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Soil Water Uptake Patterns of Pecan Trees Grown in Coarse Gravelly Soils

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SUMMARY. Soil depth for water uptake in pecan trees [*Carya illinoensis* (Wangenh.) C. Koch 'Western Schley'] is considered to be <100 cm (3.2 ft) for sites that have high water tables. The objective of this research was to determine the water uptake pattern of pecan trees grown on sites with a deep water table [>30 m (100 ft)] and irrigated at 50 kPa (0.5 bar). Trees (15- to 20-year-old trunks) were transplanted into laser-leveled terraces in 1986. Two terraces (T) were selected and irrigated (1994 and 1995) at 50 kPa (T5) and farmer controlled [T6, weekly at ≈ 30 kPa (0.3 bar)]. Soil water content was measured on a 1.3 by 1.3 m (4 ft by 4 ft) grid for one tree in each terrace using a neutron probe. In 1994, the

average soil depth for water uptake was 75 (2.5 ft) and 62 cm (2.0 ft) for T5 and T6 respectively. In 1995, the average soil depth for water uptake was 150 cm (5 ft) on T5 and 130 cm (4 ft) on T6. The total quantity of water removed below 140 cm (4.6 ft) soil depth was minor (<15%) when compared with the total water removed between 0 and 140 cm depth. T5 showed a deeper (260 cm; 8.5 ft) and wider (3.0 to 5.0 m; 10 to 16 ft) water uptake pattern compared with T6. Thus, pecan trees growing on these coarse soils with a deep water table and irrigated at 50 kPa have an effective root zone of ≈ 140 to 150 cm (4.6 to 5.0 ft).

Roots anchor plants in the soil, and absorb and transport water and nutrients to the canopy. Native pecan trees usually have an extensive root system with deep lateral roots and pronounced tap root that can extend to the water table provided the water table is 2 to 3 m (6 to 10 ft) below the soil surface (Wolstenholme, 1979). This root system absorbs water required for growth at the expense of surrounding trees or shrubs.

Hammar et al. (1953) showed that roots of 40-year-old pecan trees grown in sandy and clayey soils can extend beneath adjacent trees up to a distance of 18 m (59 ft) from the trunk implying the root spread of mature trees can be twice the branch length (9 m; 29 ft), thus competing with adjacent trees for water and nutrients. White and Edwards (1980) installed glass panels at three sites underneath 30-year-old pecan trees to observe root growth at 7.4 m (24 ft) from the trunk. They showed that roots ≤ 1 mm in diameter were distributed uniformly throughout the soil profile to 90 cm (3

ft). Larger diameter roots were in the 30 to 60 cm (1 to 2 ft) zone. Root growth first appeared in the spring near the surface and commenced at deeper depths as the soil warmed. The three sites had a water table that fluctuated between 75 and 125 cm (2.5 and 4 ft). Poor aeration most likely caused reduced root numbers below 90 cm (3 ft) soil depth.

Miyamoto (1983) measured soil water depletion in various pecan orchards in the Rio Grande Valley with various soil types, tree age, and depth to water table. Neutron probe data showed that water uptake by roots below 100 cm (3.2 ft) was <5% of the total available soil water. Local observations in orchards (El Paso, Texas and Las Cruces, New Mexico areas) indicate that root systems of pecan trees grown in these fine (heavy) soils did not go below ≈ 120 cm (4 ft) (Miyamoto, 1983).

Daniell (1981) installed tensiometers at 30, 45, and 91 cm (1.0, 1.5, and 3 ft) and irrigations were scheduled when the 45 cm (1.5 ft) tensiometer reached 35, 52, and 70 kPa (25, 52, and 70 bar). Better yields resulted from keeping the tension above 52 kPa. Hohn (1988) stated that local recommendations for the Mesilla valley was to irrigate when a pecan tree has used $\approx 50\%$ of the available water.

