat yields were collected on September 23, 1996. Eight to ten pound samples were taken from each plot for moisture and meat shellout percentages. One hundred twenty five nut samples were also collected for meat, shell and hull percentages as well as number of doubles, blanks and average kernel (meat) weights for each plot. Tree circumference measurements (one foot above soil surface) are recorded on February 3, 1995, December 7, 1995 and January 31, 1997 to assess individual tree growth during the season.

The table above gives almond meat yields for the two years the experiment has been conducted. Several significant points can be noted from the data:

(1). The boron treatment gave the highest yield in 1996 (2166 meat lbs/A) which was significantly greater than the control treatment. It gave the third highest yield in 1995 (2144 meat lbs/A).

(2). In 1996, there were 11 treatments with higher yields than the control and 10 treatments with lower yields. In 1995, there were 10 treatments with higher yields than the control and 11 treatments with lower yields. Control treatment yields were similar for the two years, 1985 meat lbs/A in 1995 and 1827 meat lbs/A in 1996.

(3). There were no consistent trends in either year for yields to improve with either one, two or three foliar nutrient applications.

(4). There were no consistent trends in either year for yields to improve with nitrogen alone, nitrogen plus phosphorus plus potassium, nitrogen plus potassium, slow release nitrogen alone (CoRoN) or nitrogen plus phosphorus plus potassium plus sucrose (Fulcrum) foliar nutrient applications.

(5). The CoRoN treatments had the greatest shift in ranking of yield, from 2 above and 3 below the control in 1995 to having all 5 treatments below the control yield in 1996.

Leaf samples taken on July 5 and October 11, 1996 were analyzed for total nitrogen, phosphorus, potassium, calcium, sulfur, zinc, manganese, and boron. The results indicate no significant differences in nutrient concentrations between the foliar treatments applied except for zinc which were all above the sufficiency range. This was a similar pattern to the data obtained in 1995 when leaf nutrient concentrations for both sample dates indicated no significant differences. The only noteworthy trend observed was that the mono potassium phosphate treatments showed slightly higher potassium leaf concentrations on both sample dates in 1996 and 1995. As was the case in 1995, no trends were observed in leaf potassium concentrations for the potassium nitrate treatments. Leaf tissue zinc concentrations were all in the greater than adequate range but were significantly higher for several of the Fulcrum treatments than other treatments on both sample dates in 1996 and 1995. The average meat weight was 0.919 grams in 1996, with a range from 0.888 to 0.945 grams but there were no significant differences between treatments. In 1995, the average meat weight was 1.125 grams with a range from 1.076 to 1.155 grams but there were no significant differences between treatments. There were no significant differences between treatments with respect to shellout percentage; meat, hull, or shell percentage; increase in tree trunk circumference or tree trunk cross-sectional area.

Fall foliar application study

Since some of the more recent research with foliar application of nutrients on citrus and peach has involved applying fertilizers in the fall just prior to leaf drop, another small trial was initiated in November 1995 to study the effect on almonds. The objective was to investigate the potential for increasing nutrient storage in the wood if the leaves were sprayed with rather high nutrient concentrations just prior to leaf drop and affect a meat yield increase. Treatments (a total of seven) included a control and foliar applications of mono-potassium phosphate alone at 1, 2 and 3% solution concentrations, and each in combination with urea at 20 lbs N/A. These applications were made on November 10, 1995 and October 23, 1996, approximately 3-6 weeks before leaf fall to provide adequate uptake of applied nutrients. Leaf samples were collected on July 8 and October 22, 1996 to evaluate nutrient concentration changes and meat yield data was collected on September 23, 1996 to measure treatment effects. No significant yield or leaf nutrient (N, P, K, Ca, S, Zn, Mn, B) concentration differences were observed.

Figure 1. Leaf K Concentrations Following Potassium Applications on 5/29, 6/29, 7/29 and 8/29/96.

