Project No. 88-R2 - Tree and Crop Research
Root Zone Acidity and Chemistry
(continuation of Project No. 87-R1)

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Objectives: To determine the effects of nitrogen (N) fertilization on soil and rhizosphere acidity and chemistry and the consequences of this acidity. Acid soils are normally high in soluble and exchangeable aluminum (Al), manganese, (Mn) and hydrogen (H) and low in calcium, Ca, magnesium (Mg) and potassium (K). Availability of Zn and other micronutrient may be enhance while phosphorus and Mo availability may be reduced under acid conditions. This project will quantify the Al, Mn, and H levels associated with soil acidification and contrast these with the conditions in soil closely associated with the root (rhizosphere soil). Tissue nutrient status will be monitored to assess tree response to acidification.

Interpretive Summary: The orchard used for this project is located near Arbuckle and was planted in 1981. Nitrogen was applied at several levels. The highest application rate was 2, 7, 16, 32, 48, 64 and 64 oz per tree in 1982, 1983, 1984, 1985, 1986, 1987 and 1988 respectively. Low nitrogen levels were 0, 0, 0, 4, 6, 8 and 8 oz per tree over the same period. Rates of 64 oz. per tree are equivalent to 800 lbs N/per acre. The the high fertilizations rates have acidified the drip zone and lowered soil pH.

Because low pH could affect growth and tree nutrition, this project has been investigating bulk soil and rhizosphere (soil in very close proximity to the roots) properties in the acid drip zone. Increases in exchangeable aluminum and increased availability of Mn and Zn are commonly associated with acid soil conditions. Leaf samples were taken in March and September to assess increases in Mn noted in earlier years. Samples of rhizosphere and bulk soil were collected from high and low N treatments in the Nonpareil plots in March 1988 to contrast with those collected in November 1987. These samples showed that extractable nitrogen was high in the high N treatments and was low in the low N treatments. Based on tree appearance and extractable soil levels, the low N treatments supply less nitrogen than necessary for good tree growth. In one of the high nitrogen plots extractable ammonium was very high and nitrate was low. This indicates that the applied urea was not being converted to nitrate and therefore not generating acidity. The less acid nature of these samples is in agreement with such a suggestion. The most likely explanations is that the high water content of the drip zone was limiting

nitrification and lowering acid production. Extractable Mn in this plot was high, indicating poor aeration, which would limit nitrification. Fertilizer reactions in drip systems can be different than those found in other irrigation methods.

In the low N treatments, pH varies from about 5 to over 7, while the high N treatments have pH levels from 3.8 to about 7. In both nitrogen treatments pH decreases with depth and the surface is less acidic. Rhizosphere pH follows the same pattern as bulk soil pH, but the rhizosphere was less acid that the bulk soil in high N treatments and more acidic than the bulk soil in the less acidic low N treatments. As acidity increased with depth, extractable Al increased in the bulk and rhizosphere samples, but rhizosphere samples had less extractable aluminum than the bulk soil and more organic matter. Thus the rhizosphere in the more strongly acidic samples is presumed to be more amenable to root growth than the bulk soil.

Tissue analyses found a higher Mn in the more acidic high N treatments sampled in the fall of 1987. In March of 1988, tissue Mn was lower than in Fall of 1987 but increased in the September 1988 samples. For example, Mn was 125 mg/kg in the high N tissue in March 1988 and increased to 343 mg/kg by September, while elevated, these levels do not appear to be toxic. Extractable Mn increased with depth in some plots to values as high as 125 mg/kg. This is most likely a response to poor aeration. Phosphorus levels were adequate but lower in the high N treatment tissue. Most likely because of better growth and dilution. Tissue potassium is lower in the high N treatments.

When the samples are processed, observations indicated that there are fewer roots in strongly acidic drip zones. Whether this is true, awaits further investigation in the coming year. In all treatments roots are more abundant in the surface which is less acidic. Surface samples from Butte and Nonpareil plots were analyzed for organic matter. Rhizosphere samples had twice as much organic matter as the bulk soil in both varieties and N treatments.