Pecan trees are being transplanted from fine (heavy) textured soils in the Rio Grande valley to well drained gravelly, loamy sand alluvium soils above the valley floor. In one new orchard, irrigation events were scheduled weekly (May through September, with longer time periods between irrigation events in the spring and fall) to reduce the risk of water stress. Total water applied exceeded 3.0 m/year (10 ft/year). Weekly irrigation events may reduce water stress but increases the risk of nutrient and water leaching below the root zone. Miyamoto (1983) estimated consumptive water use from 100 to 130 cm/year (3.0 to 4.0 ft/year) depending on tree size, planting density, and tree age. Scheduling irrigation events using an approved method, e.g., tensiometers (Daniell, 1981), in these new transplanted orchards, could reduce over irrigation. Roots could possibly extend to greater soil depths for water extraction than described by Miyamoto (1983). The soil depth and lateral extent of the effective water uptake zone of transplanted pecan trees

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Table 1. Average soil texture, gravel content, field capacity (FC), and permanent wilting point (PWP) values by soil depth for T5 and T6. T5 was irrigated at 50 kPa (0.5 bar) and T6 was irrigated using normal farm schedule.

Terrace	Soil depth (cm ²)	Soil texture (%)			Gravel vol (%)	FC [m ³ ·m ⁻³ (ft ³ /ft ³)]	PWP
		Clay	Silt	Sand			
T5	0 to 122	7.5	7.5	85	4.4	0.12	0.04
	122 to 213	6.1	6.2	87.7	21.6	0.08	0.02
	213 to 290	6.2	12.2	81.6	19.3	0.09	0.03
T6	0 to 122	5.7	5.4	88.9	3.9	0.14	0.05
	122 to 165	5.3	16.9	87.7	28.4	0.12	0.02
	165 to 270	1.7	16.5	81.8	14.7	0.14	0.06

^a2.54 cm = 1.0 inch.

growing in these gravelly, loamy sands is unknown. Knowing the effective rooting depth for water uptake on these newly cultivated soils can help schedule irrigations more effectively. This 2-year study reports the effective soil depth for water uptake and identifies the lateral extent of water uptake of pecan trees between irrigations in these coarse alluvium soils when irrigated at 50 kPa compared to the normal farm schedule.

Materials and methods

This study was conducted in a commercial pecan orchard ≈6.5 km (4 miles) south of Las Cruces, N.M., on a mesa overlooking the Rio Grand River Valley. The soil was classified as a Bluepoint loamy sand with 1% to 40% slopes, 5% to 15% gravel, and is deep and excessively drained (Bullock and Neher, 1980). Gravel consists of rock fragments ≥2 mm (0.08 inch) in diameter (Miller and Guthrie, 1984). The original topography was rolling hills and arroyos that were laser-leveled into terraces (basin irrigation) before transplanting. Table 1 shows the average soil characteristics by soil depth. Before the start of this experiment, irrigation events were scheduled weekly applying an average of 3.7 m/year (12 ft/year) (1986 to 1993). Two terraces, 16 trees each, were selected in the middle of 10 terraces. One terrace was irrigated using the normal farm schedule while the other was scheduled using tensiometers (described later).

Pecan trees were transplanted from established orchards on the valley floor in Spring 1986. The trees were 15 to 20 years old at the time of transplanting. All major limbs were cut flush with the trunk and the tree topped between 5 to 7 m (16 to 23 ft). The tree and root ball were removed

with a truck mounted tree spade to transport the trees to a new location. Trees were transplanted on a 10.6 m (35 ft) within row by 18.3 m (60 ft) between row grid pattern. By 1994 and 1995, these trees were between 13.0 and 14.5 m (30 and 47 ft) tall with a 5.0 m (16 ft) canopy radius.

Irrigation water was pumped from a 30 m (100 ft) water table into an underground irrigation system. An outlet valve was opened manually to flood irrigate each basin between the berms of adjacent terraces. Both T5 and T6 were 172 m (565 ft) long and the irrigated basin (berm to berm) was ≈13.3 m (44 ft) wide for a total basin area of ≈2290 m² (0.57 acres). The berm between each basin was ≈5.0 m (16 ft) wide and the same length as each basin. The berms (non irrigated land area) composed ≈27% of the total land area while the basin (irrigated land area) covered ≈73% of the land area.

