WEED INTERFERENCE AND ALTERNATIVE
WEED CONTROL METHODS FOR
YOUNG PECAN TREES

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PREFACE

Years of observing poor growth in young pecans surrounded by weeds led Dr. Michael Smith to suspect an allelopathic effect of weeds upon young pecan trees. The projects detailed in this thesis aim to demonstrate the importance of weed control in achieving optimal growth in a young pecan orchard. I am very grateful to have had the opportunity be a graduate student under the direction of Dr. Smith.

I am also grateful for the financial assistance I received from various organizations throughout my second college career.

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CHAPTER I

INTRODUCTION

A newly established pecan orchard or improved grove must be managed carefully to achieve optimal growth and yields. One important cultural component is weed control.

The importance of weed control in young orchards is well documented (Bould and Jarrett, 1962; Fales and Wakefield, 1981; Foshee et al., 1995; Patterson et al., 1990; Smith, 1989; Smith et al., 1959; Todhunter and Beineke, 1979). The detrimental effect of weeds may be due to competition for nutrients (Bould and Jarrett, 1962; Goff et al., 1991; Khatamian, 1984; Smith et al., 1959; Worley and Carter, 1972), or moisture (Baker, 1941; Patterson et al., 1990; Ware and Johnson, 1958), or allelopathy.

Previous studies suggest that weeds may be allelopathic to orchard crops (Rink and Sambeek, 1984; Fales and Wakefield, 1981; Menges, 1987; Friedman and Horowitz, 1970; Meissner, 1989). Molisch (Rice, 1984) used the term "allelopathy" in 1937 to describe the biochemical interactions between all types of plants including microorganisms. Allelopathy depends on the addition of a chemical compound to the environment. In contrast, competition involves the removal or reduction of some environmental factor by a neighboring plant. "Interference" is a term used to encompass both competitive and allelopathic effects (Muller, 1969). Because there are no known techniques to separate allelopathic effects during a competition study, Rice (1984) suggests that all competition studies be called "interference" studies.

Although it is impossible to separate allelopathic effects during a competition experiment, it is possible to create a situation to detect some allelopathic effects. Experiments using weed leachates are examples of avoiding competition while measuring allelopathic effects of one plant upon another (Walters and Gilmore, 1976; Todhunter and Beineke, 1979; Rink and Sambeek, 1984; Fales and Wakefield, 1980; Friedman and Horowitz, 1970; Meissner, 1989).

There are no reports of allelopathic effects of weeds upon pecan. Field observations in Oklahoma suggest allelopathic effects of bermudagrass and pigweed. Both are invasive, opportunistic species that are foreign to the pecan native habitat. For pecan growers establishing new orchards or adding to their existing orchards, the knowledge that these weeds are actually allelopathic to pecan may prompt modified cultural practices.

Use of herbicides to maintain weed-free areas around the tree has been found to increase growth of trees (Norton and Storey, 1970; Pool et al., 1990; Merwin and Ray, 1997). Oklahoma pecan growers are recommended to maintain a vegetation-free strip within tree rows while allowing turf to grow between rows (Carroll et al., 1994). The methods of eliminating turf and weeds within tree rows may vary from physical cultivation (disking or hoeing) to herbicide applications to mulching. Herbicides are currently recommended (McCraw, 1994) due to the ease of application and effectiveness. For mature trees, the danger of herbicide damage to pecan trees is fairly low. In an orchard with very young trees, however, the danger is much greater. Alternative weed control during the early years of an orchard may optimize the growth of young pecan trees. Increasing regulation of pesticides is another concern that creates a need for alternative weed control.

The benefit of mulch in soil moisture conservation has been noted in many studies (Gartner, 1978; Himelick and Watson, 1990; Mage, 1982; Merwin et al., 1994; Parfitt et al., 1980; Teasdale and Mohler, 1993; Watson, 1988). Greater growth in mulched plants compared to unmulched plants has been documented (Foshee et al., 1996; Green and Watson, 1989; Lord and Vlach, 1973; Mage, 1982; Parfitt et al., 1980; Pool et al., 1990). Drawbacks to the use of mulch include competition for nitrogen (Allison, 1965), pest harboring (Merwin et al., 1994), potential allelopathic leachate (Still et al., 1976), and expense.

For Oklahoma pecan growers, two types of easily available mulch are grass hay and wood chips. Grass hay may be cut from adjacent pastures and moved to the orchard. Wood chips are often available free from local power companies or contractors clearing under power lines.