Experimental Procedure: Samples of soil from the drip zone were collected using coring methods as described in previous reports. The high and low N treatments irrigated at the high water level were sampled in March. Surface samples from the Butte and Nonpareil plots were obtained in July. Leaf samples from Nonpareil plots were obtained in March and September. Rhizosphere samples were obtained by screening the soil to remove roots and tightly adhering soil. These roots were dried at 60 C and shaken to remove the rhizosphere soil. Soil pH, organic matter and extractable Al and H were determined on bulk and rhizosphere samples. Extractable nitrate and ammonium as well as extractable Mn was determined on the bulk samples. Leaf samples were washed to remove dust, ground and analyzed by atomic absorption or inductively coupled plasma.

Results: Figures 1 and 2 represent the pH data for high and low N treatments in relation to soil depth. In both N treatments pH is higher near the surface and generally decreases with depth. In the low N treatments, pH increases below 30-40 cm which is not evident in the high N treatments. In replication 2 of the high N treatment, pH is nearly the same as the pH in the low N treatments. This is most likely due to the limited nitrification of the added urea. Two lines of evidence support this suggestion. First there is a large amount of extractable ammonium in replication 2 (Figure 3) which indicates a lack of conversion to nitrate. There is also a dramatic increase in the amount of extractable Mn in replication 2 (Figure 4) indicating reduced aeration which would also limit nitrification. Rhizosphere pH is consistently less acid than the bulk soil in the high N treatments. The opposite is true in the low N treatments. The difference between bulk soil pH (pH_b) and rhizosphere pH (pH_r) is more clearly shown in Figures 5 and 6. In the low N treatment the rhizosphere is consistently more acidic than the bulk soil, while in the high N treatment the rhizosphere is consistently less acidic than the bulk soil. Since the high N treatment is more acidic than the low N treatment, this difference in pH between the rhizosphere and bulk soil should be related to the bulk soil pH. This relationship is shown in Figure 6.

If the rhizosphere is less acidic than the bulk soil, then the rhizosphere should be a more amenable to root growth in the more acid high N treatments. Figure 7 shows the data for extractable Al in relation to soil depth in the bulk and rhizosphere soil in the more acidic high N treatment. The rhizosphere consistently has less extractable Al than the bulk soil.

Acidic conditions in the root zone could enhance the accumulation of Mn and Zn and reduce the availability of phosphorus. Data from analysis of leaf tissue collected in March and September are present in Table 1. Higher N treatment has resulted in substantially lower P and K, and some what higher Mn. By September, Mn, Ca and Mg increased in both N treatments, while Zn, K and P decreased.

Discussion: High levels of urea application can significantly increase soil acidity. This increased acidity is not uniformly distributed. The surface is less acidic and acidity increases with increasing depth. In the low N treatments pH increases again below 1 to 2 feet in the drip zone. Conditions in the drip zone also influence acidification. Acidification appears to be limited in poorly aerated conditions. It is also evident that the rhizosphere is different from the bulk soil and can be less acidic and have lower levels of exchangeable Al and more organic matter. Thus the rhizosphere is a more amenable environment for roots. How almond roots respond to the soil conditions which are generated by the applied N is not known. Tissue Mn levels are higher in the more acidic high N plots, but the levels do not appear to be toxic. Levels of potassium are lower in the high N plots and should be closely monitored. The high N treatments are yielding well and trees do not show signs of reduced growth or vigor, while on low N plots, trees appear less vigorous. Producing roots in the less acidic surface soil or tolerating acidic conditions are two ways the tree could respond to the soil conditions associated with high urea-N applications. Future studies should determine whether almonds are tolerant of the acidic conditions, benefit from increased availability of some nutrients associated with acid conditions or whether roots avoid the zones of strong acidity. Monitoring root distribution between and in the drip zone as well as root tolerance of acidic conditions is proposed for future research.