Soil matric potential was measured using tensiometers installed at 50 cm (1.6 ft) (shallow) and 100 cm (3.2 ft) (deep) below the soil surface and placed at 1.3, 2.6, 3.9 and 5.2 m (4.3, 8.5, and 17 ft) from each tree. T5 was irrigated when the shallow tensiometer placed at 2.6 m distance from the tree trunk reached ≈50 kPa (0.5 bar). T6 was irrigated on a weekly basis, which was the normal orchard irrigation schedule (corresponding to tensiometer measurements of 30 kPa (0.3 bar), tensiometer at the same soil depth and distance from the tree as the one in T5). Tensiometer depths and water potential for scheduling irrigations on T5 correspond to values described by Daniell (1981) for best yields. Tensiometer data were collected daily. Irrigation scheduling for T5 began in June 1994 and March 1995.

Before an irrigation, the soil wa-

ter content data were collected using a neutron probe. Thirty-four 3 m (10 ft) long access tubes were installed adjacent to the down row half of the middle tree in each terrace using a 1.3 by 1.3 m (4.3 by 4.3 ft) grid pattern (Fig. 1). The area around the tree was separated into three annular areas designated ring 1 [0.0 to 3.0 m (0 to 10 ft)], ring 2 [3.0 to 5.0 m (10 to 16 ft)], and ring 3 [5.0 to 6.5 m (16 to 21 ft)] based on the distance from the tree trunk. The area associated with each ring was 28 m² (302 ft²) for ring 1 (21% of total area monitored), 50 m² (538 ft²) (38%) for ring 2, and 54 m² (581 ft²) (41%) for ring 3. There were 12 access tubes (35%) in ring 1, 13 access tubes (38%) in ring 2, and 9 access tubes (27%) in ring 3. The tree canopy radius was ≈5.0 m (16 ft) for both terraces such that rings 1 and 2 were underneath the tree canopy while ring 3 was at or just outside the tree canopy (Fig. 1).

Neutron probe cable stops were set to take measurements at 20 cm (8 inch) from the soil surface and every 30 cm (12 inch) thereafter to a maximum depth of 260 cm (8.5 ft). It was assumed that water extraction had occurred and the soil depth documented, when the water content at any soil depth had decreased 0.01 cm³·cm⁻³ (ft³/ft³) from the water content value determined at field capacity at that same soil depth. Effective rooting depth for each access tube was recorded from neutron probe measurements collected before an irrigation.

The water content at field capacity (FC) was determined with a neutron probe within 2 weeks after a winter irrigation (1994) when evaporation and transpiration were negligible. Permanent wilting point, PWP [–1500 kPa (15 bar)] was determined using water retention data derived from pressure plate and thermocouple psychrometer techniques (Rawlins and Campbell, 1986). Table 1 shows FC and PWP values by depth for this soil.

Neutron probe water content data were analyzed to determine percent water depletion for each access tube and average water depletion for each ring area. Percent depletion was calculated by subtracting the depth of water in the soil profile at FC (Table 1) from the depth of water in the soil profile measured before an irrigation divided by the total water at FC. A negative value indicated water storage, a zero value indicated water storage was equal

to field capacity, and a positive value indicated water depletion. Soil depth for water uptake was determined for each access tube using neutron probe data recorded before an irrigation event.

Pump flow rate measurements were taken throughout the irrigation season using a sonic flow meter. Water samples were taken to determine the total amount of nitrogen applied to each terrace (fertigation). Liquid fertilizer (26N-0P-0K-6S or 5N-0P-0K-8S) was injected into the irrigation system from a 3785 L (1000 gal) supply tank through a piston injector pump. The pump was adjustable to output between 0 and 113 L·h⁻¹ (0 to 30 gal/min) of liquid fertilizer material. The quantity of nitrogen applied to each terrace was modified by changing the fertilizer analysis in the supply tank, rate of injection, or the quantity of water applied (length of time to irrigate each terrace). T5 received 564 and 387 kg·ha⁻¹ (500 and 345 lb/acre) of total N in 1994 and 1995, respectively. T6 received 604 and 747 kg·ha⁻¹ (540 and 665 lb/acre) of total N in 1994 and 1995, respectively. Zinc and iron micronutrients were applied by the land owner using a high pressure/volume foliar sprayer (amounts and concentrations were not recorded for this study).