Few studies have been conducted examining the relationship between tree growth and the density of surrounding weeds (Merwin and Ray, 1997; Welker and Glenn, 1989), but results of studies involving agronomic crops indicate that increasing weed density decreases yield (Klingaman and Oliver, 1994; Knezevic et al., 1994; Schrefler et al., 1994). Early season weeds may affect tree growth more than late season weeds (Merwin and Ray, 1997; Patterson et al., 1990).

The need for weed control in young orchards is evident. Competition by weeds for nutrients and moisture inhibit establishment and growth of young trees. Weeds potentially leach allelopathic compounds that inhibit growth of young trees. Alternatives to the current herbicide practices may be environmentally and economically attractive to pecan growers.

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CHAPTER II

INTERFERENCE OF BERMUDAGRASS AND PIGWEED ON PECAN TREE GROWTH AND NUTRITION

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Additional index words: Carya illinoinensis, Cynodon dactylon, Amaranthus sp., weed, allelopathy, leachate.

Abstract: Weed leachate and media-incorporated weed tissue occasionally reduced pecan (Carya illinoinensis [Wangenheim] K. Koch) tree height, leaf area, or root weight in three experiments. Leachate of bermudagrass (Cynodon dactylon (L.) Pers.) and pigweed (Amaranthus sp.) were applied to one-year-old pecan trees during the time that they broke dormancy and grew for 3 months. Leachate significantly reduced tree height compared to the control. Leaf areas were 18% and 21% less in bermudagrass and pigweed leachate treatments, respectively, than in controls. Leaf elemental concentrations were similar between treatments, indicating that nutrition was probably not responsible for these growth differences. In the second experiment, leachate from live bermudagrass or a control (no plants) was applied to pecan seeds growing in either peat/bark/perlite mix or calcined clay. Interactions of media and leachate were identified only in leaf N concentration. Peat/bark/perlite mix resulted in greater leaf area, trunk diameter, and dry mass of leaf, trunk and root than the calcined clay. Bermudagrass leachate reduced root dry mass compared to the control. Results of leaf nutrient analysis indicated that overall, trees grown in peat/bark/perlite mix had greater nutrient concentrations than trees grown in calcined clay. Interaction between media type and leachate indicated lower leaf N concentrations in trees grown in calcined clay and treated with bermudagrass leachate compared to the other treatments. All nutrient concentrations were sufficient for normal growth except for Zn, which was low in all treatments. The third experiment compared live weeds or dried weed tissues incorporated at two rates (3% w/w or 6% w/w) into the pecan pots plus a control. Dried pigweed reduced pecan root dry mass compared to dried bermudagrass. Weed tissue at 6% w/w decreased tree height compared to 3% w/w. Leaf elemental concentrations of N, P and Zn were higher in trees with the dried weed treatments than the live weed treatments. Calcium was higher in trees with live weed treatments than in the dried weed treatments. Manganese was higher in trees with the live pigweed treatment than in the live bermudagrass treatment. Trees in the dried pigweed treatments had more N, P, K and Zn than trees in the dried bermudagrass treatments. Mg was lower in trees in the controls than in other treatments while Fe was higher in trees in controls than in the other treatments.

Introduction

Pecan trees growing in their native habitat experience different conditions than those in many new orchards. Moist alluvial soil, humid air, partial shade, and native species neighbors provide a typical environment that has led to the survival of pecan.

Pecan orchards are often started on sites quite unlike the native pecan habitat. At these sites, other species may be in their optimal environment while the pecan is not. In such a case, the pecan is at a disadvantage.

Molisch used the term "allelopathy" in 1937 to describe the biochemical interactions between all types of plants including microorganisms (Rice, 1984). Allelopathy depends on the addition of a chemical compound to the environment. In contrast, competition involves the removal or reduction of some environmental factor by a neighboring plant.

"Interference" is a term used to encompass both competitive and allelopathic effects (Muller, 1969). Because there are no known techniques to separate allelopathic effects during a competition study, Rice (1984) suggests that all competition studies be called "interference" studies.

Although it is impossible to separate allelopathic effects during a competition experiment, it is possible to create a situation to detect some allelopathic effects. Experiments using weed leachates are examples of avoiding competition while measuring allelopathic effects of one plant upon another.

