Project Number: 84-Q3

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ANNUAL REPORT TO THE ALMOND BOARD OF CALIFORNIA

December 28, 1984

Nitrogen on Drip Irrigated Almonds

by

Roland D. Meyer

Cooperators: Herbert Schulbach, John Edstrom and Nickels Trust

Objectives: (1) To evaluate the effects of different nitrogen rates applied at two water levels on growth, nutrient concentrations in leaves and twigs, and nut yields of almonds. (2) To assess the extent of soil acidification from nitrogen application under drip emitters. (3) To develop recommendations for nitrogen, irrigation and soil management for use in the establishment of almond orchards.

Interpretive Summary: Drip irrigation has a dramatic influence upon the rooting pattern of trees. Because of the confined soil area from which the tree roots must take up both water and nutrients, this situation offers opportunities and potential problems. Numerous applications of fertilizer injected into the drip irrigation system throughout the growing season provide a way to maximize the utilization of plant nutrients. The high concentrations of some fertilizers, such as the ammonium form of nitrogen, may result in an undesirable plant root environment. The low pH created may bring into solution sufficient levels of manganese and aluminum to reach toxic proportions. Monitoring the nitrogen status of trees with the help of early dormant season twig samples may provide an effective and more desirable time for growers to develop fertility management strategies.

Almond meat yields during 1984 (fourth season) ranged from about 400 to slightly over 1800 pounds per acre (12' X 18' spacing, 196 trees/A). It should be noted that the weather in the spring of 1984 was very favorable for attaining high yields. The three varieties responded somewhat differently with the Nonpariel having the same yield level for the 1.0 and 0.6 ET irrigation treatments and an increase from about 700 to 1400 pounds meats per acre for the 0 to 16 ounce per tree nitrogen rates. The Carmel variety had nearly the same average response to nitrogen but showed a markedly greater response to nitrogen at the 1.0 ET irrigation level (approx. 1700 at the 16 oz N/tree rate). The Butte variety showed a constant yield difference between the two irrigation levels at all rates of nitrogen with the 1.0 ET treatment averaging about 200 pounds more meats. Also, the 8 and 16 ounces N/tree rates gave nearly the same yields. Highest yields at the 1.0 ET level were approximately 1300 pounds meats per acre.

The pattern established in 1983 of total nitrogen concentration in the leaves being the same in April and then gradually increasing as more nitrogen and water are applied was repeated during 1984. The initial levels were somewhat different however, with the concentration being about 3.7% in April 1983 compared to 2.2% in April 1984. The rather low concentration in April 1984 could be due in part to the extremely large set and developing nut yield. Increasing nitrogen concentrations did start appearing in the May and

June leaf samples following the differential nitrogen rates applied. It is very interesting to note that twig total nitrogen concentrations in samples taken on December 28, 1983 showed higher levels of nitrogen with higher rates of applied nitrogen but no difference between irrigation levels. This was the situation observed in fall leaf sample total nitrogen concentrations.

Average increases in cross-sectional tree trunk area relationships from 1982-83 have shown larger differences with increasing rates of applied nitrogen and water. Whereas the difference between the 0.6 and 1.0 ET water level was the same for all nitrogen rates during the 1981-82 period, the higher water level combined with higher nitrogen rates is showing larger increases in cross-sectional trunk area.

Preliminary investigations of soil acidification indicate a dramatic lowering of pH levels immediately under the point of emitter discharge. This warrants continued evaluation as higher rates of nitrogen will be necessary for the growing trees and as more intense soil acidification could bring certain elements such as aluminum and manganese into soil solution in concentrations that may become toxic to tree roots.

Experimental Procedure:

The orchard was planted on the Nickels Estate Ranch in the spring of 1981 to three almond varieties-Butte, Carmel and Nonpareil. In the spring of 1982, five-5 tree plots were selected from each of the four-28 tree rows of each variety to which the two replications of the ten treatments were assigned. The ten treatments included two water levels-0.6 and 1.0 of evapotranspiration (ET) each with five nitrogen rates-0, 0.5, 1.0, 1.5 and 2.0 ounces per tree in 1982; 0, 0.8, 1.7, 3.5 and 7.0 ounces per tree in 1983; and 0, 2, 4, 8 and 16 ounces per tree in 1984. The 1.0 ET irrigation level is based on climatic data and visual observation of the tree growth. The 0.6 ET treatments receive 60% of the water quantity of the 1.0 ET treatments. Urea was used as the nitrogen fertilizer source. In 1982 and 1983 the lower two nitrogen rates were split into thirds and applied three times during the season (60 day intervals) while the two higher rates were split into fourths and applied four times during the season (40 day intervals). During 1984, all rates of nitrogen were split into fourths and applied four times during the season. Both application regimes began on April 1st and ended on August 1st. Leaf samples were taken from each of the 60 individual plots each month beginning April 1st and ending October 1, 1982 or November 1st in 1983 and 1984. Twig samples were taken once during the December 1981-January 1982 period, three times during the December 1982-January 1983 period and two times during December 1983-January 1984 period. Only moderate pruning was carried out after the first growing season with much more severe pruning at the completion of the second season. Only minor pruning was carried out after the third season (Dec 1983-Jan 1984). Leaf and twig samples were analyzed for total, nitrate, and ammonium nitrogen, total phosphorus, potassium, calcium, magnesium and selected sample dates were chosen for micronutrients-zinc, manganese, copper, iron and boron. Tree trunk diameters were recorded during January of 1982, 1983 and 1984 to calculate the change in cross-sectional area for the five tree plots.