During the 1994 growing season water content data were collected before 9 irrigations in T5 and 12 irrigations in T6. In 1995 water content data were collected before 10 irrigations in T5 and 13 irrigations in T6. Water content data were analyzed to determine the mean soil depth for water uptake and mean percent water depletion, in each ring area between irrigations for each growing season. Standard error about the means were determined for each access tube and ring area within each terrace for soil depth and percent soil water depletion for each growing season. Mean values and standard errors about the means were determined for each access tube and ring area during 1994 and 1995.

Results and discussion

Irrigation scheduling for T5 began in June 1994. Before this date both terraces were irrigated using the same schedule (weekly events). T5 was irrigated 17 times during the irrigation season (including irrigations before June). Irrigation events occurred at

≈13-d intervals with an average water application of 13 cm/irrigation (5.1 inch). T6 was irrigated 20 times (1994) during the season, at ≈10-d intervals between irrigations, and had an average irrigation water depth of 14 cm/irrigation (5.5 inch).

In 1995, T5 was irrigated 14 times with an average 15 d between irrigations and 13 cm/irrigation. T6 was irrigated 23 times with ≈9-d intervals between irrigations and 16.2 cm/irrigation (6.4 inch). In early Spring 1995, the deep well bowels and motor were replaced increasing the flow rate from 7,950 to 10,030 L·min⁻¹ (2,100 to 2,650 gal/min). The length of time each valve was open on T6 did not decrease. This explains the large difference for the total depth of water applied at each irrigation in T6 compared with T5.

AVERAGE SOIL DEPTH FOR WATER UPTAKE. Figure 2A shows the average soil depth for water uptake on T5 and T6 during 1994. This figure shows the pecan tree in T5 extracted soil water deeper than the tree in T6 but only in rings 1 and 2. The average soil depth for water uptake across all ring areas for T5 was ≈89 cm (3 ft) and for T6 was ≈59 cm (2 ft).

Figure 2B shows the soil depth for water uptake for T5 and T6 during 1995. Soil depth for water uptake for T5 across all ring areas was deeper than for T6. Soil depth for T5 averaged ≈143 cm (4.7 ft) while T6 averaged ≈79 cm (2.6 ft). Thus, T5 had a deeper soil depth for water uptake than T6 for both years.

The possible increase in soil depth for water uptake shown in T5, ring 3 in 1995 compared to 1994 could be attributed to the delay of irrigation scheduling in 1994, which did not start until June. The delay in scheduling irrigations until June (1994) allowed less time for treatment effects to occur while full season irrigation scheduling (1995) allowed maximum time for tree roots to respond. Tree row spacing are such that within row trees were transplanted closer together than between row trees. This close tree spac-

ing within row compared to between row could allow for possible root cross-over from the adjacent within row tree assuming the adjacent tree had the same expanding water uptake pattern as the tree monitored in T5. Within row trees are 10.6 m (35 ft) apart with a tree canopy of 5.0 m (16 ft) resulting in a closed canopy. However, between rows trees are 18.3 m (60 ft), which implies an open canopy. Data from access tubes between rows and greatest distance from the tree trunk showed little or no water depletion (data not shown). Therefore, the average soil depth for water uptake decreases as distance increases from the tree with little water uptake outside of the tree canopy. These data also show that roots can extract some water outside the crop canopy corresponding to results described by Hammar et al. (1953), however, roots extending long distances from the tree do not necessarily uptake large amounts of water. Figure 2A and B also show that roots can extract water deeper than the 1.0 m (3.3 ft) soil depth described by Miyamoto (1983).

WATER EXTRACTED BY ANNULAR DISTANCE FROM THE TRUNK. Figure 3A shows the average percentage of water extracted between ring areas during 1994 for both T5 and T6. T5 showed higher depletion values than T6 in rings 1 and 2. The average depth of water extracted in T5 was 6.4, 2.3, and 0.0 cm (2.5, 1.0, and 0 inch) for rings 1, 2, and 3, respectively. The 6.4 cm depth

Fig. 1. Neutron probe access tube grid and annular rings for a pecan tree in T5 and T6. T5 was irrigated at 50 kPa (0.5 bar) and T6 was irrigated using normal farm schedule (1 m = 3.28 ft).

of water extraction corresponds to the calculated 50% depletion value determined from water retention data (6.0 cm (2.4 inch) for the 0 to 180 cm (6 ft) soil depth), which relates to the 50% irrigation rule suggested by Hohn (1988). On a volume basis, ring 1 depleted 1.8 m³ (475 gal) while ring 2 depleted 1.2 m³ (317 gal) (0 to 260 cm (8.5 ft) soil depth). In T5, more water was extracted near the tree than farther away.