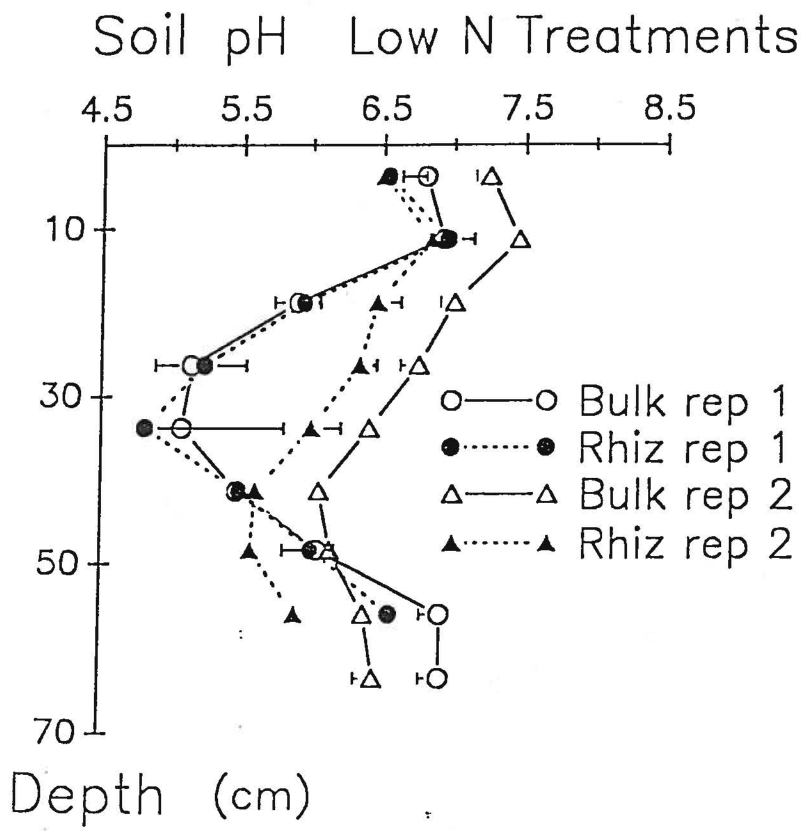

Figure 1. Rhizosphere and bulk soil pH in the low N treatments.

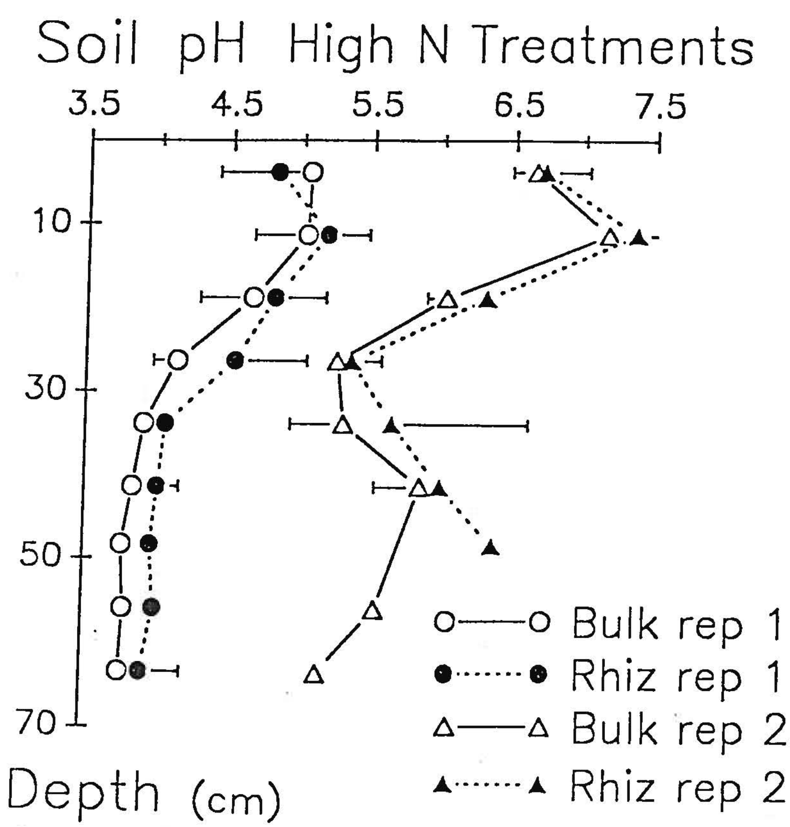

Figure 2. Rhizosphere and bulk pH in the high N treatments.

