ROOT DISTRIBUTION OF COTTON: EFFECTS OF WATER APPLICATION AMOUNTS UNDER SUBSURFACE DRIP IRRIGATION

R.B. Hutmacher
Univ. CA Cooperative Extension
UC Davis Agronomy Dept. (formerly USDA-ARS)
Fresno, CA
K.R. Davis, S.S. Vail, M.S. Peters,
A. Nevarez and J. Covarrubias
USDA-ARS-WMRL
Fresno, CA

Abstract

Root distribution can be influenced by many soil and environmental factors in addition to the influence of genetics and environment on crop morphology and plant vigor. In semi-arid and arid environments, soil water availability during much of the growing season in largely determined by irrigation practices once limited water from rainfall is depleted. Some irrigation methods attempt to apply water uniformly across the entire soil surface area (solid-set sprinklers, dead-level basin, border checks). Others (furrow, drip) apply the water to a more limited portion of the soil, after which some redistribution and lateral movement of water can occur. A three-year study was initiated under subsurface drip and furrow irrigation in cotton to evaluate the influence of time of growing season, irrigation method, and amount applied per irrigation on root length density (RLD) and distribution within the soil profile. Furrow irrigated plots receiving full irrigation had RLD values significantly lower than SDI plots in within-plant row cores, but significantly higher values within cores from the furrow area. Under full (100% ETc) irrigation, the root system of the SDI plots was more concentrated (higher RLD and root mass) near the emitter (within 35 to 45 cm) than near the surface or at greater depths or distances from the emitter. Lint yields in all treatments were good to excellent, exceeding 1700 kg lint/ha.

Introduction

Drip irrigation has been operated at a wide range of frequencies in studies across the world. Much of the work done at the USDA-ARS Water Management Research Laboratory in California has involved high-frequency irrigation with subsurface drip systems. Research in the San Joaquin Valley of California with several crops, including tomatoes and cantaloupe has shown yield and quality advantages with daily or more frequent irrigation when compared with 3 to 4 day intervals. In cotton, we have not typically observed this yield response to increasing irrigation frequency (when comparing daily or multiple times per day versus every 3 to 4 days in a clay loam soil).

Work done in Israel in several studies over the past ten years suggests that higher frequency drip irrigation/fertigation tends to restrict the root zone to a more limited volume of wetted soil and concentrated zone of nutrient placement when compared with lower frequency fertigation. These studies were generally done in soils with sandy loam or similar textures, where lateral water distribution from a point source (drip emitter) is generally more restricted than in heavier soils. Our previous work in sweet corn (which has a fibrous root system) indicated that measurements describing root system depth and density were largely unaffected by irrigation frequencies ranging from multiple irrigations per day to once every 3 to 4 days.

A study was initiated in cotton grown in a clay loam soil in California's San Joaquin Valley to: (1) determine cotton root system responses (rooting depth, lateral distribution and density) to irrigation frequency and amounts; (2) determine the influence of irrigation frequency (with the same net water application amounts) on the depth, density of cotton root systems at different times of the growing season; and (3) evaluate the impact of a two irrigation amounts (60 versus 100 percent of estimated crop evapotranspiration (ETc)) on lateral water movement and root distribution in subsurface drip-irrigated cotton.

Materials and Methods

Cultural Conditions

The experiment was conducted in a clay loam soil (Panoche clay loam) at the University of CA West Side Research and Extension Center near Five Points, CA. Cotton (Gossypium hirsutum, cv. "GC510") was planted in mid-April in 1991, 1992, and 1993 on corrugations (low beds) spaced 76 cm apart. All treatments received a pre-plant application of 11-52-0 and potassium sulfate fertilizer equivalent to 30 kg N ha-1 and 140 kg K ha-1. With the exception of a furrow irrigated comparison treatment, all treatments received a total of 150 kg N and 67 kg P per ha via fertilizers injected through the drip system. In the furrow plots, the fertilizers were applied as a dry, banded application. All plots were germinated and established using 140, 140 and 90 mm of sprinkler irrigation in 1991, 1992 and 1993, respectively.