One such study by Walters and Gilmore (1976) employed a stairstep apparatus using gravity flow to supply tall fescue (Festuca arundinacea Shreb. Var. Ky 31) leachate to sweetgum (Liquidambar styraciflua L.) trees. They compared the effects of live fescue root leachate to dead fescue root leachate and dead fescue leaf leachate. Sweetgum growth inhibition was more severe when leachate from dead fescue leaf or root tissue leachate was applied than it was when leachate from living fescue plants was applied. Sweetgum trees receiving live fescue root leachate had significantly lower leaf dry mass and total plant dry mass than the controls, while the trees receiving dead tissue leachate also had a significantly lower root dry mass, stem dry mass, and height than the controls. Live fescue leachate increased leaf K, Mg, and Ca, and decreased P of treated tree leaf tissue compared to the controls, but did not affect leaf N concentration. Dead fescue leachate resulted in trees with significantly less leaf P than controls, but other elements tested were not affected.

Todhunter and Beineke (1979) conducted another study showing interference of fescue. Black walnut (Juglans nigra L.) trees were planted into a field with fescue cover. Fescue was found to significantly reduce height, sweep (the greatest distance from the stem to an imaginary line running perpendicular from the ground to the tip of the tree), diameter at breast height, and volume of black walnut tree trees.

Rink and Sambeek (1984) used previously collected fescue leachate to irrigate black walnut trees. Irrigation treatments included a high and low moisture level. Under high moisture conditions, fescue-treated trees were 10% shorter than controls with 14% less dry mass than controls. Under low moisture, fescue-treated trees were 17 to 33% shorter with 36 to 48% less dry mass than controls. They concluded that fescue leachate was phytotoxic to walnut trees.

Fales and Wakefield (1981) found that three turfgrasses (perennial ryegrass (Lolium perenne L.), red fescue (Festuca rubra L.), and Kentucky bluegrass (Poa pratensis L.) produce water-soluble leachates that inhibit top growth of forsythia (Forsythia intermedia Spaethe.). Root growth of forsythia was inhibited by leachates of ryegrass and red fescue, but not Kentucky bluegrass.

Many studies have indicated allelopathic effects of pigweeds (Amaranthus spp.). Munger et al. (1984) prepared extracts of redroot pigweed (Amaranthus retroflexus L.) which were toxic to both cotton (Gossypium hirsutum) and sorghum (Sorghum bicolor L. Moench.). Menges (1987) showed that media-incorporated Palmer amaranth (Amaranthus palmeri S. Wats.) tissue severely inhibited the growth of roots and shoots of grain sorghum, cabbage (Brassica oleracea, var. capitata L.), carrot (Daucus carota L.), and onion (Allium cepa L.) The inhibition of grain sorghum root growth decreased from 54% to 16% when 16000 mg $\cdot L^{-1}$ of Palmer amaranth in soil was held for five and ten days at 28 C, respectively (Menges, 1987).

Bermudagrass has also been shown to have allelopathic properties. Friedman and Horowitz (1970) mixed dried and ground root tissues of bermudagrass into clay soil (60% clay) or sandy soil (one part clay soil plus three parts sand). After incubating these mixes for four months, leachate from the pots inhibited radicle elongation in barley (Hordeum distichum L. cv. Esperanza), mustard (Brassica juncea (L.) Czerniak.), and wheat (Triticum sativum). During incubation, the phytotoxic substances may have been produced either as a direct product of decomposition or by microorganisms developing on the plant residues. In a similar study, the duration of tissue incubation in soil and the soil type (clay or sand) affected barley growth (Friedman and Horowitz, 1970). Radicle lengths were reduced significantly in the clay soil after two months, but after four months, there was no significant difference.

In sandy soil, radicle length was reduced more at the end of four months than at the end of two months. These results indicate that the physical properties of the soil interact with the allelopathic effects of weed tissues incorporated into soil.

Meissner (1989) tested nine crops in soil previously infested with bermudagrass. Compared to plants grown in similar uninfested soil, treated plants were shorter and had less shoot dry mass.

There is no documentation of allelopathic effects of weeds on pecan. Field observations in Oklahoma of stunted pecan tree growth suggest allelopathic effects of bermudagrass and pigweed. Both bermudagrass and pigweed are invasive, opportunistic species that are foreign to the pecan native habitat. For pecan growers establishing new orchards or adding to their existing orchards, the knowledge that these weeds are actually allelopathic to pecan may prompt modified cultural practices. The objectives of these three experiments were to isolate and detect the effects of bermudagrass and pigweed leachates on selected growth characteristics of young pecan trees.

Materials and Methods

Allelopathy of bermudagrass and pigweed leachate on young pecan trees.