Results:

Visual observation of the orchard indicated that the zero and two lower nitrogen rate treatments showed yellow-green leaf color while the two higher rates had very dark green color. The difference in color between nitrogen treatments was more dramatic in 1984 than 1983 or 1982. This would be expected with the higher rates of nitrogen applied for the second and third year as compared to treatments receiving little or no nitrogen. In addition the very favorable weather in the spring of 1984 provided for an extremely large set and developing nut yield which served as a nitrogen sink. Treatments receiving the 0.6 ET water level showed some leaf wilt indicating plant moisture stress during the latter part of the growing seasons.

Although nut yields were recorded after the third season of growth (1983) the small and erratic nature of these yields was not related to applied treatments. During 1984 however, the very favorable weather in the spring provided for a large set and the development of high meat yields. The fourth season meat yields ranged from about 400 to slightly over 1800 pounds per acre (12' X 18' spacing, 196 trees/A). The three varieties responded somewhat differently with the Nonpariel having the same yield level for the 0.6 and 1.0 ET irrigation treatments and an increase from about 700 to 1400 pounds meats per acre for the 0 to 16 ounce per tree nitrogen rates (Figure 1). The Carmel variety had nearly the same average response to nitrogen (about 800 to 1500 pounds meats per acre), but showed a markedly greater response to nitrogen at the 1.0 ET irrigation level (approx. 1700 at the 16 oz N/tree rate, Figure 2). The Butte variety showed a yield difference between the two irrigation levels at all rates of nitrogen with the 1.0 ET treatment averaging about 200 pounds more meats. Also, the 8 and 16 ounces nitrogen per tree rates gave nearly the same yield (Figure 3). Evaluation of 100 nut samples for relative weights of meats, shells and hulls as well as chemical anaylses of each fraction has not been completed.

Results of leaf analyses show the previously well documented decline in total nitrogen concentration throughout the growing season. There has been a progressively lower initial average concentration for the trial beginning in April of 1982 with 4.5%, 3.7% in 1983 and 2.2% in 1984. Although chemical analyses have not been completed on all samples collected, early season results indicate a similar trend exists in 1984. The rather low concentration in April 1984 could be due in part to the extremely large set and developing nut yield. The unassimilated nitrogen fractions, nitrate and ammonium, show the same pattern of declining concentration throughout the season. Total nitrogen concentrations indicated no difference between water or nitrogen treatments until the August 4, 1982 sampling when the total nitrogen increased with increasing water and nitrogen applications. These relationships were not as apparent in later samplings in 1982. Unassimilated nitrate and ammonium concentrations were not effected by nitrogen or water treatments. The pattern established in 1983 of total nitrogen concentration in the leaves being the same for all treatments in April and then gradually increasing as more nitrogen was applied throughout the season also appears in the April, May and June sample dates of 1984. It is very interesting to note that twig total nitrogen concentrations in samples taken on December 28, 1983 followed closely the trends indicated in the later leaf sample dates of 1983 but by April 1984 leaf concentrations of total nitrogen were the same. This seems to indicate that irregardless of tree levels of nitrogen and past nitrogen or water applications that the initial leaves of each season will usually have the same nitrogen concentration.

Twig samples taken during the dormant period (December 1982-January 1983) following the first season of treatment application show a trend for higher nitrogen concentrations with increasing rates of applied nitrogen. The lower level of applied water (0,6 ET) however, indicated a trend of having greater total nitrogen concentrations. Samples taken during the December 1983-January 1984 dormant period showed the trend of higher nitrogen concentrations with increasing rates of applied nitrogen but no difference between irrigation levels (Figure 4).

During the dormant periods of January 1982, 1983 and 1984 tree trunk diameters have been recorded and cross-sectional areas for the five trees per plot calculated. Since the January 1982 samples were taken prior to the establishment of any treatments, cross-sectional areas for the five trees per plots were not expected to be nor were they different. Average increases in cross-sectional tree trunk area relationships during the 1983 growing season have shown larger differences with increasing rates of applied nitrogen and water. Whereas the difference between the 0.6 and 1.0 ET water level was the same for all nitrogen rates during the 1982 growing season, the higher water level combined with higher nitrogen rates showed larger increases in cross-sectional trunk area during 1983.

Preliminary investigations of soil acidification indicate a dramatic lowering of pH levels immediately under the point of emitter discharge. This warrants continued evaluation as higher rates of nitrogen will be necessary for the growing trees and as more intense soil acidification could bring certain elements such as aluminum and manganese into soil solution in concentrations that may become toxic to tree roots.

Discussion:

It appears that the first four years growth (second, third and fourth with treatments applied) of the experimental orchard has been normal to slightly better than expected. The trees receiving higher rates of nitrogen are making good growth and attained excellent meat yields for the fourth season. There is some concern that trees having received no nitrogen and currently showing tip dieback plus other signs of unthrifty growth should begin to receive some nitrogen. Nitrogen concentrations in plant tissues have been in the range desired with low applied nitrogen rates falling below and higher applied rates remaining above adequate levels. Based on only two years of data, twig samples taken before January 1st should have concentrations of total nitrogen of approximately 0.85% or above after the second growing season and 0.7% after the third. If any nitrogen rates were to be suggested from the study for the early years of growth they would be in the range of 1 to 3 ounces nitrogen per tree during the first season, 2 to 6 ounces the second, 4 to 8 ounces the third and 6 to 16 ounces the fourth. If a larger set and potential nut yield is developing, the higher rates should be used.

Publications:

Meyer, R. D., Schulbach, H. and Aldrich, T. M. 1983. Rates of Nitrogen at Two Drip Irrigation Levels on Almonds. Soil and Water Newsletter 55:1-3. Summer 1983.

Meyer, R. D., Schulbach, H. and Aldrich, T. M. 1984. Rates of Nitrogen at Two Drip Irrigation Levels on Almonds. Handout for May 9, 1984 Nickels Estate Ranch Field Day.