Drip System/Furrow Irrigation

The subsurface drip irrigation (SDI) system consisted of in-line, turbulent-flow emitters with 2 liter per hour output on 0.91 m emitter spacing. Lateral spacing was 1.52 m, with the laterals placed 40 cm below the average soil depth and centered under alternate furrows. Estimated crop evapotranspiration (ETc) was calculated using a locally-derived crop coefficient multiplied by grass refererence evapotranspiration (ET_o). ET_o was determined by the modified Penman method using an adjacent (100 m distant)

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1491-1495 (1998)
National Cotton Council, Memphis TN

weather station. Irrigation amounts equivalent to 60% and 100% ETc were applied in the two SDI trts. The furrow irrigated plants were watered on a 12 to 14 day schedule, with one treatment receiving water applications equal to 60% ETc and another 100% ETc.

Treatments

Root system development was evaluated as a function of time (monthly samples in late-June, late-July, and late-August or early-September), irrigation frequency and irrigation amount. Irrigation frequencies evaluated included: (1) SDI irrigation after each 2 mm of accumulated ETc (three to four irrigations per day under peak ETc); (2) SDI irrigation after 25 mm accumulated (every four to six days) ETc; and (3) furrow irrigation every 12-14 days (with 100% of estimated ETc applied). The effects of reduced water application amount (60% ETc) on root systems was evaluated under SDI at the 2 mm frequency and under furrow irrigation (12-14 day frequency).

Root System Measurements

Root length density and root fresh and dry weights were measured in samples collected from a 5.1 cm diameter soil core in 15 cm increments to a depth of 1.2 m, then 22.5 cm increments from the 1.2 through 2.92 m depths. All samples analyzed represent a composite collected from two sampling locations within each field block. Three field blocks were sampled in all treatments. Roots were separated and prepared by: (1) soaking soil cores for 1-1.5 hours in a dilute acetic acid solution; (2) washing several times to separate soil and organic materials; (3) hand-separating viable roots from dead roots and soil organic matter; (4) staining roots in dilute methyl violet to enhance contrast; (5) float roots on water and estimate length using a Delta-T video camera system with light table and image analyzer. Core bulk density, water content and soil dry weights were determined on subsamples from each core. Root length density was expressed per unit dry weight of soil and root fresh and dry weights were determined on each sample.

The six sampling locations used within each plot and their relationship to the plant rows and emitter / lateral locations were as follows: (1) sample locations A1, A2 and A3 were located 10, 40 and 70 cm away from and perpendicular to an emitter (away from the drip emitter, across the furrow); (2) sample locations M1, M2 and M3 were located 10, 40 and 70 cm perpendicular to the midpoint between emitters (same distance from drip lateral as A1, A2, A3 respectively, but further from the emitters. These grid sampling locations were selected to represent a cross-section of the root system from close to the plant row and emitter to the maximum distance from emitters. It is important to note that the drip lines were 1.52 m apart (in alternate furrows), so the increasing perpendicular distance from the emitters (40 cm and particularly 70 cm distance) represented a much drier location almost in the middle between laterals.

Results and Discussion

Effects of Soil Sample Location

The six soil core locations (relative to the plant row and emitter locations in SDI plots) had a large influence on root distribution and root length densities (RLD) (Fig. 1 and 2) in SDI plots. Samples near the lateral (A1, M1) and within 40 cm of the emitters (A2) had higher RLD than at greater distances from the emitters/laterals. Differences across sampling locations were much smaller in furrow-irrigated plots, with only slightly higher root densities in within-plant row locations when compared with in-furrow sites (data not shown).