Pigweed and bermudagrass were transplanted into 15 cm diameter x 23 cm deep pots containing calcined clay (Turface, AIM Corp., Buffalo Grove, IL) amended with dolomite (2 kg $\cdot m^{-3}$). Once these weeds were well established, each pot (with or without weeds) was placed on an elevated bench in a funnel connected to a hose. The hose directed leachate from the weed or control (no weed) pot into a pot holding a pecan tree.

One-year-old dormant pecan trees were transplanted into 10 L pots. The media was shaken from the tree roots before transplanting. The new pot contained a calcined clay media (Turface) that was amended with dolomite at a rate of 2 kg •m^{-3}. Pecan trees were watered thoroughly for 3 successive days with tap water to saturate the media. Thereafter, pecan trees were irrigated with leachate from the respective treatment pots. After pecan tree leaves unfolded, a slow-release fertilizer (Osmocote 14N-6.02P-11.7K, The Scotts. Co., Marysville, OH) was applied at 20 g/pot. The same fertilizer was also applied to the weed and control pots at 10 g/pot. Soluble trace element mix (0.6 g •L^{-1}, S.T.E.M., Peters Plant Products, Marysville, OH) was applied to the weed or control pot and allowed to drain into the pecan pot.

Throughout the 4-month period, the greenhouse temperature averaged 33 °C daily and 18 °C nightly. Day length was extended to a 12-hr day using incandescent lights.

Treatments were leachates from growing bermudagrass and pigweed plants, and a control. Each was replicated ten times and arranged in a completely randomized design.

After four months growth, leaves were removed and leaf area was measured using a Li-Cor model 3100 area meter. Final trunk diameters and heights of all tree trees were recorded. Leaves, roots, and tree tops were dried at about 70°C several weeks, then their weights were recorded. Leaves were then ground to pass a 20-mesh (850-μm) screen and stored in airtight containers until analysis. Leaf elemental concentrations of N were determined using the macro-Kjeldahl method (Horowitz, 1980). Phosphorous was determined colorimetrically (Olsen and Sommers, 1982).

Potassium, Ca, Mg, Zn, Fe, and Mn were analyzed using atomic absorption spectroscopy (Model #2380, Perkin-Elmer, Norwalk, Conn.). Data were analyzed using single degree of freedom orthogonal contrasts.

Allelopathy of bermudagrass leachate on pecan seeds.

'Giles' seed were stratified at 3-4 ° C for five months. On Nov.18, 1996, the seeds were germinated in 29-32 °C aerated water. On Nov. 22, 1996, three germinated seeds were planted in each 15 x 15 x 45 cm (10 L) pot then covered with 5 cm media.

Media used in this experiment was calcined clay for the control and bermudagrass pots. For the pecan tree pots, two types of media were used; calcined clay and peat-bark-perlite mix (Terramix, Grace, Cambridge, Mass.). Each combination of weed and media type was replicated seven times and arranged in a completely randomized design.

Benches were arranged as in Experiment #*1 (Allelopathy of bermudagrass and pigweed leachate on young pecan trees*) with three subsamples per pot. Seeds were irrigated daily through weed or control pots, allowing the leachates and water to flow into the pecan pot. Daylength was extended to a 12-hour day using incandescent lights. Average temperatures in the greenhouse were 29°C daily and 19°C nightly.

Shoots began to emerge Dec. 9, 1996. By Jan. 5, 1997, 73 shoots had emerged. On Jan. 21, Osmocote 14N-6.02P-11.7K was applied at rates identical to those in Experiment #1. Soluble trace element mix was also applied at a rate of 1 L/pot to weed or control pots at 0.6g $\cdot L^{-1}$. S.T.E.M. was reapplied Feb. 17, at 2 L/pot at the same concentration. On Feb. 27, Osmocote was reapplied at the same rate as before.

On Mar. 20, the experiment was terminated. Data gathered included leaf area, trunk diameter, tree height, and dry mass of leaves, roots, and trunks. Leaf elemental concentrations of N were determined using macro-Kjeldahl method (Horowitz, 1980). Phosphorous was determined colorimetrically (Olsen and Sommers, 1982). Potassium, Ca, Mg, Zn, Fe, and Mn were analyzed using atomic absorption spectroscopy (Model #2380, Perkin-Elmer, Norwalk, Conn.).

Data were analyzed using ANOVA, testing for main effects of media and treatments and interaction of media and treatment.

Interference of young pecan tree growth by live or dried and media-incorporated bermudagrass and pigweed .