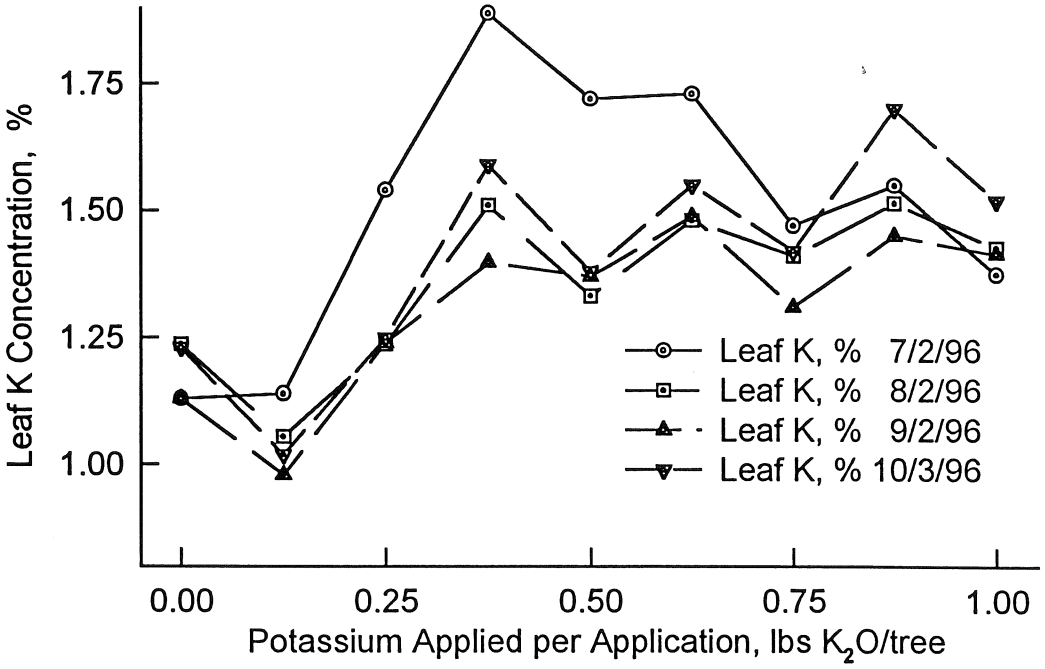
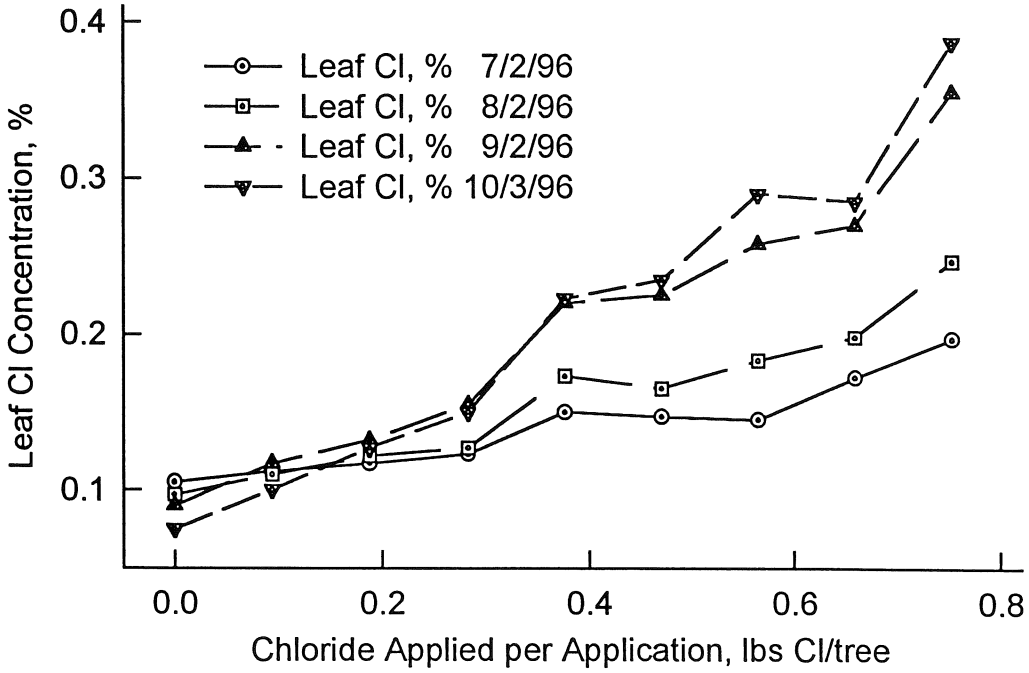


Figure 2. Leaf Cl Concentrations Following Chloride Applications on 5/29, 6/29, 7/29 and 8/29/96.