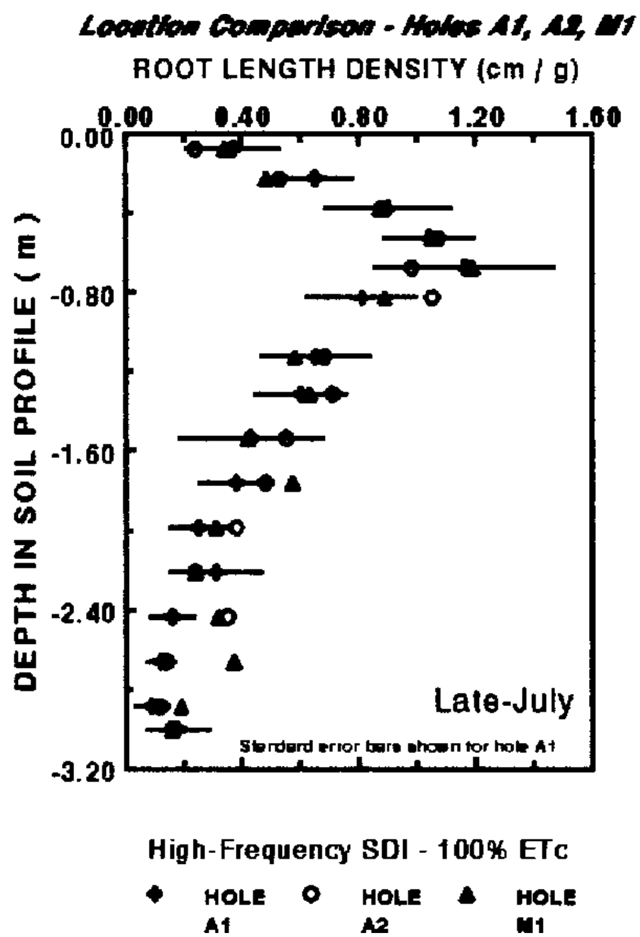
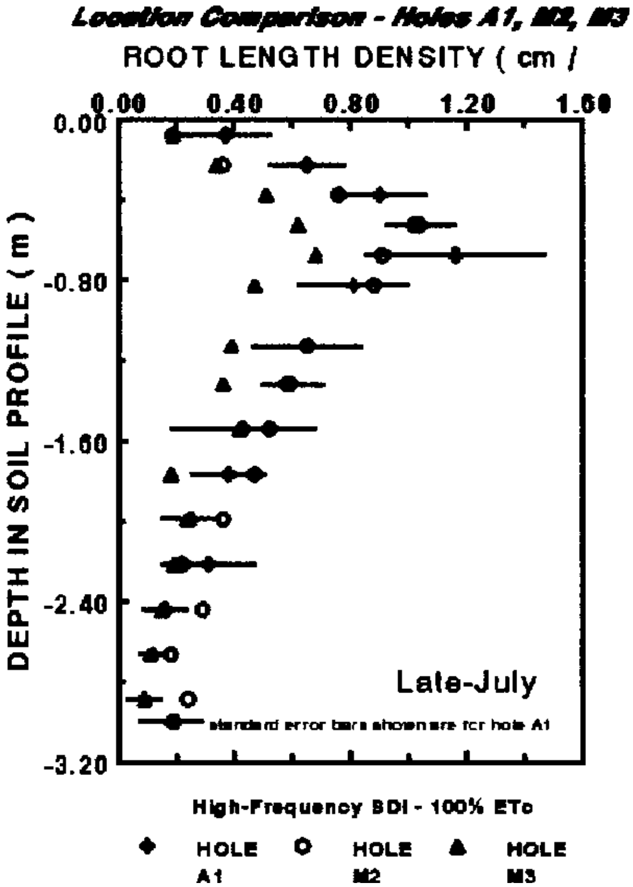


Figure 1. Cotton root length density (in cm/g dry wt. soil) as a function of depth in profile and hole sample locations (A1, A2, M1) in late-July, 1993. Data shown is only for 100% ETc subsurface drip irrigation treatment. Standard error bars are shown only for hole A1.



Location Comparison - Holes A1, M2, M3
ROOT LENGTH DENSITY (cm /
0.00
0.40
0.80
1.20
1.60
0.00
-0.80
-1.60
-2.40
-3.20
DEPTH IN SOIL PROFILE (m)
Late-July
standard error bars shown are for hole A1
High-Frequency SDI - 100% ETo
HOLE A1
HOLE M2
HOLE M3

Figure 2. Cotton root length density (in cm/g dry wt. soil) as a function of depth in profile and hole sample locations (A1, M2, M3) in late-July, 1993. Data shown is only for 100% ETc subsurface drip irrigation treatment. Standard error bars are shown only for hole A1.

Baseline RLD measurements were done pre-plant in weed-free areas to identify potential for error in RLD based upon "carryover" roots difficult to distinguish from current season roots. These plots had either: (1) cotton grown in the previous year, or (2) fallow conditions. Data indicated a baseline RLD value of 0.08 cm/g in fields with cotton the previous year versus 0.03 cm/g in fallow fields.

Time of Year/Location Effects

RLD increased with the rapid period of plant root and canopy growth during the June through July period.