One-year-old pecan trees that had their chilling requirement satisfied were transplanted into treatment pots at the beginning of Feb 1997. Pecan-pots were deep tree pots, 15 x 15 x 45 cm (10 L). Media used was calcined clay (Turface, AIM Corp., Buffalo Grove, IL) amended with dolomite (2 kg $\bullet m^{-3}$).

Seven treatments were applied to the pecan pots. Four of the treatments were dried weed root tissue (two species) mixed into the calcined clay at two rates. These weed roots had been harvested the previous fall, washed then dried at 70°C, ground to pass a 10 mesh (850-µm) screen, then stored at -10°C until used. The treatments were as follows: 1) one living bermudagrass sprig, 2) one living pigweed seedling, 3) dried bermudagrass tissue incorporated into media at 3% w/w, 4) or at 6% w/w, 5) dried pigweed root tissue at 3% w/w, 6) or at 6% w/w, and 7) a control (no weed or weed tissue). Each treatment was replicated ten times in a randomized complete block design. Blocking was based on tree size.

After planting, the trees were watered thoroughly so that the calcined clay would become water-soaked. After tree leaves unfolded, each pot was fertilized every 30 days with Osmocote 14N-6.02P-11.7K at 20 g/pot. S.T.E.M. was applied 0.66g $\cdot L^{-1}$ at 45 day intervals.

At the end of the study, parameters of tree growth measured included leaf area, trunk diameter, height, new shoot growth, dried leaf mass, dried top mass, and dried root mass. Leaf elemental concentration of N was determined using the macro-Kjeldahl method (Horowitz, 1980). Phosphorous was determined colorimetrically (Olsen and Sommers, 1982). Potassium, Ca, Mg, Zn, Fe, and Mn were analyzed using atomic absorption spectroscopy (Model #2380, Perkin-Elmer, Norwalk, Conn.). Data were analyzed using single degree of freedom contrasts.

Results

Allelopathy of bermudagrass and pigweed leachate on young pecan trees.

Pecan trees receiving bermudagrass and pigweed leachate were 10% shorter and had 19% less leaf area than the controls (Table 2.1). Trunk diameter was not affected by weed leachate. There were no significant differences in tree height, trunk diameter, or leaf area between trees receiving bermudagrass or pigweed leachate.

Leaf N and Zn concentrations in trees receiving bermudagrass leachate were significantly higher than concentrations in trees receiving pigweed leachate (Table 2.2). Neither weed treatment had significantly different leaf N or Zn concentrations than the control. Mean zinc concentrations in all trees were below recommended concentrations (Smith, 1991). Trees receiving bermudagrass and pigweed leachate had significantly less P and Mn in their leaf tissue than the control trees. All other elemental concentrations tested were not affected by treatment, and were within the sufficiency range for optimal growth (Smith, 1991).

Allelopathy of bermudagrass leachate on pecan seeds.

A significant interaction was found between media and leachate for N concentrations only; therefore main effects are reported for all other responses measured. Tree trees grown in the peat-bark-perlite mix had more than twice the leaf area as those grown in the calcined clay media (Table 2.3). Leaf dry mass per tree was more than double for trees growing in the mix compared to those in the calcined clay. Top dry mass per tree, root dry mass per tree, and trunk diameter were all significantly greater for trees grown in the peat-bark-perlite mix compared to those in the calcined clay.

Weed leachate treatment significantly reduced root dry mass (Table 2.4). Average root weight of trees receiving bermudagrass leachate was 23% less than control trees. Pecan trees receiving bermudagrass leachate also had 23% less leaf area than the controls, although this difference was not statistically significant at the 5% level (significant at 10%). Trunk diameter, leaf dry mass and trunk dry mass were not affected by leachate treatment.

The type of media (Table 2.5) affected nutrition of the pecan trees. Statistical analysis for N showed an interaction between media and weed leachate. Concentrations of P, Mg, Zn, and Mn were higher in leaf tissue of trees grown in the peat-bark-perlite mix than in trees grown in calcined clay. The mean concentration of Zn in the trees grown in the calcined clay media was in the deficiency range (Smith, 1991). Calcium was greater in leaf tissue of trees growing in the calcined clay. There was no significant difference in the concentrations of K between the types of media. Zinc concentrations were lower when trees were grown in calcined clay than in the mix. Leaf Zn concentrations were within the suggested concentrations when trees were grown in the mix, but were below the sufficiency range in the calcined clay (Smith, 1991). Leachate treatment did not significantly affect nutrient uptake in the pecan trees, except for N, which interacted with media type and leachate (Table 2.6). Leaf N concentration in leachate and control treatments were similar when the trees were grown in peat/bark/perlite mix. When grown in calcined clay, trees receiving leachate had significantly lower N leaf concentrations than the trees in the control treatment.