Schulbach, H. and Meyer, R. D. 1984. Yields of Three Varieties of Fourth Year Almonds as Influenced by Nitrogen and Water Applied Through Drip Irrigation System. Handout for November 1, 1984 Almond Short Course.

Schulbach, H. and Meyer, R. D. 1984. Nitrogen Effects at Two Drip Irrigation Levels on Almonds. Abstract for Third International Drip/Trickle Irrigation, Fresno, California. November 17-21, 1985.

Figure 1

NONPARIEL ALMOND MEAT YIELDS IN 1984 AS INFLUENCED BY NITROGEN RATE AND WATER APPLIED THROUGH DRIP SYSTEM. NICKELS RANCH.

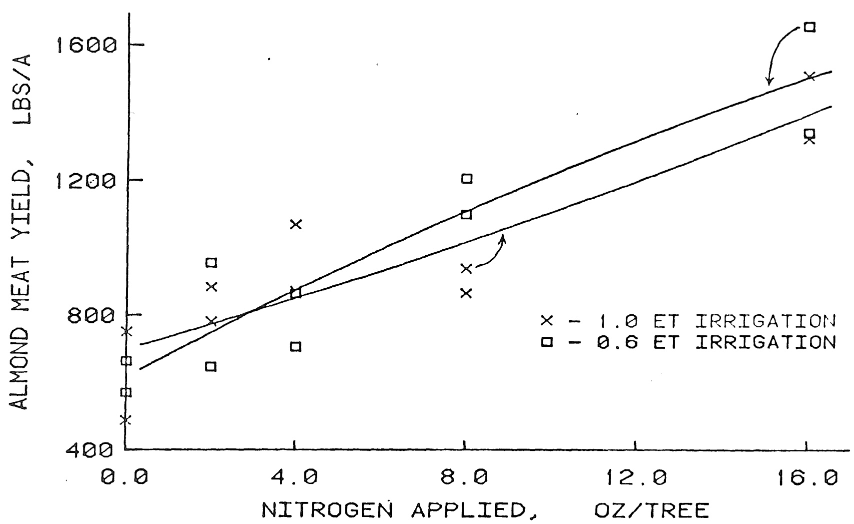


Figure 2

CARMEL ALMOND MEAT YIELDS IN 1984 AS INFLUENCED BY NITROGEN RATE AND WATER APPLIED THROUGH DRIP SYSTEM. NICKELS RANCH

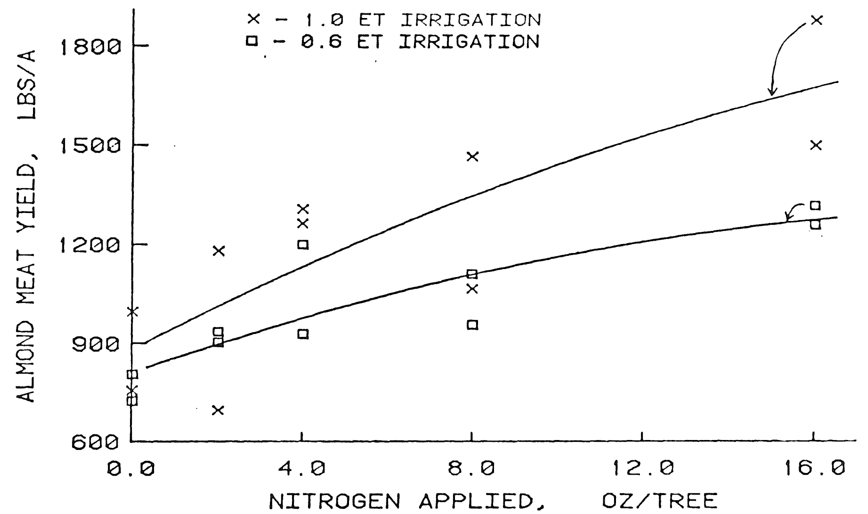


Figure 3

BUTTE ALMOND MEAT YIELDS IN 1984 AS INFLUENCED BY NITROGEN RATE AND WATER APPLIED THROUGH DRIP SYSTEM. NICKELS RANCH

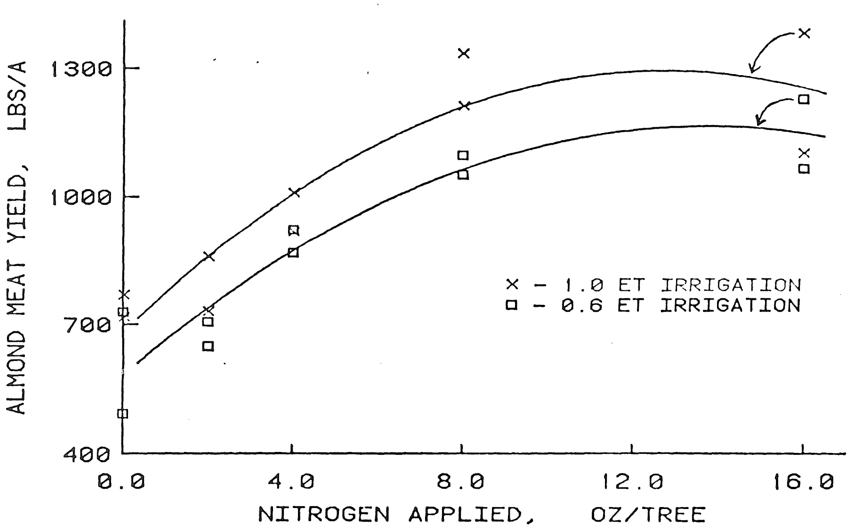
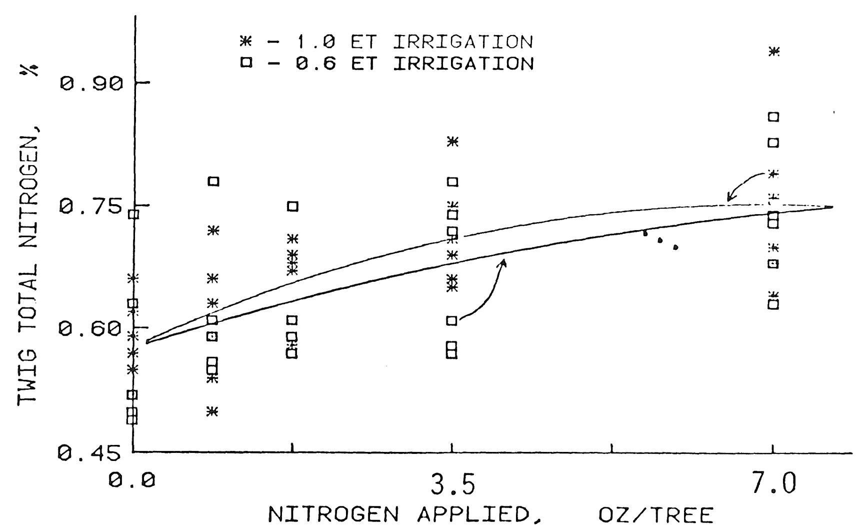