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Problem and its Significance:

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Potassium fertilization regimes study: The Butte and NonPareil rows of the irrigation system comparison trial on the Marine Avenue location of Nickels Soil Laboratory are being used for this study. The potassium sources: potassium sulfate, mono-potassium phosphate, potassium chloride, and potassium thiosulfate are compared at several rates injected through three irrigation systems (micro sprinkler, single line drip and double line drip) versus higher rates applied on the soil surface as bands 3-4 inches wide approximately 4 feet from the tree on both sides of the tree row. Several higher rates are also included in the micro-sprinkler treatments because the wetted soil area is larger. The trial was initiated with the band applications being made the fall of 1995 which is a practice often used by growers. Injection treatments were applied beginning the summer of 1996 and will normally begin in the spring and continue throughout the growing season. The orchard was planted in the spring of 1990 to 4 varieties: Butte (B), NonPareil (N), Carmel (C), and Monterey (M) in a B-N-C-B-N-M sequence. The soil at the site is an Arbuckle gravely loam (Fine-loamy, mixed, thermic Typic Haploxeralf) having a pH of just below neutral (~6.7). Tree spacing is a "diamond" 16' x 22' (145 trees/A) with individual plots having 5 trees each. There are a total of 72-five tree plots. Tree circumference measurements were recorded for each tree and the five tree plot totals were ranked from lowest to highest to establish the "blocks" or replications. Treatments listed below were then randomly assigned to the four replications of the single line drip irrigation system, two replications of the micro irrigation system and two replications of the double drip irrigation system. Liquid fertilizer injection systems were designed, built and installed the summer of 1996 to inject fertilizer for each 5 tree plot. The main irrigation system valves, one for the drip (both single and double line) and one for the micro sprinkler, are turned on approximately 3 hours before any fertilizer is injected to improve the uniformity of application. Dry granular potassium sulfate (0-0-52) is used to apply the fall banded applications. Liquid K_2SO_4 is applied as Great Salt Lake ESP (1-0-8), potassium thiosulfate (KTS) is a liquid 0-0-25, mono potassium phosphate (MKP) is a dry granular material (0-51.5-34) we add to water, and we also dissolve KCl (0-0-60) in water to apply it as a liquid. All liquid treatments will be split and applied as two injected applications on approximately May 15 and June 15.

Single line drip (4 replications)

1. Control (No K)
2. 1 lb K_2O/tree K_2SO_4
3. 2 lbs K_2O/tree K_2SO_4
4. 1 lb K_2O/tree MKP
5. 2 lbs K_2O/tree MKP
6. 1 lb K_2O/tree KTS
7. 2 lbs K_2O/tree band K_2SO_4
8. 4 lbs K_2O/tree band K_2SO_4
9. 1 lb K_2O/tree KCl

Double line drip (2 replications)

1. Control (No K)
2. 1 lb K_2O/tree K_2SO_4
3. 2 lbs K_2O/tree K_2SO_4
4. 1 lb K_2O/tree MKP
5. 1 lb K_2O/tree KTS
6. 2 lbs K_2O/tree band K_2SO_4

Micro-sprinkler (2 replications)

1. Control (No K)
2. 1 lb K_2O/tree K_2SO_4
3. 2 lbs K_2O/tree K_2SO_4
4. 4 lbs K_2O/tree K_2SO_4
5. 1 lb K_2O/tree MKP
6. 2 lbs K_2O/tree MKP
7. 4 lbs K_2O/tree MKP
8. 1 lb K_2O/tree KTS
9. 2 lbs K_2O/tree KTS
10. 2 lbs K_2O/tree KCl
11. 2 lbs K_2O/tree band K_2SO_4
12. 4 lbs K_2O/tree band K_2SO_4

Leaf samples (25 leaves from each of the 5 trees per plot) will be taken three times each year (April 1, July 1 and October 1) to evaluate the nutrient status (Total N, P, K, Ca, Mg, S, Zn, Mn, B, Cl) and yield data will be collected in September (NonPareil variety) and October (Butte variety) to determine treatment effects. Eight to ten pound samples are collected from each plot for moisture and meat shellout percentages. One hundred twenty five nut samples are also collected for meat, shell and hull percentages as well as number of doubles, blanks and average kernel (meat) weights for each plot. Tree circumference measurements (one foot above soil surface) are recorded in January of each year to assess individual tree growth during the season. Soil samples will be taken at the end of 1998 to evaluate potassium and phosphorus movement.