Interference of young pecan tree growth by live or dried and media-incorporated bermudagrass and pigweed .

There were no significant differences in any of the growth parameters measured between the control and the average of the other treatments (Table 2.7). The orthogonal contrast interaction between weed species and rate of incorporation showed no significant differences for any growth parameters measured. None of the orthogonal comparisons showed any differences in leaf area, leaf dry mass, or trunk dry mass between treatments. Trees were shorter when 6% organic matter as either pigweed roots or bermudagrass was incorporated into the media compared to 3% organic matter. Either live pigweed or bermudagrass inhibited tree growth less than incorporating 3% or 6% dried and ground pigweed or bermudagrass. Root growth, as indicated by dry mass was inhibited by 18% when pigweed was incorporated into the medium compared to bermudagrass. Other treatments did not affect pecan root growth.

Orthogonal contrasts indicated that trees in the control had less leaf Mn and more leaf Fe than the average of all other treatments (Table 2.7). There was no significant difference in any other elemental concentration between the control and the average of all other treatments. Trees receiving any type of pigweed leachate (dead or live) had more leaf N, P, and K than trees receiving bermudagrass leachate. Conversely, leaf Zn concentration was higher in trees receiving bermudagrass leachate than those receiving pigweed leachate. Leaf Ca, Mg, Fe, and Mn were not affected by type of weed. Comparison of live pigweed leachate to live bermudagrass leachate showed no difference in leaf elemental concentrations except for Mn, which was higher in the pigweed leachate treatments. There was no significant difference in leaf elemental concentrations between incorporating 3% w/w or 6% w/w organic matter. Trees receiving leachate from live weeds had lower leaf N, P, and Zn, but higher leaf Ca than dried and ground weeds. Other elemental concentrations were not different between live and dried treatments. No significant difference in elemental concentrations were found when comparing the average of 3%w/w bermudagrass and 6% w/w pigweed to the average of 6% w/w bermudagrass and 3% w/w pigweed.

Discussion

These three experiments were designed to detect what influence dried and media-incorporated weed tissue and live weed leachate would have on the growth of young pecan trees. The first two experiments separated the weed plants from the pecan plants, eliminating competitive effects while allowing leachate-carried allelopathic compounds to contact the pecan roots. In contrast, the third experiment introduced live weeds and dried weed tissues to compare effects that these weed components may have on the growth and nutritional uptake of pecan.

Leaf area and tree height were significantly reduced by weed leachate in the first experiment. Similarly, Rink and Van Sambeek (1985) found that fescue leachate decreased leaf area of black walnut trees. Their leachate-treated trees had less dry mass than controls, especially when grown in low moisture conditions. These results suggest the presence of a growth or leaf expansion inhibitor in the leachate.

In the second experiment, root dry mass was the growth parameter most affected by leachate. Because this experiment used pecan seed rather than trees, the effect of leachate upon the pecan root may have been more detectable than in experiments using pecan trees, since the leachate was or was not present during initial root system development. Nutrition was clearly superior in the peat/bark/perlite mix. Leachate did not appear to affect nutrition significantly except for N, which interacted with the growth medium. Leaf N concentration was lower in leachate-treated trees when those trees were growing in calcined clay. However, all leaf N concentrations were within optimal range, indicating that N was probably not responsible for the difference in growth. An important result of this study is that allelopathic effects may be detected when using either peat/bark/perlite or calcined clay as the growth medium.