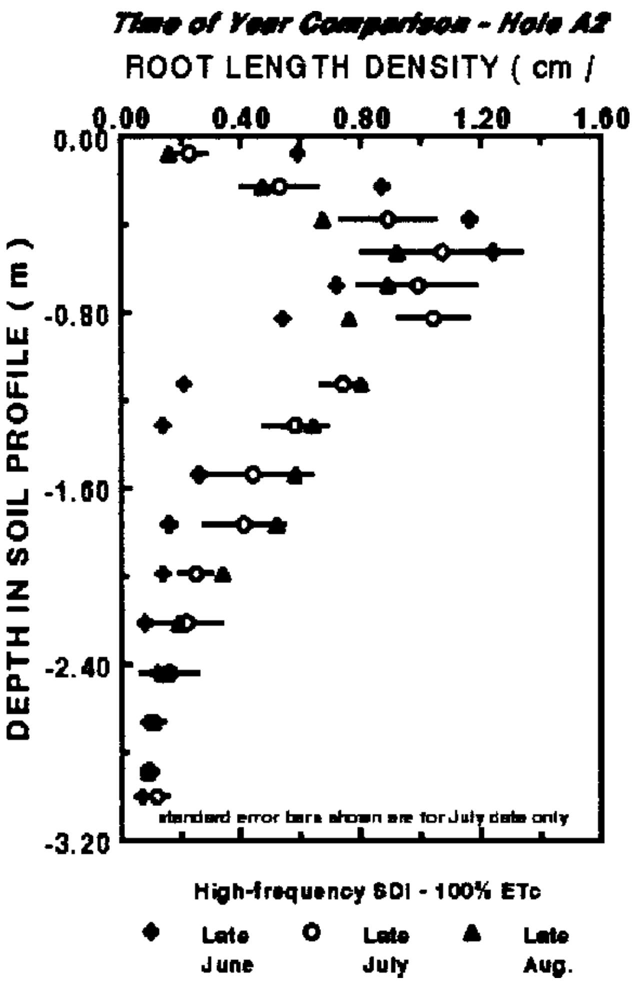


Figure 3. Cotton root length density (in cm/g dry wt. soil) as a function of depth in profile and time of year for hole location A2. Data shown is only for 100% ETc subsurface drip irrigation treatment. Standard error bars are shown only for July date.

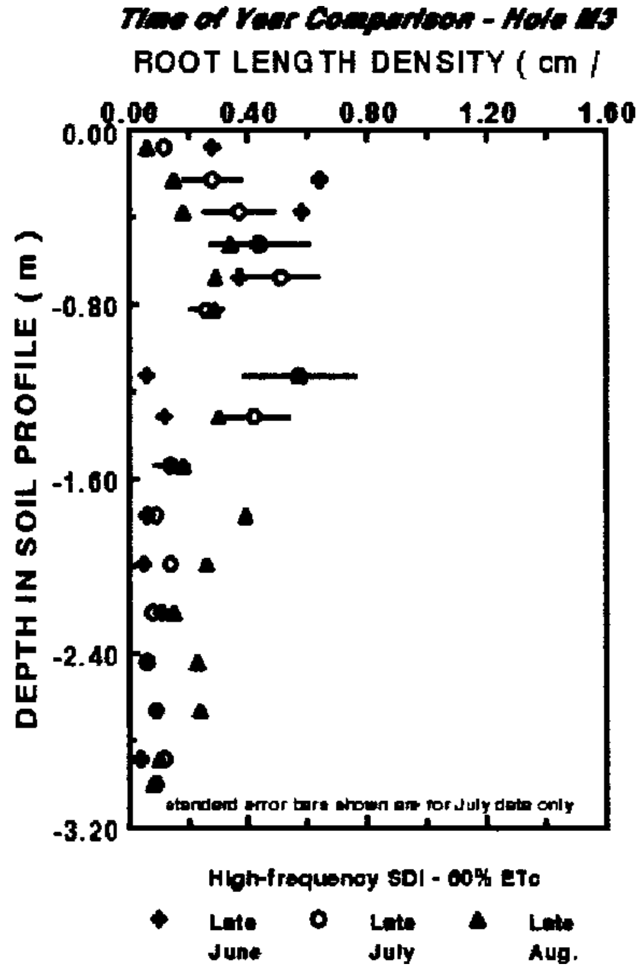


Figure 4. Cotton root length density (in cm/g dry wt. soil) as a function of depth in profile and time of year for hole location M3. Data shown is only for 60% ETc subsurface drip irrigation treatment. Standard error bars are shown only for July date.