In T6 (1994) little of the soil water storage was being used before the next irrigation was scheduled. The average depth of water removed below field capacity was 1.2 cm (0.5 inch) for ring 1 and 0.0 cm for rings 2 and 3, respectively (0 to 260 cm (8.5 ft) soil depth). The average depth of water applied at each irrigation was 16.2 cm (6.4 inch) implying that excessive drainage was probably occurring in T6 in all areas around the tree.

Both terraces show more water extraction closer to the tree and decreasing with distance from the tree. The depth of water removed at each ring was less than the depth of irrigation water applied. Therefore, drainage was probably occurring in both terraces. Depth of irrigation should be corrected to resemble the depth of water removed to help reduce deep drainage and nitrate leaching. Soil salinity levels reached 5.0 dS·m⁻¹ (salinity data not shown) in T5 during the 1994 growing season exceeding the 3.0 dS·m⁻¹ described by Miyamoto (1986). However, orchard owners typically apply a winter irrigation either before or just after harvest to fill the soil profile for winter. This management technique lowered the electrical conductivity (EC) of the soil to 1.0 dS·m⁻¹ in T5. T6 had an EC value of ≈1.0 dS·m⁻¹ throughout both irrigation seasons. Therefore, scheduling irrigations properly to match the quantity of water extracted may increase salinity levels during the irrigation season, but a winter irrigation could alleviate possible salinity complications.

Fig. 2. Average soil depth for water extraction at three annular distances from the pecan tree (ring 1, 0 to 3 m; ring 2, 3 to 5 m; and ring 3, 5 to 6.6 m) for T5 and T6 during 1994 (A) and 1995 (B). Bars represent the $\pm$ SE about the mean. T5 was irrigated at 50 kPa (0.5 bar) and T6 was irrigated using normal farm schedule (1 m = 3.28 ft, 2.54 cm = 1 inch).

Figure 3B shows the average percentage of water extracted for T5 and T6 before an irrigation event for rings 1, 2, and 3 during 1995. T5 showed higher depletion percentages than T6. In T5, the depth of water removed below field capacity for rings 1, 2 and 3 was 7.0, 4.6, and 2.0 cm (2.6, 1.8 and 0.8 inch), respectively. Rings 2 and 3 showed more water was extracted between irrigations in 1995 than in 1994 (T5). The average volume of water extracted in T5 was 2.0, 2.3, and 1.1 m³ (528, 608, and 291 gal) in rings 1, 2, and 3, respectively. Rings 1 and 2 show about the same amount of water removed. Longer intervals between irrigation in T5 allowed a larger volume of water to be extracted at greater distances from the tree. However, with constant irrigation depths of 13 cm/irrigation (5.1 inch), about half of the water applied

went to deep percolation in ring 1 and with increased percentages in rings 2 and 3.

With either irrigation schedule (weekly on T6 versus 50 kPa on T5) water extracted outside the crop canopy [5.0 m (16 ft) radius] was minimal. The largest quantity of soil water extracted was underneath the crop canopy and not outside the dripline. Roots may extend beyond the crop canopy and uptake water but the total water removed is minimal when compared with the total amount of water extracted closer to the tree. Therefore, in this orchard in these soils when determining water use and calculating crop coefficients for orchards growing on these soils, one should use the area of the crop canopy and not the total irrigated area. Use of the total irrigated area assumes that roots are depleting water from the total area when in

reality most of the water is being removed beneath the tree.