In the third experiment, pigweed tissue was found to be more detrimental to root growth than bermudagrass tissue. However, live pigweed showed no difference from live bermudagrass. Media with more dried weed tissue resulted in shorter pecan trees. These results suggest that the degradation of dead weed tissue may be more detrimental to pecan growth than the competition of a live weed. These results are similar to those of Friedman and Horowitz (1971) in that leachate from incubated soils that contained incorporated dried and ground bermudagrass tissue inhibited radicle elongation in barley, mustard, and wheat. In clay soils, inhibition of radicle elongation was greatest after the incorporated tissue incubated for two months. In sandy soils (one part clay soil plus three parts sand), inhibition of radicle elongation was greatest after the incorporated tissue had incubated for four months. They concluded that the faster degradation in the clay soil could be accounted for by the larger population of microorganisms or the higher content of mineral and organic colloids which might have caused adsorption, and hence inactivation, of a greater fraction of the produced toxins. Similarly, in the experiment involving interference of young pecan tree growth by live or dried and media-incorporated bermudagrass and pigweed, there was significantly less height with 6% w/w incorporation compared to 3% w/w. If you consider that the 6% w/w correlates to a clay soil, and the 3% w/w correlates to a sandy soil, then this increased tissue incorporation (6% vs. 3%) may correlate to increased soil "heaviness" (clay fraction) in the Friedman and Horowitz's study. A clay (heavier) soil is generally more moisture retentive. If a soil is moister, the allelopathic compounds may have greater contact with the plant roots for a longer duration. Also, the degradation of the dead tissues may occur more quickly with greater moisture. It may also be possible that the increased percentage of incorporated weed tissue may decrease media porosity, although considering the coarseness of the calcined clay, this is probably not a factor. In fact, the contrast between live weed treatments and dried weed tissue treatments shows that final height was more adversely affected by the dried weed treatments than by live weed treatments. Menges (1987) also found that media-incorporated weed tissue inhibited crop-plant growth. Pigweed tissue was more inhibitory than other weeds in his study. Many studies of possible allelopathy involve agronomic crops. Media-incorporated Palmer amaranth inhibited roots and shoots of grain sorghum (Menges 1987). Incorporation of dried bermudagrass tissue into growth media was examined by Friedman and Horowitz (1971). Leachate from these incubated mixes inhibited radicle elongation of barley when compared to control. Meissner (1989) found that crops grown in soil that had previously been infested with bermudagrass were shorter and had less shoot dry mass. It is probable that the bermudagrass residues in the soil were affecting the crop.

The mechanism by which these residues inhibit other plant growth is not understood. Nevertheless, results of these experiments and previous studies suggest there are some water-soluble allelopathic compounds that are detrimental to pecan tree growth.

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Table 2.1. Effects of weed leachate on pecan tree growth.

Treatment	Tree height (cm)	Trunk diameter (mm)	Leaf area (cm^2)	Leaf dry mass (g)	Root dry mass (g)
Control	40	6.7	1227	7.5	23.1
Bermudagrass	36	7.1	1009	6.0	27.0
Pigweed	36	7.2	967	6.0	26.1
Contrasts					
Control v. other	*	NS	*	*	NS
Bermudagrass v. pigweed	NS	NS	NS	NS	NS

*,NS Significantly different at 5% level and no significant difference, respectively

Table 2.2. Effects of leachate on pecan tree leaf elemental concentrations.

	Dry mass (%)					Dry mass (μg/g)		
Treatment	N	P	K	Ca	Mg	Fe	Zn	Mn
Control	3.51	0.27	0.74	0.84	0.45	47	46	331
Bermudagrass	3.95	0.23	0.76	0.86	0.46	50	49	283
Pigweed	3.49	0.25	0.86	0.87	0.46	47	40	234
Contrasts								
Control v. other	NS	*	NS	NS	NS	NS	NS	*
Bermudagrass v. Pigweed	*	NS	NS	NS	NS	NS	*	NS

*, NS Significantly different at 5% level and no significant difference, respectively

Table 2.3. Effects of media and leachate on growth of pecan tree.

Treatment	Total leaf area (cm^2)	Trunk dia. (mm)	Dry mass (mg) Leaf	Trunk	Root
		Media			
Peat/bark/perlite mix	461	11.2	2292	526	6387
Calcined clay	217	9.5	965	324	4268
Pr ≥ F	0.001	0.048	0.001	0.007	0.001
		Weed sp.			
Bermudagrass	287	9.9	1464	407	4629
None	391	10.8	1793	443	6026
Pr ≥ F	0.093	0.303	0.181	0.603	0.002

Table 2.4. Effects of leachate and media on pecan tree leaf elemental concentrations.

	Dry mass (%)					Dry mass (ppm)		
Treatment	N	P	K	Ca	Mg	Zn	Fe	Mn
				Media				
Peat/bark/perlite mix	3.68	0.31	0.95	1.00	0.43	65	66	1359
Calcined clay	3.18	0.26	0.86	1.36	0.32	17	85	734
Pr > F	0.001	0.080	0.173	0.001	0.001	0.001	0.012	0.001
				Weed sp.				
Bermudagrass	3.34	0.29	0.89	1.13	0.39	41	78	1004
None	3.54	0.28	0.93	1.23	0.36	42	73	1088
Pr > F	0.001	0.784	0.537	0.221	0.321	0.957	0.479	0.502

Table 2.5. Interaction of media and treatment on pecan tree leaf N concentration.