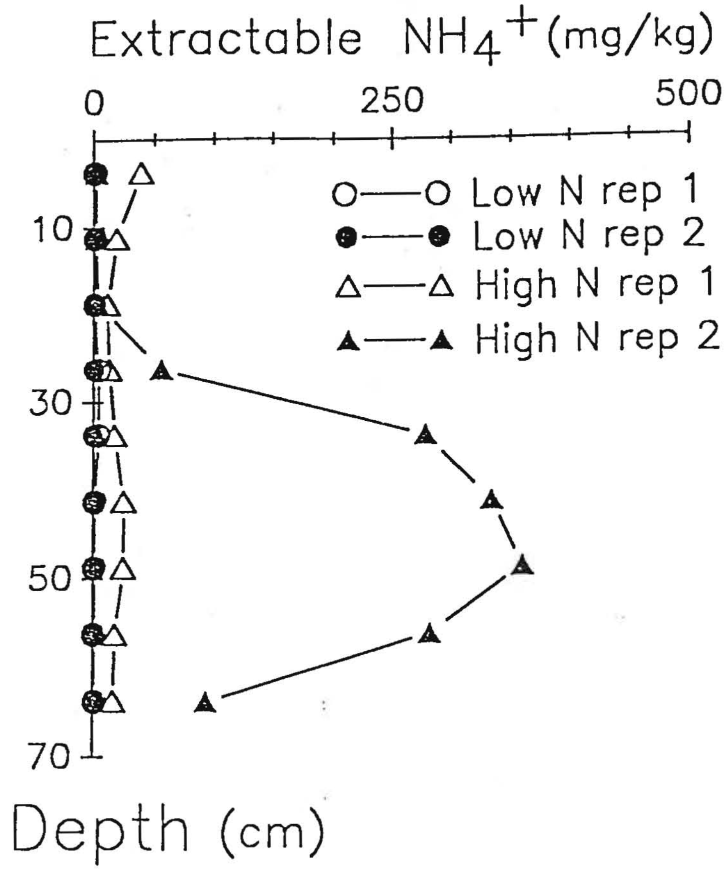

Figure 3. Extractable ammonium in relation to soil depth.

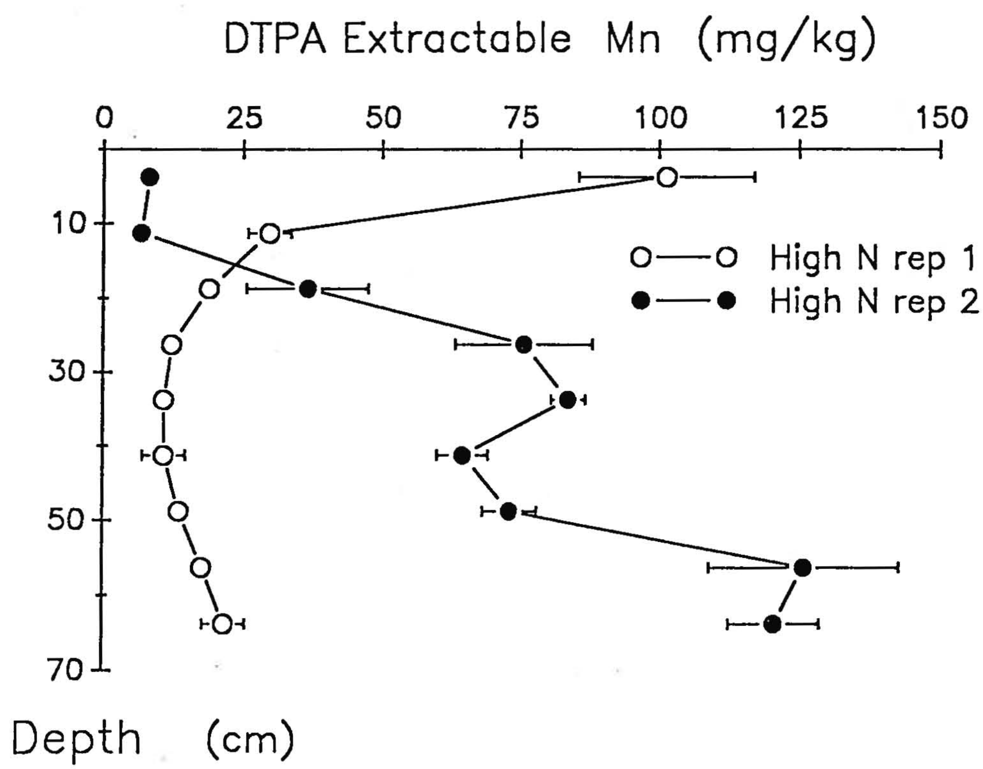

Figure 4. Extractable manganese in relation to depth.