PERCENT MOISTURE DEPLETION BY SOIL DEPTH. Figure 4A shows the average percentage of moisture depletion before an irrigation for each ring by soil depth in T5 in 1994. In ring 1, the percentage of moisture depletion was $\approx 75\%$ at the 80 cm (31 inch) soil depth. At soil depths >80 cm, water depletion decreased to $<5\%$ with water storage occurring at the 260 cm (8.5 ft) soil depth. Ring 2 shows about the same depletion pattern as ring 1 between 0 to 170 cm (5.5 ft) soil depth, but at about half the depletion values of ring 1. Water storage was shown below the 170 cm soil depth with a slight amount of depletion at the 200 cm (6.5 ft) soil depth. Ring 3 shows little depletion at the 0 to 140 cm (4.5 ft) soil depths. Soil water storage dominated below the 170 cm soil depth except at the 260 cm soil depth where there was $\approx 5\%$ moisture depletion.

The greatest percentage of water depletion was between 50 and 110 cm (1.5 to 2.6 ft) soil depth. Below 140 cm for all rings, the water content was at or above field capacity. This implies an effective water uptake zone of ≈ 140 to 150 cm (4.5 to 5.0 ft). The depth of water removed in the 0 to 140 cm soil depth for rings 1, 2, and 3 was 6.5, 2.6, and 0.13 cm (2.6, 1.0, and 0.05 inch), respectively. The volume of water depleted in each ring (1, 2, and 3) was 1.8, 1.3, and 0.07 m^3 (475, 343, and 18 gal), respectively. These volumes of water removed were similar to the soil profile data presented earlier for the 0 to 260 cm soil depth. This implies that the effective root zone was at a soil depth of ≈ 0 to 150 cm (5.0 ft) underneath the tree canopy (rings 1 and 2).

In T6, 1994, ring 1 shows water depletion occurred at the 0 to 140 cm depth with water storage at lower soil depths (Fig. 4B). The percentage of water depletion was greater at the 20 and 50 cm (8 and 20 inch) soil depths compared to the 80 to 140 cm soil depths. Ring 2 shows water depletion between 20 to 50 cm soil depth with water storage below this depth. Ring 3 shows some water depletion at the 20 cm soil depth, but water storage throughout the rest of the soil profile.

In ring 1 of T6, water was extracted to the 140 cm soil depth. The total depth of water extracted in the 0 to 140 cm soil depth was 2.07, 0.33 and 0.0 cm (0.81, 0.13, and 0.0 inch)

for rings 1, 2, and 3, respectively. This indicates that more water was extracted closer to the tree trunk. Below 140 cm in all ring areas, soil water storage dominated. This implies that the water content at these soil depths is greater than the water content at field capacity and that percolation below 260 cm was probably occurring. T6 was irrigated often enough that water depletion below field capacity did not occur at these soil depths, making it difficult to quantify the depth of water attributed to ET or drainage.

The average percent depletion for T5 (1994, Fig. 4A), in the top 140 cm (0 to 140 cm soil depth) was 50%, 21%, and 1% in rings 1, 2, and 3, respectively. The average depletion for T6

(1994, Fig. 4B) at these same ring areas but only at the top 80 cm (0 to 80 cm) was 11%, 9%, and 0%, respectively.

Figure 5A shows the percentage of water depletion by soil depth for T5 in 1995. Rings 1, 2, and 3 show that water was extracted throughout the entire root zone with $<5\%$ water depletion at 260 cm soil depth. The deple-

Fig. 3. Average percent moisture extracted before an irrigation event at three annular distances from a pecan tree (ring 1, 0 to 3 m; ring 2, 3 to 5 m; and ring 3, 5 to 6.5 m) for T5 and T6, (A) 1994 and (B) 1995. Bars represent the $\pm$ SE about the mean. T5 was irrigated at 50 kPa (0.5 bar) and T6 was irrigated using normal farm schedule (1 m = 3.28 ft).

Fig. 4. Average percent moisture depletion for ring areas versus soil depth for T5 (A) and T6 (B) during 1994. Bars represent the $\pm$ SE about the mean. T5 was irrigated at 50 kPa (0.5 bar) and T6 was irrigated using normal farm schedule (2.54 cm = 1 inch).

tion pattern for T5 at the 0 to 140 cm soil depth was similar to 1994 (Fig. 4A). Below 140 cm soil depth, there was generally <25% water depletion.