Figure 4

TOTAL NITROGEN CONCENTRATION IN ALMOND TWIGS ON DECEMBER 28, 1983 AS INFLUENCED BY NITROGEN RATE AND WATER APPLIED THROUGH DRIP SYSTEM. NICKELS RANCH.



COOPERATIVE EXTENSION UNIVERSITY OF CALIFORNIA

SOIL and WATER

Summer 1983-No. 55

Rates of Nitrogen at Two Drip Irrigation Levels on Almonds

-Roland Meyer-

During the past several years, growers and agricultural advisors have been interested in what effect drip irrigation has on the nitrogen requirements of new almond plantings. The first few years of tree growth with less than complete canopy cover result in less water use with drip irrigation because of reduced evaporation from the bare soil surface. Past research with other crops has shown that fertilizer materials applied by drip are distributed differently in the soil than when broadcast on the surface.

Multiple applications throughout the growing season are possible with drip systems which should result in greater efficiency of nitrogen use. The high concentrations of some fertilizers, such as the ammonium form of nitrogen, may result in an undesirable plant root environment. The low pH may bring into solution sufficient levels of manganese and aluminum to reach toxic proportions.

The objectives of this experiment are to evaluate the effect rates of nitrogen at two water application levels have on growth, nutrient concentrations of several plant parts, fertility, and nut yield of almonds.

The experiment was established with ten treatments, five rates of nitrogen at each of two water rates. During the irrigation season, the water rates were 1.0 and 0.6 of evapotranspiration, and nitrogen rates were 0, 1, 2, 3, and 4 ounces per tree. The nitrogen source used was urea with the one and two ounce treatments divided equally among April, June, and August applications. The three and four ounce treatments were divided among April, May, June, and August applications. Each treatment was applied to two replications of the three almond varieties--Butte, Carmel, and Nonpareil. During the 1982 season, leaf samples were taken monthly beginning in April and ending in November.

Photo Credit: Dr. Roland Meyer
LAWR/Hoagland Hall
UC Davis

(continued)

Figure 1 shows the decline in total nitrogen throughout the growing season. Unassimilated nitrogen fractions, nitrate, and ammonium show the same trend. Little if any difference between water levels or nitrogen rates appeared until the August 4 leaf sampling date.

Figure 2 indicates that the total nitrogen in the leaves on August 4 increased with increasing water and nitrogen application rates. It is somewhat difficult to explain why these relationships were not observed in the months that followed the August sample date.

During the dormant period, January 1982 and January 1983, tree trunk diameters have been recorded and cross-sectional areas for the five trees per plot calculated. A trend, increasing trunk size with increasing water and nitrogen application rates, appears to exist (Fig. 3).

Plans for the 1983 season include taking twig, leaf, trunk diameter, and perhaps other measurements. Because of the rapid growth and size of the trees, the nitrogen rates were changed to 0, 1, 2, 4, and 8 ounces per tree for the season.