Foliar application study: The experiment was established on a March 1989 planting of Butte variety with a 15 feet by 20 feet "diamond" tree spacing arrangement. Tree circumference measurements were recorded for each tree and the five tree plot totals were ranked from lowest to highest to establish the three "blocks" or replications. Treatments were then randomly assigned to the three blocks. The foliar nutrient treatments listed below are applied beginning with the prebloom (A timing) application when the tip of the bloom is pink. The second (B timing) foliar nutrient treatments are applied 30 days after the prebloom treatments and the third (C timing) foliar nutrient treatments are applied 60 days after prebloom. Rates of applied nutrients were chosen to minimize any possible damage with increasing amounts being applied as the leaf area increases 30 and 60 days after the prebloom application. Almond leaves are observed after each foliar application for any phytotoxicity. Leaf samples are taken the first week in July and October. Almond meat yields are collected in late September or early October. Eight to ten pound samples are collected from each plot for moisture and meat shellout percentages. One hundred twenty five nut samples are also collected for meat, shell and hull percentages as well as number of doubles, blanks and average kernel (meat) weights for each plot. Tree circumference measurements (one foot above soil surface) are recorded in January of each year to assess individual tree growth during the season.

Fall foliar application study: Since some of the more recent research with foliar application of nutrients on citrus and peach has involved applying fertilizers in the fall just prior to leaf drop, another small trial was initiated in November 1995 to study the effect on almonds. The objective was to investigate the potential for increasing nutrient storage in the wood if the leaves were sprayed with rather high nutrient concentrations just prior to leaf drop and affect a meat yield increase. Treatments included foliar applications of mono-potassium phosphate alone at 1, 2 and 3% solution concentrations and in combination with urea at 20 lbs N/A. These applications were made on November 10, 1995, and October 23, 1996, approximately 3-6 weeks before leaf fall to provide adequate uptake of applied nutrients.

Results:

Potassium fertilization regimes study: A preliminary experiment to evaluate the effectiveness and potential detrimental effect of injecting potassium chloride (0-0-60) was initiated on two almond varieties: NonPareil and Butte with two irrigation levels: 0.6 and 1.0 ET_c each with nine rates of potassium chloride: 0, 0.125, 0.25, 0.375, 0.5, 0.625, 0.75, 0.875, and 1.0 lbs K_2O/tree. The potassium chloride treatments were applied every 30 days beginning May 29, 1996 for four applications. This resulted in a season total application of 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0 lbs K_2O/tree or 0, 0.83, 1.67, 2.5, 3.3, 4.2, 5.0, 5.8, and 6.7 lbs potassium chloride (0-0-60) per tree. Leaf samples were taken every two weeks (8 times) after the first application of fertilizer with the last sample date being October 3, 1996. Visual observation of the trees beginning a week after the first fertilizer application and for the remainder of the season indicated no leaf burning from any of the rates applied. Figure 1 illustrates the leaf potassium

concentrations for four of the eight sample dates. It can be noted that there is a small increase in leaf potassium of about 0.3% for most of the rates applied with the July 2nd sample date showing the higher K levels at the 0.25 to 0.625 lb K_2O/tree rates. Figure 2 illustrates the leaf chloride concentrations for the same leaf sample dates. The chloride concentrations show a consistent and gradual increase on each sample date and increasingly higher concentrations with the later sample dates. The information obtained in this experiment has indicated that the 1.0 lb K_2O/tree/season rate for the single line drip system would be in the beneficial region and pose a minimal if any detrimental effect. It is also interesting to note that the NonPareil variety had higher concentrations of K (0.3-0.4%), Mg (0.1%), and early season N (0.1-0.15%) than did the Butte variety. The Butte variety had a small but significantly higher Cl level on 3 of 6 sample dates tested and a significantly higher Mn level (ave. of 75 ppm) on the 3 sample dates tested. The higher water treatment (1.0 ET_c) resulted in higher leaf N, Ca, and Mg but lower K levels than the 0.6 ET_c water treatment.