The 1995 water depletion data show the water uptake zone in T5 had expanded deeper and farther from the tree than shown in 1994. The percentage of water depletion shown in ring 3 peaks at 140 cm at $\approx$ 25% depletion. In

1995, irrigation scheduling began at the first of the irrigation season (March) allowing root growth for the entire growing season where in 1994 about a third of the irrigation season had passed before irrigation scheduling began (June). A late start for irrigation scheduling in 1994 may explain why there is less root expansion when compared with 1995.

In 1995, if the water uptake patterns are the same for all trees as shown in Fig. 5A then it is possible for roots from the adjacent within row tree to expand and extract water from the region between these trees (ring 3 at 140 cm soil depth). The combination of two trees extracting water from the same

volume of soil would result in greater water depletion values than from one tree alone. Hence, water depletion between within row trees (ring 3) and at the 140 cm soil depth could be from two trees. At the 0 to 140 cm soil depth, the average water depletion in T5 was 54%, 21%, and 13% for rings 1, 2, and 3, respectively. Below 140 cm the average percentage of water depletion for all three rings was just over 10%. The average depth of water extracted for T5 from the total soil profile (0 to 260 cm) for rings 1, 2, and 3 was 7.0, 4.6, and 2.0 cm (2.8, 1.8, and 0.8 inch), respectively. If we use the 140 cm soil profile, the average depth of water extracted was 6.1, 3.9, and 1.5 cm (2.4, 1.5, 0.6 inch) for rings 1, 2, and 3, respectively. These data show that most of the water was being extracted beneath the tree canopy (rings 1 and 2) and decreased as distance increased away from the tree (ring 3). Therefore, using a 140 to 150 cm effective root zone can be valid when scheduling irrigations in this orchard.

In Fig. 5B, ring 1 shows the distinct pattern of decreased water depletion as soil depth increased. Ring 2 had the same water depletion pattern as ring 1 but with $\approx$ 10% less depletion at each sampling depth to 140 cm. Water storage dominated from 170 to 260 cm. Ring 3 had depletion at the 20 cm soil depth then decreased to almost zero depletion at 80 cm. The average water depletion in the top 140 cm for rings 1, 2, and 3 was 24%, 12%, and 6%, respectively. Below 140 cm, water storage generally occurred and not water depletion.

Worley et al. (1974) and White and Edwards (1980) showed that most of the pecan roots were in the 0 to 90 cm (3 ft) soil depth. Miyamoto (1983) showed that water depletion was minimal below 100 cm (3.3 ft) for trees growing in fine textured soils. Both these studies were conducted on soils with high water tables. Pecan trees grown in coarse soil with deep water tables have deeper water extraction patterns.

In both terraces (T5 and T6) most of the water removed from the soil was from the area beneath the canopy. Water extraction outside the 5.0 m (16 ft) tree canopy radius between tree rows was minimal. Soil moisture extraction can occur at depths below 140 cm, however, the quantity of water removed at soil depths below 140 cm was minor (<15% of the total) when

Fig. 5. Average percent moisture depletion for ring areas versus soil depth for T5 (A) and T6 (B) during 1995. Bars represent the $\pm$ SE about the mean. T5 was irrigated at 50 kPa (0.5 bar) and T6 was irrigated using normal farm schedule (2.54 cm = 1 inch).

compared to the quantity of water removed at the 0 to 140 cm soil depth. The greatest soil water extraction occurred at the 80 cm soil depth underneath the tree canopy (rings 1 and 2).

Pecan trees transplanted to non-traditional type soils, i.e., coarse soils with deep water tables, have a different water extraction pattern when compared with literature values reported on traditional sites with fine soils and high water tables. The results of this study show that pecan trees grown on coarse gravelly soils, with a deep water table (>30 m; 100 ft), and irrigated at 50 kPa (0.5 bar) have an effective water uptake zone of $\approx$ 140 to 150 cm and a lateral distance equal to the

canopy radius. This is 40 to 50 cm (15 to 20 inch) deeper if compared with trees grown on traditional sites with shallow water tables (Miyamoto, 1983). Deeper water extraction patterns will allow a longer time period between irrigation events and could result in less drainage and nitrogen leaching provided irrigation depth reflects soil water depletion depth.

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