(Fig. 3,4). The root system increased greatly in mass, RLD and depth from late June levels to those at the late-July sampling. By late-August, RLD generally declined in the upper 1 m of the profile from late-July levels, but increased in the 1 to 2 m deep zone during the same period (Fig. 3,4). The strong effects of low irrigation amount and distance from the emitters can be seen in Fig. 4, which shows an even larger reduction in RLD in the upper 1 m of the profile during the June to August period.

Irrigation Frequency/Method/Amount

The irrigation method (furrow versus SDI) and the amount applied with each irrigation influenced the wetted soil volume (data not shown) and RLD (Fig. 5, 6). Near the plant row and within 40 cm of the emitter in SDI plots, RLD was higher in SDI than in furrow plots. By late-July (data not shown) and late-August (Fig. 6), water did not move sufficiently from emitters out to the A3 or M3 sampling locations, resulting in much lower RLD in 60% ETc SDI plots when compared to all others.

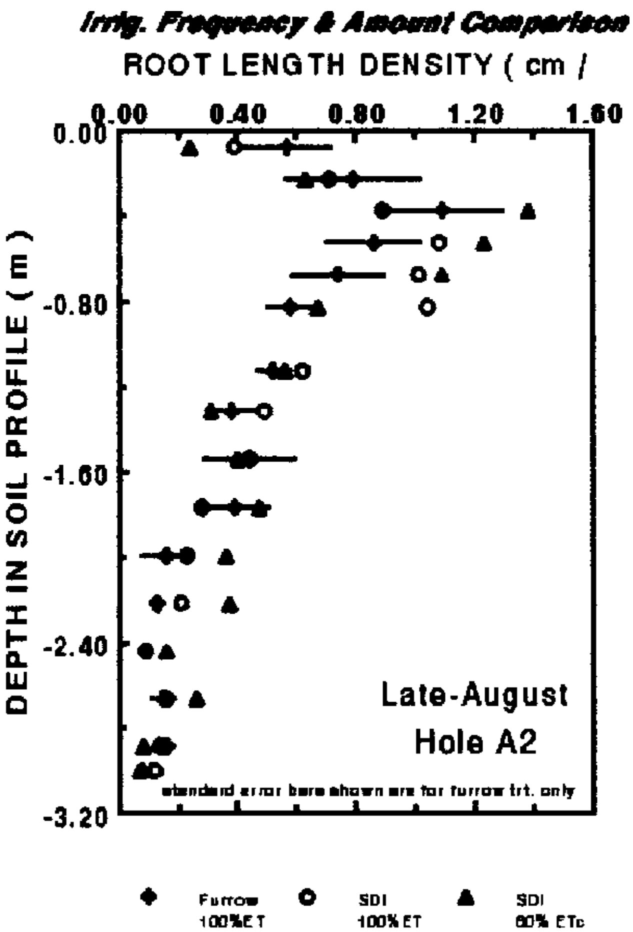


Figure 5. Cotton root length density (in cm/g dry wt. soil) as a function of depth in profile and irrigation method (furrow versus drip) and amount (60% or 100% Etc) for hole location A2. Standard error bars are shown only for furrow treatment.