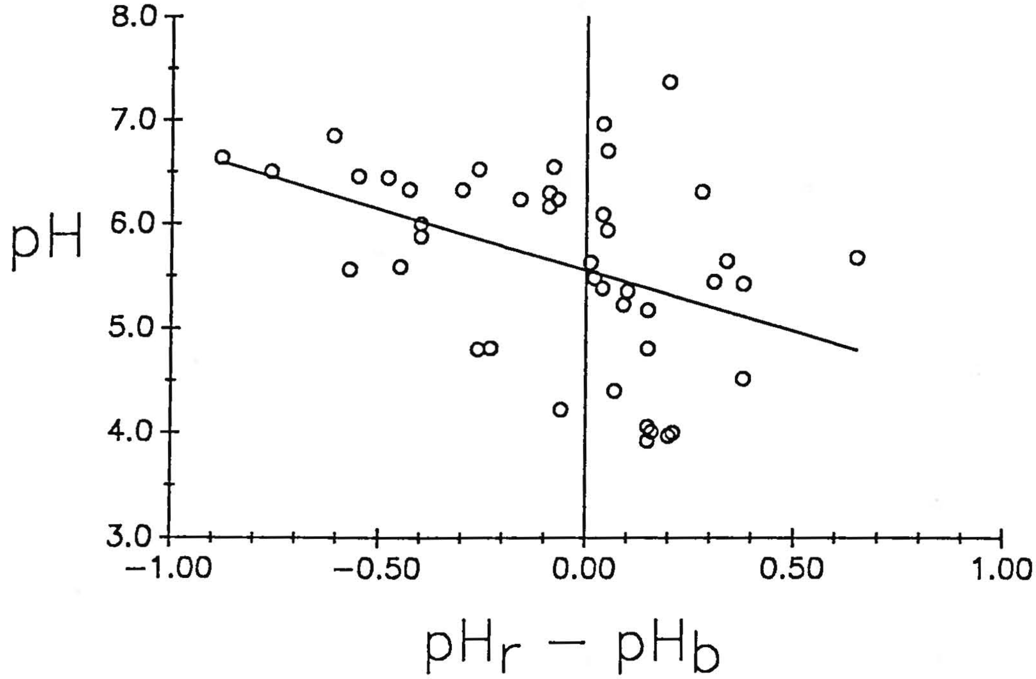

Figure 5. The difference between rhizosphere and bulk pH in all nitrogen treatments.