The Butte and NonPareil rows of the irrigation system comparison trial on the Marine Avenue location of Nickels Soil Laboratory were used for the larger potassium by irrigation system study. The potassium sources: potassium sulfate, chloride, thiosulfate and mono-potassium phosphate are compared at several rates injected through three irrigation systems (single and double line drip and micro-sprinkler) versus higher rates applied on the soil surface as bands 3-4 feet from the tree on both sides of the tree row. The treatments and the number of replications are listed under the experimental procedures. The band applications were made in January 1996 and November 22, 1996. Injection treatments were made on July 30-31 and August 19-20, 1996. Leaf samples were taken on April 4, July 3 and October 16, 1996 to evaluate nutrient concentrations for total N, P, K, S, Zn, Mn, B, Cl. Yield data was collected on September 11, (NonPareil) and 26, 1996 (Butte) to determine treatment effects. Eight to ten pound samples were taken from each plot for moisture and meat shellout percentages. One hundred twenty five nut samples were also collected for meat, shell and hull percentages as well as number of doubles, blanks and average kernel (meat) weights for each plot. Tree circumference measurements (one foot above soil surface) are recorded on December 6, 1995 and February 3, 1997 to assess individual tree growth during the season.

Since the fertilizers were applied during the current growing season it is unlikely that they would have any effect on the 1996 yields so this year's yield data are being considered more of a baseline against which future yields can be compared. Average yields for the three irrigation systems were as follows: single-line drip-1906 meat lbs/A, micro-sprinkler-2283 meat lbs/A, and double-line drip-1854 meat lbs/A. The average yield for the NonPareil variety was 2315 meat lbs/A and for the Butte variety was 1686 meat lbs/A. The average meat weight of 1.19 grams for NonPareil was significantly greater than the 1.01 grams per meat for the Butte variety. There were no significant differences between varieties or irrigation systems with respect to meat shellout percentage. The 125 nut samples indicated no difference in meat percent but the NonPareil variety had a significantly higher hull percentage (55 versus 47%) and a significantly lower shell percentage (16 versus 24%) than the Butte variety. Leaf nutrient concentrations of N, P, K, S, Zn, Mn, B, and Cl were not significantly different consistently for the season as measured on the early April, July and October dates. There was a trend for higher leaf potassium levels for all the potassium treatments in samples taken on October 16, 1996. Tree size as measured by the average circumference of 5 trees on December 5, 1995, was significantly larger for the Butte variety (55.1 cms) than the NonPareil variety (51.8 cms). This same pattern was the case on February 3, 1997 when the Butte variety averaged 62.5 cms in circumference while the NonPareil averaged 57.7 cms. There was a significantly greater increase in growth for the Butte variety as measured by tree trunk circumference and cross-sectional area than for the NonPareil variety (7.37 cms versus 5.92 cms for circumference and 69.1 sq. cms versus 51.6 sq. cms for cross-sectional area). There was also a significantly larger increase in average tree circumference for the micro-sprinkler (6.94 cms) versus the single line drip (6.61 cms) versus the double line drip irrigation

system (6.38 cms). A trend was apparent for the band application treatment of potassium sulfate to have the highest increase in tree trunk circumference.

Foliar application study: The experiment was established on a March 1989 planting of Butte variety with a 15 feet by 20 feet "diamond" tree spacing arrangement. Tree circumference measurements were recorded for each tree and the five tree plot totals were used to establish the three blocks or replications. Treatments were then randomly assigned to the three blocks. The foliar nutrient treatments listed below were applied beginning with the fall application of boron (Trt #14 on 11-10-95), the prebloom application (A timing) on February 13 (Trt #2-8) and 14, 1996 (Trt #9-13 & 15-22). The second (B timing-30 days after prebloom) foliar nutrient treatments (4-8, 10-13, 16-17, & 19-22) were applied on March 19, 1996, and the third (C timing-60 days after prebloom) foliar nutrient treatments (6-8, 12-13, 17, & 21-22) were applied on April 30, 1996. All materials were applied in a spray volume of 3 gal/tree on individual plots having 5 trees each. Almond tree leaves were observed for any phytotoxicity but none was