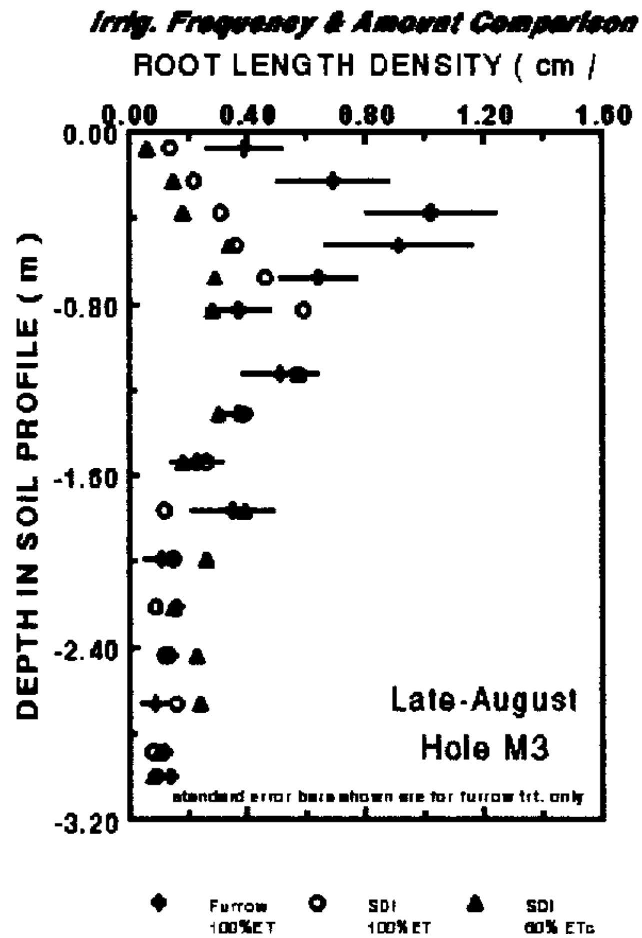


Figure 6. Cotton root length density (in cm/g dry wt. soil) as a function of depth in profile and irrigation method (furrow versus drip) and amount (60% or 100% Etc) for hole location M3. Standard error bars are shown only for furrow treatment.

Root Distribution - Generalizations

When comparing total root mass in late-August across treatments, the long-term effects of deficit irrigation in 60% ETc plots were evident (Fig. 7). RLD and root mass tended to be higher in deficit-irrigated plants (when compared with full irrigation treatments) below the 1.4 m depth in the soil profile, while surface soil root mass was reduced only in the furrow 60% ETc treatment. This agrees with the greater soil water depletions measured with depth in the low water application treatments (data not shown).

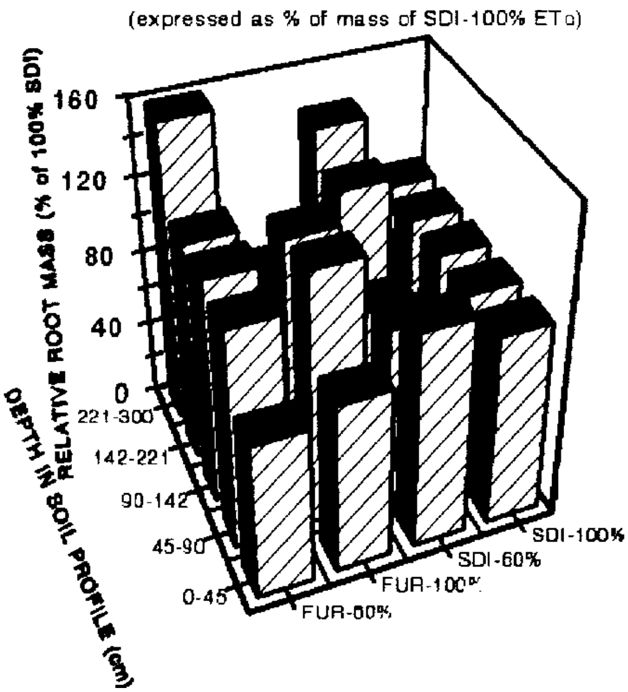


Figure 7. Average root mass (dry weight) expressed as a percentage of the root mass of the SDI-100% Etc treatment in late-August, 1993 as a function of depth in the soil profile and irrigation treatment.

Summary

Furrow irrigated plots receiving full irrigation had RLD values significantly lower than SDI plots in within-plant row cores, but significantly higher values within cores from the furrow area. Under full (100% ETc) irrigation, the root system of the SDI plots was more concentrated (higher RLD and root mass) near the emitter (within 35 to 45 cm) than near the surface or at greater depths or distances from the emitter. This core sampling method indicated that distance from emitters has a significant impact on root distibution with high-frequency SDI even in a clay loam soil. Lint yields in all treatments (including that receiving 60% estimated crop evapotranspiration) were good to excellent (exceeding 1700 kg lint/ha in all treatments). Yields were higher in the full irrigation treatments, but the significant soil water uptake throughout the soil profile allowed continued growth and good yields even under deficit irrigation in this high-water-holding capacity soil.

Acknowledgements

The assistance of the staff of the University of CA West Side Research and Extension Center at Five Points, CA is gratefully acknowledged for providing staff and equipment to prepare, plant and maintain plots during the growing season and for providing refrigerated storage for the root samples. Staff of the chemistry laboratory at the USDA-ARS Water Management Research Laboratory are acknowledged for assistance in preparation and analysis of soil/root samples.