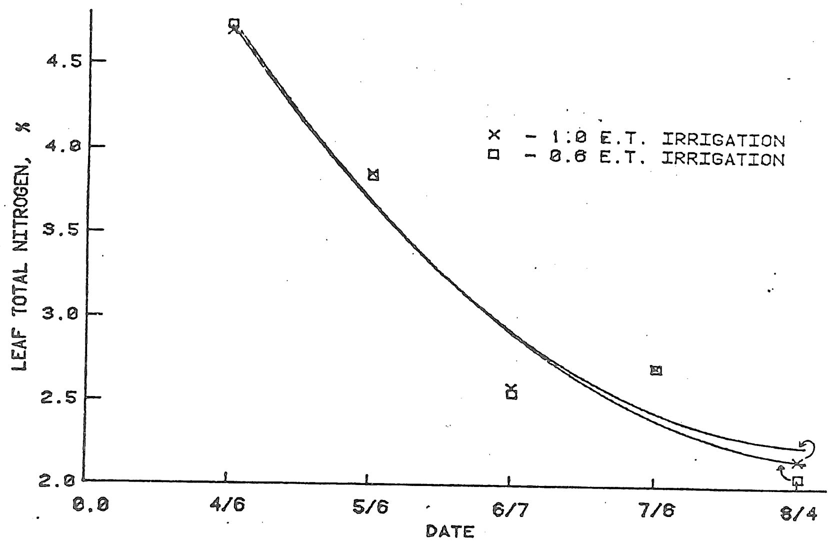


FIGURE 1

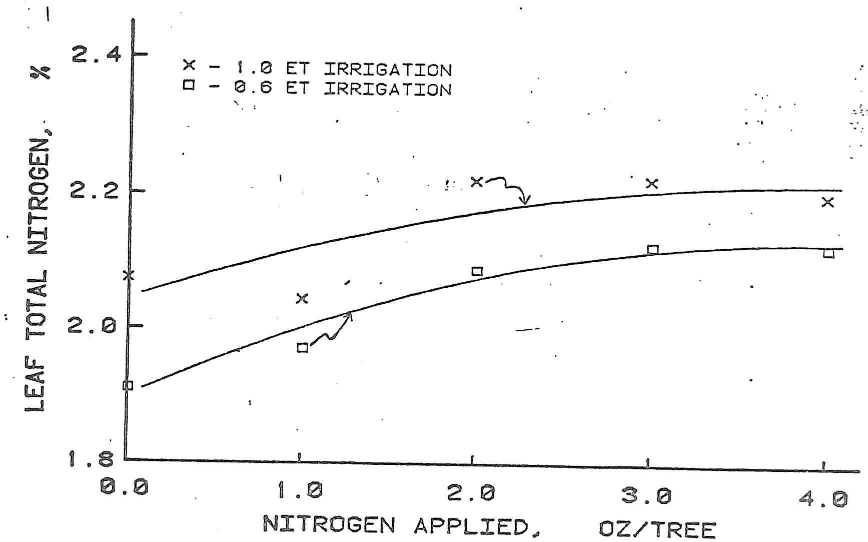


FIGURE 2

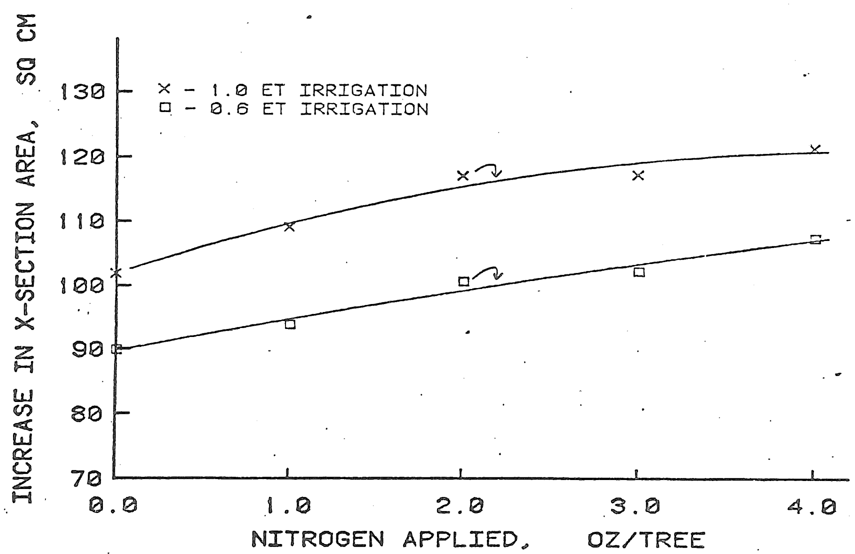


FIGURE 3

Estimating Soil Water Contents with the Neutron Probe--How Important is a Tight-Fitting Access Tube?

Dave Goldhamer and Roger Kjelgren

Introduction

Accuracy, i.e. the closeness of neutron probe soil water content measurements to the actual values, depends on a number of factors. These include developing an accurate calibration curve, using a well-maintained and properly functioning instrument, and correctly installing the access tubes. Access tubes are required, of course, so the radioactive source/detector-containing probe can be lowered into the profile. Although much discussion has been focused on errors in measurement caused by poor development, selection, or usage of calibration curves, relatively little attention has been paid to the effects of access tube installation procedures.

Every worker preparing to use the neutron probe for an agronomic application is faced with a decision concerning access tube installation. Numerous procedures have been used. Each method requires different equipment, time expenditure, and physical effort. Just as significantly, each method can result in different closeness of fits between the access tube and the soil. Most would agree that the easier the method, with respect to physical effort and time required, the poorer the access tube fit. In order to prevent erroneous field measurements, is it necessary to spend the time and energy normally required to obtain a tight fit? Specifically, how does the presence of an air gap between the wall of the access tube and the surrounding soil influence the accuracy of the measurement?

Experiment

Soil water contents were measured at a given site and depth in the field using both tight and loosely fitting access tubes. The experimental procedure involved first installing a tight-fitting tube. A hole was drilled approximately 36 inches into the profile (Hanford sandy loam soil at 12.4% volumetric water content) with a 2 inch bucket auger. This size auger produces a hole that is 1.88 inches in diameter. The access tube, EMT (electrical metal tubing), was then driven into the hole with a hammer and a special fitting that avoids damaging the top of the tube. We used standard 2 inch EMT (2.197 inch O.D., 2.067 inch ID.), with the inside edge of the tube bottom sharpened to facilitate movement through the slightly smaller augered hole. A bucket auger, small enough to move freely inside the EMT, was used to withdraw the soil that collected in the tube. Finally, soil adhering to the inside of the tube was removed with a wire brush.

The neutron probe (Campbell Pacific Nuclear Model 503 with a helium 3 detector tube) was immediately lowered into the tube and the detector positioned at the 18 inch depth. Ten, 15-second counts were then taken. After withdrawing the probe, the access tube was carefully removed from the hole. The hole was immediately enlarged, using a clay-type 2.5 inch bucket auger,to a diameter of 2.28 inches. (The access tube was again lowered into the hole, with care taken to locate the now sloppy-fitting tube in the middle of the hole, thus creating an air gap of .04 inches around the tube. The probe measurement procedure was repeated at 18 inches. The final treatment involved pouring fine grain cement sand into the air gap between the tube and the soil and repeating the water measurements.