Treatments No. Fertilizer	Rate of Application, lbs N, P_2O_5, K_2O/A A*		B*		C*	Yield, meat lbs/A 1995**	1996**
1. Control	0-0-0	+	0-0-0	+	0-0-0	1985 (11)	1827 (12)
2. Urea (low biuret)	5-0-0					2259 (1)	1871 (8)
3. Urea (low biuret) plus MKP***	5-3-2					1879 (15)	1799 (15)
4. Urea (low biuret)	5-0-0	+	10-0-0			2089 (6)	1851 (10)
5. Urea (low biuret) plus MKP***	5-3-2	+	10-6-4			1813 (18)	1868 (9)
6. Urea (low biuret)	5-0-0	+	10-0-0	+	10-0-0	1777 (20)	1694 (20)
7. Urea (low biuret) plus MKP***	5-3-2	+	10-6-4	+	10-6-4	1886 (14)	1784 (16)
8. Urea (low biuret) plus MKP***	5-3-2	+	10-6-4	+	20-12-8	2063 (7)	1943 (3)
9. CoRoN	5-0-0					1777 (19)	1602 (21)
10. CoRoN	5-0-0	+	5-0-0			2054 (8)	1810 (14)
11. CoRoN	5-0-0	+	10-0-0			1691 (21)	1751 (19)
12. CoRoN	5-0-0	+	10-0-0	+	10-0-0	2131 (4)	1820 (13)
13. CoRoN	5-0-0	+	10-0-0	+	20-0-0	1597 (22)	1487 (22)
14. Boron-Solubor 20% B (3 lbs/A)	0.6 lb B/A					2144 (3)	2166 (1)
15. Urea (low biuret) plus KNO_3	5-0-2					1868 (16)	1754 (18)
16. Urea (low biuret) plus KNO_3	5-0-2	+	10-0-4			2099 (5)	1925 (4)
17. Urea (low biuret) plus KNO_3	5-0-2	+	10-0-4	+	10-0-4	1887 (13)	1845 (11)
18. Fulcrum	5-3-2					2239 (2)	1909 (6)
19. Fulcrum	5-3-2	+	5-3-2			2043 (9)	1886 (7)
20. Fulcrum	5-3-2	+	10-6-4			2013 (10)	1780 (17)
21. Fulcrum	5-3-2	+	10-6-4	+	10-6-4	1823 (17)	1924 (5)
22. Fulcrum	5-3-2	+	10-6-4	+	20-12-8	1952 (12)	2106 (2)
$LSD_{0.05}$						496	321

* Timing of treatment applications: (A). Prebloom - 2/3-4/95; 2/13/96-trts 2-8 and 2/14/96 trts 9-13 & 15-22, (B). 30 days after prebloom application - 3/6/95-trts 4, 5, 6, 7, 8 and 3/30/95-trts 10, 11; 3/19/96, and (C). 60 days after prebloom application - 4/4/95-trts 6, 7, 8 and 5/2/95-trt 11; 4/30/96. The fall application of treatment #14 was made on 11/10/95 and 10/23/96. All materials were applied in a spray volume of 3 gal/tree on individual plots having 5 trees each. Unfortunately the entire trial received a foliar boron application of 0.82 lb B/A on 10/30/96.

** Rank of yield for each year follows the yield in ( ).

*** MKP=Mono Potassium Phosphate (0-51.5-34).

found. Rates of applied nutrients were chosen to minimize any possible damage with increasing amounts being applied as the leaf area increased 30 and 60 days after the prebloom application. Leaf samples were taken on July 5, and October 11, 1996. Almond meat yields were collected on September 23, 1996. Eight to ten pound samples were taken from each plot for moisture and meat shellout percentages. One hundred twenty five nut samples were also collected for meat, shell and hull percentages as well as number of doubles, blanks and average kernel (meat) weights for each plot. Tree circumference measurements (one foot above soil surface) are recorded on February 3, 1995, December 7, 1995 and January 31, 1997 to assess individual tree growth during the season.

The table above gives almond meat yields for the two years the experiment has been conducted. Several significant points can be noted from the data:

(1). The boron treatment gave the highest yield in 1996 (2166 meat lbs/A) which was significantly greater than the control treatment. It gave the third highest yield in 1995 (2144 meat lbs/A).