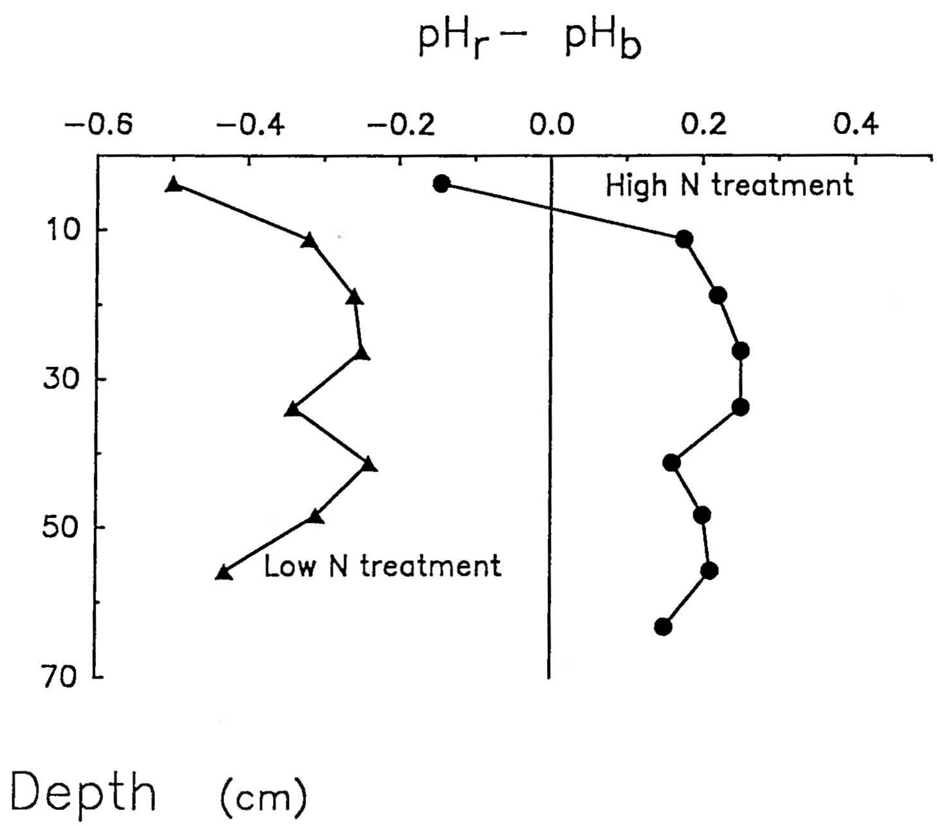

Figure 6. The difference between rhizosphere and bulk pH in relation to depth.

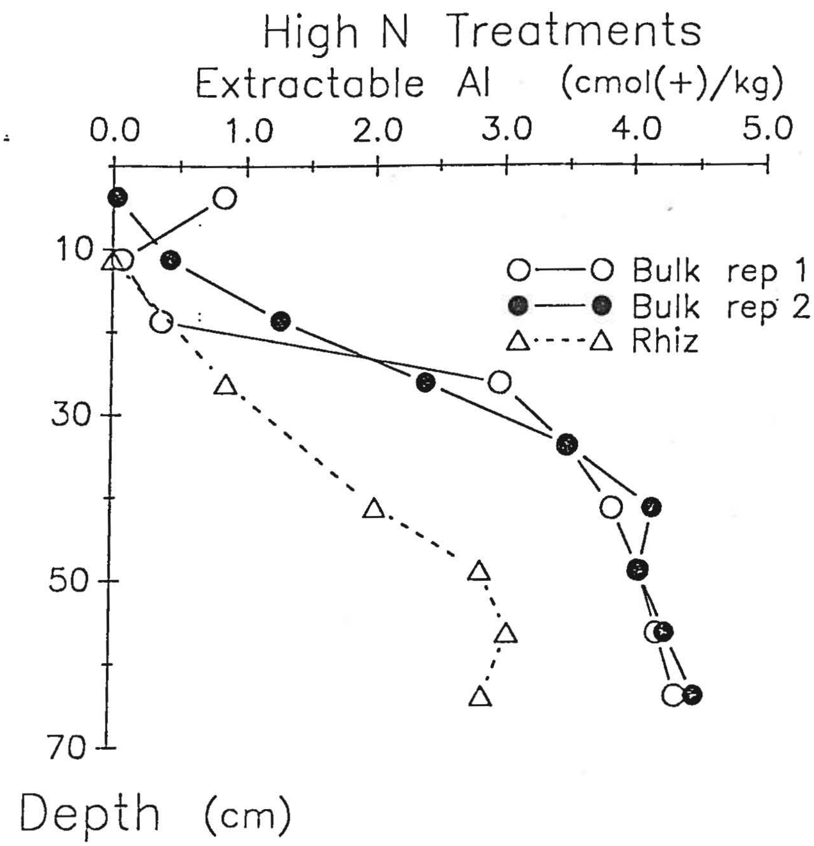

Figure 7. Extractable aluminum in the high N treatment in relation to depth in the bulk and rhizosphere soil.

Table 1. Nutrient concentrations in Nonpareil leaves collected in March 1988.

Nutrient		Low N		High N	
		March	September	March	September
P	%	0.31	0.12	0.25	0.10
K	%	3.08	1.54	2.12	1.23
Ca	%	0.15	0.44	0.12	0.34
Mg	%	0.45	0.95	0.38	0.93
Mn	mg/kg	90	152	125	344
Zn	mg/kg	39	14	44	12