The measurements, expressed as a ratio (CR) of the field-measured counts to a standard count, appear in Table 1. They show no significant difference between the tight- and sloppy-fitting tubes. Thus an external air gap of .04 inches, or slightly more than 1 mm, does not cause errors in measurement, at least under the conditions of this experiment. Keep in mind that an additional air space existed inside the tube: the 1.865 inch O.D. probe and 2.067 inch I.D. access tube created a .101 inch gap, assuming the probe remained centered in the middle of the tube. Some concern has been expressed in the past that this internal air gap, which is significantly greater in 2 inch EMT than standard 2 inch aluminum tubing (.10 vs. .02 inches), may induce errors. The above results indicate that relatively small changes in the size of air gaps around the probe, if one does not distinguish between internal and external air space, do not significantly influence the probe measurement. Indeed, an Australian publication (E.L. Greacen, Soil Water Assessment by the Neutron Method) indicates that an internal air gap of 0.06 to .15 inches is satisfactory as long as the hole is straight and vertical. Regardless of the access tube material used, however, it is imperative that the <u>same</u> material and installation methods be used for both calibration and field site tube installation procedures.

We do not want to imply that the measurements are completely insensitive to gaps of any size. Greacen reports that the effect is dependent on the cavity width, and is also influenced by the water content of the surrounding soil. An external air gap of .39 inches resulted in count ratio errors of approximately 20 and 30% with volumetric water contents of 18 and 36%, respectively. Moreover, structural voids between the tube and the soil are unlikely to maintain their integrity for very long and undoubtedly will evolve into zones of disturbed soil as the soil along the walls of the hole sluffs off due to, among other things, shrink-swell forces. Thus, the pore geometry and bulk density of these zones will be much different than the native profile, with consequent effects on both water movement and soil water holding capacity.

We believe this situation creates the possibility of serious errors; not in the accuracy of the soil water measurement, per se, but in the utility and interpretation of the data that is supposed to represent an undisturbed profile. Altered water transport and root proliferation properties can quickly make the environment around the tube unrepresentative of the native conditions. Therefore, while the probe may be accurately monitoring the existing water contents, it is not accurately indicating the status of the field, in general. Numerous observations have been made of significantly higher root densities around access tubes, either for neutron probes or rhizotrons, presumably because the installation procedure resulted in excessive soil disturbance. The importance of this problem in almost every type of agronomic neutron probe application cannot be overemphasized.

<u>Conclusions</u>

We conclude that while our experimental work showed no significant influence of a small air space on the accuracy of neutron probe measurements, the danger in augering an oversize or sloppy hole lies in the altering of soil water transport, retention, and root proliferation properties. Because of the usually large commitment of man hours involved in taking measurements throughout an experiment, or growing season, relative to the time and effort needed for access tube installation, we believe that whenever possible, access tubes should be installed with: 1) a minimum of soil disturbance around the access hole, and 2) a tight fit between the tube and the surrounding soil.

References

Greacen, E. L. 1981. Soil Water Assessment by the Neutron Method. Published by Commonwealth Scientific and Industrial Research Organization (CSIRO), 314 Albert Street, East Melbourne, Victoria, Australia, 3002.

Table 1. The effect of different access tube installation procedures on neutron probe measurements. Each mean represents 10 measurements.

	Tight-fitting Tube	Loose-fitting Tube	Loose-fitting Tube With Sand Filler
	Ratio Count*		
Arithmetic Mean	.684	.681	.682
Standard Deviation	0.101	.0065	.0084

*Count Ratio=Field measured count/Standard (shield) count

The salinity research projects in the following lists are being published at the request of the Salinity Nutrient Interactions Workgroup of the Third Annual CE/LAWR Workshop held in Napa on March 29-30, 1983.

KEARNEY FOUNDATION FUNDED PROJECTS

These are projects that have been or will be funded by Kearney Foundation. Most projects are funded for two or three years.

1. Plant Physiological Responses to Interactions Between Salt and Water Stress and N Utilization. V. Rendig. LAWR-Hoagland, UCD.

2. Nitrogen-use Efficiency as Influenced by Sulfur Assimilation in Wheat Exposed to Salinity. R. Huffaker and D. W. Rains. Agron.& Range Sci., UCD.

3. Responses of Crops to Fluctuating Salinity. A. Lauchli. LAWR-Hoagland, UCD.

4. Salinity Responses of Crop Plants at Different Levels of Mineral Nutrient Supply. N. Terry and L. J. Waldron. Plt.& Soil Biol., UCB.

5. Genetic Engineering of Osmoregulation (osm) Genes; Response of Rhizobium Host Plant Symbiosis to Specific Salts in Saline Soils. D. Munns and R. C. Valentine. LAWR-Hoagland, UCD.

6. Ultrastructural Studies on the Effect of Salinity on Seed Germination. W. Thomson. Bot. & Plt. Sci., UCR.

7. Response of Plants to Dissolved and Adsorbed Boron. F. Bingham. Soil & Env. Sci., UCR.

8. Boron Interactions in Saline Soils as Affected by Sodium, Calcium and Magnesium. S. Mattigod. Soil & Env. Sci., UCR.

9. Competitive Exchange and Adsorption of Ionic Solutes in Low Quality Waters During Transport Through Soil. G. Sposito. Soil & Env. Sci., UCR.

10. Estimate of the Mean Value and Variance of Solute Concentrations, Soil Water and Solute Fluxes from Discrete Measurements and Computer Modeling for a Field Experiment using Saline Water for Crop Irrigation. W. Jury. UCR.