(2). In 1996, there were 11 treatments with higher yields than the control and 10 treatments with lower yields. In 1995, there were 10 treatments with higher yields than the control and 11 treatments with lower yields. Control treatment yields were similar for the two years, 1985 meat lbs/A in 1995 and 1827 meat lbs/A in 1996.

(3). There were no consistent trends in either year for yields to improve with either one, two or three foliar nutrient applications.

(4). There were no consistent trends in either year for yields to improve with nitrogen alone, nitrogen plus phosphorus plus potassium, nitrogen plus potassium, slow release nitrogen alone (CoRoN) or nitrogen plus phosphorus plus potassium plus sucrose (Fulcrum) foliar nutrient applications.

(5). The CoRoN treatments had the greatest shift in ranking of yield, from 2 above and 3 below the control in 1995 to having all 5 treatments below the control yield in 1996.

Leaf samples taken on July 5 and October 11, 1996 were analyzed for total nitrogen, phosphorus, potassium, calcium, sulfur, zinc, manganese, and boron. The results indicate no significant differences in nutrient concentrations between the foliar treatments applied except for zinc which were all above the sufficiency range. This was a similar pattern to the data obtained in 1995 when leaf nutrient concentrations for both sample dates indicated no significant differences. The only noteworthy trend observed was that the mono potassium phosphate treatments showed slightly higher potassium leaf concentrations on both sample dates in 1996 and 1995. As was the case in 1995, no trends were observed in leaf potassium concentrations for the potassium nitrate treatments. Leaf tissue zinc concentrations were all in the greater than adequate range but were significantly higher for several of the Fulcrum treatments than other treatments on both sample dates in 1996 and 1995. The average meat weight was 0.919 grams in 1996, with a range from 0.888 to 0.945 grams but there were no significant differences between treatments. In 1995, the average meat weight was 1.125 grams with a range from 1.076 to 1.155 grams but there were no significant differences between treatments. There were no significant differences between treatments with respect to shellout percentage; meat, hull, or shell percentage; increase in tree trunk circumference or tree trunk cross-sectional area.

Fall foliar application study

Since some of the more recent research with foliar application of nutrients on citrus and peach has involved applying fertilizers in the fall just prior to leaf drop, another small trial was initiated in November 1995 to study the effect on almonds. The objective was to investigate the potential for increasing nutrient storage in the wood if the leaves were sprayed with rather high nutrient concentrations just prior to leaf drop and affect a meat yield increase. Treatments (a total of seven) included a control and foliar applications of mono-potassium phosphate alone at 1, 2 and 3% solution concentrations, and each in combination with urea at 20 lbs N/A. These applications were made on November 10, 1995 and October 23, 1996, approximately 3-6 weeks before leaf fall to provide adequate uptake of applied nutrients. Leaf samples were collected on July 8 and October 22, 1996 to evaluate nutrient concentration changes and meat yield data was collected on September 23, 1996 to measure treatment effects. No significant yield or leaf nutrient (N, P, K, Ca, S, Zn, Mn, B) concentration differences were observed.

Figure 1. Leaf K Concentrations Following Potassium Applications on 5/29, 6/29, 7/29 and 8/29/96.