11. Crop Response to Temporal and Spatially-Variable Soil Salinity Profiles. D. Rolston. LAWR-Hoagland, UCD.

12. Influence of Salinity and Sodicity on Mineralization of N, P and S in soils. F. Broadbent. LAWR-Hoagland, UCD.

13. Plant Response to Potassium-sodium Ratios under Saline Conditions. L. Stolzy, W. Jarrell, O. Lunt, and D. Devitt, Soil & Env. Sci., UCR.

14. Designing Subsurface Drainage Systems for Irrigated Cropland to Minimize the Soil Salinity Effects. A. Chang. Soil & Env. Sci., UCR

15. Mechanisms of Boron Toxicity in the Metabolism of California Crop Plants. C. Lovatt and W. Dugger. Bot. & Plt. Sci., UCR.

16. Microbial Nutrient Transformations in Saline Soils and Adaptations of Microorganisms to Soil Salinity. M. Firestone. Plt. & Soil Biol., UCB.

17. Photosynthetic Responses to Salinity in Glycophytes and Halophytes: A Comparative Study. N. Terry and L. Waldron. Plt. & Soil Biol., UCB.

18. Ultrastructural Studies on the Effects of Salinity on Seed Germination. W. W. Thomson and R. Bliss. Bot. & Plant Sci., UCR.

19. Response of Plants to Dissolved and Adsorbed Boron: Boron Regeneration Subproject. F. T. Bingham and Frank J. Peryea. Soil & Env. Sci., UCR.

20. Additive and Interactive Effects of Soil Salinity and Water Regimes on Crop Growth Responses and Osmoregulation. T. Hsiao. LAWR-Veihmeyer, UCD.

21. Compartmentation of Omotic Solutes in Plants Exposed to Saline Stress. L. Packer and M. Ball. Physio-Anat. UCB.

22. Competitive Exchange and Adsorption of Ionic Solutes in Low Quality Waters During Transport Through Soil. G. Sposito, C.S. LeVesque and P. Baveye, Soil & Env. Sci., UCR

23. Salt Tolerance of Mature Plum Trees. G. J. Hoffman, P. B. Catlin and D. Goldhamer. U. S. Salinity Lab, 4500 Glenwood Dr., Riverside, CA 92501.

24. Spectral and Cospectral Analyses of Crop and Soil Observations in Relation to Infiltration and Soil Salinity. D. R. Nielsen. LAWR-Veihmeyer Hall, UCD.

25. The Relationship of Inorganic N and S Assimilation and Their Interactions to Adaptation to Salt Stress by Barley. R. C. Huffaker and D. W. Rains.

26. Carbonate and Sulfate Chemistry and Mineralogy in Salt-Affected Soils. K. K. Tanji and L. D. Whittig, LAWR-Hoagland, UCD.

27. Responses of Sorghum to Chloride and Sulfate Salinity and Interaction with Root Aeration. A. Lauchli and E. Epstein. LAWR-Hoagland, UCD.

28. Analysis of the Salinity Responses of Crop Plants in Terms of Leaf Expansion and Photosynthesis. N. Terry and L. J. Waldron. Plt & Soil Biol., UCB.

29. Optimizing Management of Saline Soils. K. Knapp. Soil & Env. Sci., UCR.

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18. Rate Limiting Steps for Metabolic Ion Uptake by Plant Roots. Francis N. Dalton.

19. Electrical Properties of Plant Roots in Relation to Their Mass. F. N. Dalton and M. C. Shannon.

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21. The Submerged Drain Concept to Avoid Precipitation of Iron and Manganese. L. B. Grass and B. D. Meek.

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23. The Performance of Two Types of Steel Mill Slag Used as Drain Envelopes. L. B. Grass and L. F. Hermsmeier.

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26. Criteria for Design of Drainage Systems--Depth and Spacing Requirements of Subsurface Drains (Egypt-USA; PL480). H. K. Bakhati and G. J. Hoffman.

27. Field Evaluation of Pipe and Envelope Materials for Effective Drainage (Egypt-USA; PL480). N. M. El-Mowelhi and G. J. Hoffman.

28. Phytotoxic Effects of Various Herbicides on Guayule. L. B. Grass and C. Bell.

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29. Kinetics of $CaCo_3$ Dissolution-Precipitation in the Rootzone. D. L. Suarez and J. D. Wood.

30. Precipitation Kinetics of $CaCO_3$ in the Lower Colorado River. D. L. Suarez.

31. Effects of Irrigation Frequency and Temperature on Soil CO_2 Concentrations. D. L. Suarez and J. D. Wood.

32. Comparative Study of Several Methods for Soil Water Extraction From Unsaturated Soils. D. L. Suarez, A. Nadler, and J. D. Wood.

33. A One-Dimensional Numerical Model for Diffusion Through Reactive Porous Media Under Saturated Conditions. D. L. Corwin and M. Th.van Genuchten.

34. A Model of the Movement and Distribution of Boron in Soil Under Various Irrigation Strategies. D. L. Corwin, J. D. Rhoades, F. T. Bingham, M. Th. van Genuchten, and W. A. Jury.

35. The Location of Potential Areas of Salinization in the Yuma-Wellton Area Using Computer Aided Mapping Techniques. D. L. Corwin and J. D. Rhoades.

36. Measurement of Inverted Electrical Conductivity Profile Using Electromagnetic Induction. D. L. Corwin and J.D. Rhoades.

37. Use of San Joaquin Valley Saline Drainage Waters for Irrigation. J. D. Rhoades, R. D. LeMert and R. M. Mead.

38. Use of Saline Drainage Water for Irrigation of Crops in the Imperial Valley. J. D. Rhoades, F. T. Bingham, G. J. Hoffman, and J. T. Letey.