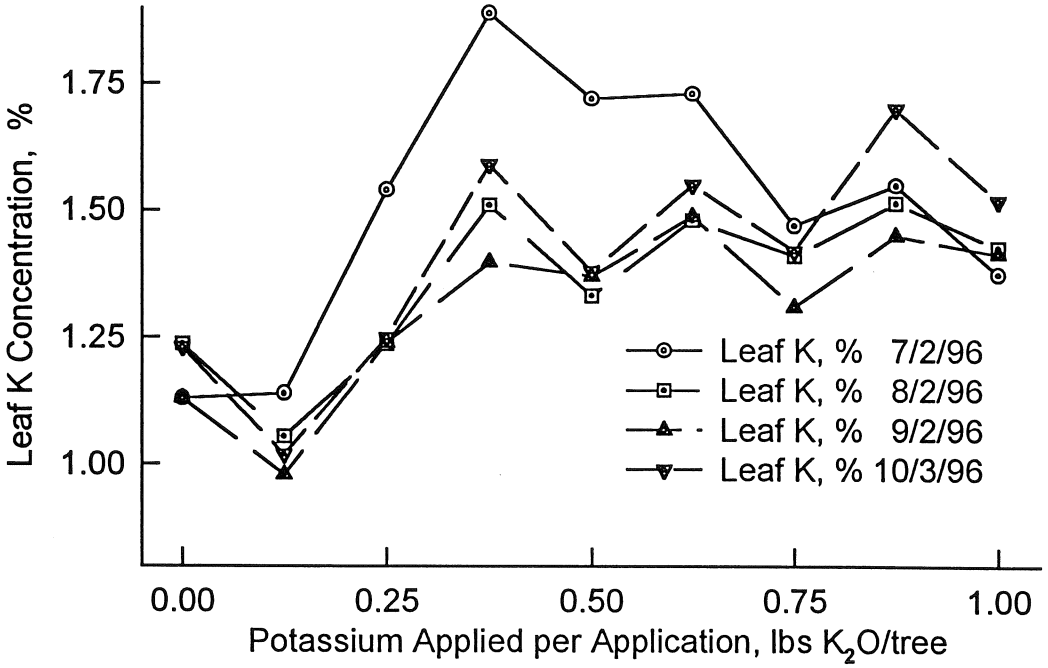
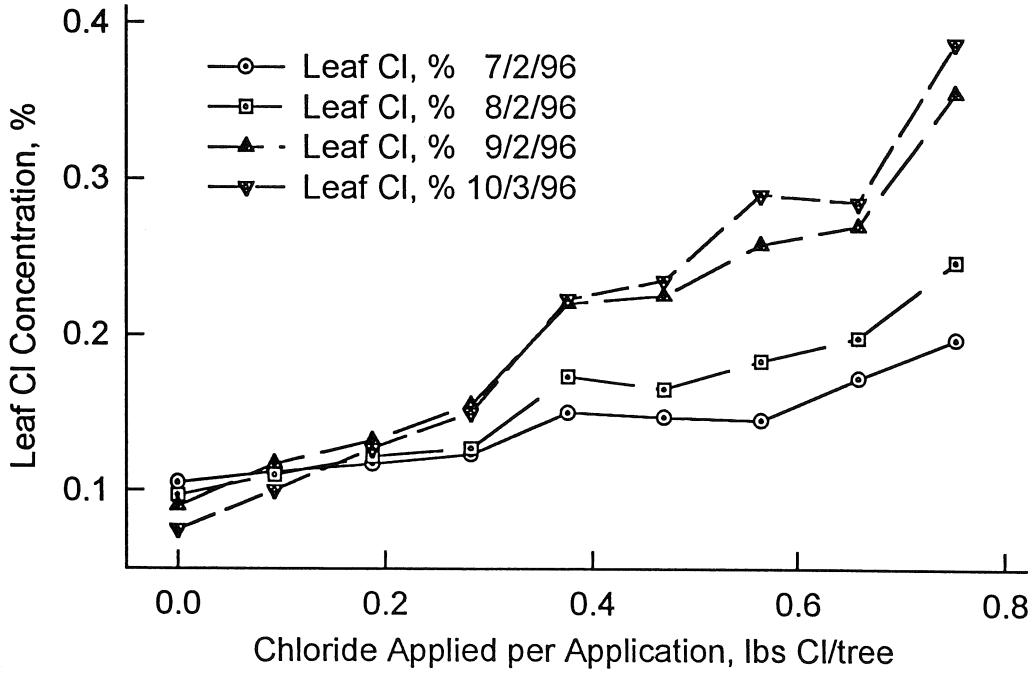


Figure 2. Leaf Cl Concentrations Following Chloride Applications on 5/29, 6/29, 7/29 and 8/29/96.



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April 15, 1997

Chris Heintz
Research Director
Almond Board of California
1104 12th Street
Modesto, CA 95354

Dear Chris:

Enclosed are two copies of our 1996 annual report on Project No 96-RM1 "Potassium Fertilization Regimes and Foliar N, P, K, B Studies on Almonds". John, Larry, Wilbur and I want to express our appreciation for the continued support of this project by the Almond Board.

Please feel free to get in touch if you have any questions or comments (916-752-2531 or FAX 916-752-1552 or email rdmeyer@ucdavis.edu).

Sincerely,

Roland D. Meyer
Extension Soils Specialist

Enclosures

cc: John Edstrom
Larry Schwankl
Wilbur Reil
Warren Micke