39. Variability of Bulk Soil Electrical Conductivity--Soil Salinity Calibrations. J. D. Rhoades, D. L. Suarez, F. T. Bingham, D. L. Corwin, J. O. Goertzen, and A. Nadler.

40. Calibrating *in situ* Soil Water Salinity and Bulk Soil Electrical Conductivity: New Methods. J. D. Rhoades, J.O. Goertzen, D. L. Corwin, D.L. Suarez, J. W. Wood, and A. Nadler.

41. Comparison of Bulk Electrical Conductivity--Soil Salinity Calibrations Obtained by Laboratory and Field Methods. J. D. Rhoades and A. Nadler.

42. Establishing Electrical Conductivity--Salinity Calibrations for Field Soils at Various Water Contents. J. D. Rhoades, D. L. Corwin and J.O. Goertzen.

43. Effect of Exchangeable Sodium and Water Content on Soil Electrical Conductivity--Soil Salinity Calibrations. J. D. Rhoades.

44. Development of an Electromagnetic Inductive Probe for Measuring Soil Electrical Conductivity in Neutron Probe Access Holes. J. D. Rhoades.

45. Specific Effect of Magnesium on the Hydraulic Conductivity of Sodic Soils. N. Alperovitch, I. Shainberg, and J. D. Rhoades.

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47. Thermogravimetric Method for the Quantitative Determination of 2:1 Layer Silicate Clay Minerals. R. E. Nelson and J. D. Rhoades.

48. Response of Plants to Dissolved and Adsorbed Boron. F. T. Bingham and J. D. Rhoades.

49. Response of the Crop Water Stress Index of Cotton to Soil Salinity. T. A. Howell and J. D. Rhoades.

50. Response of Crops to Sodicity and Calcium Concentration. J. D. Rhoades, E. V. Maas, and J. O. Goertzen.

51. Soil and Water Analytical Laboratory. M. C. Clark

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52. The Energy Basis of Salt-Induced Growth Suppression. A. Nucleotide chromatography. R. A. Clark, R. H. Nieman, and J. J. Behrmann.

53. The Energy Basis of Salt-Induced Growth Suppression. B. Effects of salt stress on adenine nucleotide levels and adenylate energy charge of pepper and safflower. R. H. Nieman and R. A. Clark.

54. The Energy Basis of Salt-Induced Growth Suppression. C. Suppression of radish seed germination. R. H. Nieman, R. A. Clark, and J. Behrmann.

55. The Energy Basis of Salt-Induced Growth Suppression. D. Suppression of bean seed germination. R. H. Nieman and R. A. Clark.

56. The Energy Basis of Salt-Induced Growth Suppression. E. Studies of salt injury and tolerance in plants using NMR spectroscopy of living plant tissues. Justin K. M. Roberts. and R. H. Nieman.

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60. Accumulation of Quaternary Ammonium Compounds in Sorghum. C. M. Grieve and E. V. Maas.

61. Accumulation and Metabolism of Quaternary Ammonium Compounds in Salt Stressed Wheat. S. R. Grattan and C. M. Grieve.

62. Accumulation of Quaternary Ammonium Compounds by Selected Crop Plants. E. V. Maas and C. M. Grieve.

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66. Salt Tolerance of Tomato Germplasm. A. Salinity effects on species. M. C. Shannon and J. Gronwald.

67. Salt Tolerance of Tomato Germplasm. B. Na/Ca ratios. M. C. Shannon and J. Gronwald.

68. Salt Tolerance of Tomato Germplasm. C. Effect of high salinities. M. C. Shannon and J. Gronwald.

69. Salt Tolerance of Tomato Germplasm. D. Effect of Moderate Salinities. M. C. Shannon and J. Gronwald.

70. Salt Tolerance of Tomato Germplasm. E. Differences between cultivars. M. C. Shannon and J. H. Draper.

71. Salt Tolerance of Tomato Germplasm. F. Effect of Salinity and irrigation frequency in sand cultures. M. C. Shannon, J. H. Draper, and J. Gronwald.

72. Salt Tolerance of Tomato Germplasm. G. Characterization of Root Membrane ATPase. J. Gronwald and M. C. Shannon.

73. Salt Tolerance of Lettuce Germpasm. M.C. Shannon and J. H. Draper.

74. Selection of Parthenium Germplasm for Salt Tolerance. M. C. Shannon, G. J. Hoffman, and L. Grass.

75. Salt Tolerance of Guayule. E. V. Maas, T. Donovan and L. E. Francois.

76. Salt Tolerance of Asparagus. L. E. Francois.

77. Salt Tolerance of Grain Sorghum. T. Donovan, E. V. Maas and L. E. Francois.

78. Salt Tolerance of Summer Squash. L. E. Francois.

79. Salt Tolerance of Triticale. L. E. Francois, T. Donovan and E. V. Maas.

80. Salt Tolerance of Two Wheat Species. E. V. Maas, L. E. Francois, T. Donovan and C. M. Grieve.

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87. Boron Tolerance of Broccoli and Cauliflower. L. E. Francois.

88. Supplement to Plant Responses to Salinity: An Indexed Bibliography. L. E. Francois ad E. V. Maas.

89. Plant Analysis Laboratory. D. A. Layfield.

90. Studies in Photosynthesis and Productivity of Crop Plants of Kolhapur (India) and Adjoining Areas. (Egypt-USA PL480 Project.) G. V. Joshi (Deceased) and R. H. Nieman.

91. Development of High Salt Tolerant Rice Varieties Adapted to the Northern Coastal Area in Egypt. (Egypt-USA PL480 Project.) Abdel-Fattah El-Azizi and M. C. Shannon.

92. The Use of Growth of Tropical Plants: A Feasibility Study. S. M. Siegel, B. Z. Siegel (Univ. of Hawaii), and E. V. Maas.