Treatment	Media type	N (% dry mass)
Control	Peat/bark/perlite mix	3.71
	Calcined clay	3.34
Bermudagrass	Peat/bark/perlite mix	3.64
	Calcined clay	3.03
$LSD_{0.05}$		0.14

Table 2.6. Effects of live weeds or media-incorporated weed tissue on pecan tree growth.

Treatment	Total leaf area (cm^2)	Tree height (cm)	Dry mass (g) Leaf	Trunk	Root
Control	1004	28.4	6.9	3.2	25.2
Live pigweed	986	32.8	6.9	3.1	22.9
Live bermudagrass	915	30.1	6.4	2.9	22.7
Bermudagrass root, 3% w/w	1084	30.0	14.4	3.4	27.5
Bermudagrass root, 6% w/w	1046	27.0	7.4	3.1	25.8
Pigweed root, 3% w/w	1310	30.9	8.7	3.3	22.3
Pigweed root, 6% w/w	944	26.2	6.4	2.5	20.9
Contrasts			Pr>F		
Control vs. Other	0.742	0.528	0.624	0.737	0.568
Pigweed root vs. Bermudagrass root	0.615	0.976	0.226	0.222	0.045
Live pigweed vs. Live bermudagrass	0.683	0.250	0.894	0.609	0.948
3% w/w vs. 6% w/w	0.102	0.025	0.096	0.112	0.523
Live vs. dead	0.172	0.051	0.295	0.785	0.544
(P vs. B)(3% vs. 6%)	0.183	0.613	0.394	0.529	0.960

Table 2.7. Effects of live weeds or media-incorporated weed tissue on pecan tree leaf elemental concentrations.

	Dry mass (%)					Dry mass (ppm)		
Treatment	N	P	K	Ca	Mg	Zn	Fe	Mn
Control	3.00	0.178	0.98	1.03	0.42	22	93	634
Live pigweed	2.65	0.176	0.88	1.00	0.47	17	79	713
Live bermudagrass	2.83	0.170	0.96	1.03	0.48	19	75	417
Bermudagrass, 3% w/w	3.16	0.197	0.76	0.96	0.51	27	79	515
Bermudagrass, 6% w/w	3.09	0.179	0.83	0.94	0.49	27	74	533
Pigweed, 3% w/w	3.35	0.221	1.12	0.92	0.55	21	80	434
Pigweed, 6% w/w	3.41	0.237	1.07	0.84	0.50	23	76	484
Contrasts	Pr > F							
Control v. other	0.500	0.256	0.657	0.166	0.033	0.963	0.012	0.144
Pigweed v. bermudagrass	0.020	0.009	0.002	0.183	0.407	0.016	0.775	0.380
Live pigweed v. live bermudagrass	0.243	0.779	0.509	0.767	0.817	0.501	0.562	0.006
3% w/w v. 6% w/w	0.955	0.947	0.926	0.368	0.329	0.599	0.498	0.650
Live v. dried	0.001	0.009	0.766	0.032	0.208	0.001	0.926	0.256
(P v. B)(3% v. 6%)	0.540	0.264	0.540	0.604	0.635	0.599	0.929	0.835

CHAPTER III

VARYING TYPE AND SIZE AREA OF ORGANIC MULCH: EFFECTS UPON THE GROWTH AND NUTRITION OF PECAN TREE AND SOIL MOISTURE IN IRRIGATED OR NON-IRRIGATED ORCHARD FLOOR.

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Additional index words: Carya illinoinensis, competition, irrigation, leaf elemental concentration, non-bearing, soil matric potential, tensiometer, weed control.

Abstract: Tree height, trunk diameter, and leaf elemental concentrations were measured in young pecan (Carya illinoinensis [Wangenh.] K. Koch) trees grown under a factorial treatment combination of irrigation, mulch type, and mulch areas. Three- to four-year-old pecan were mulched with two types of organic mulch (wood chip and grass) in varying size areas (1 sq. m., 4 sq. m., and 9 sq. m.) or maintained weed free with herbicides or given no weed control with irrigation or no irrigation during 1996 and 1997. Soil moisture was monitored in two replications of each treatment. Weedy controls showed more soil moisture fluctuations than weed-free controls in both years. Mulch with perimeter weed control retained more soil moisture than weedy controls. Irrigation increased tree height both years and increased tree trunk diameter one year compared to no irrigation. Grass mulch decreased trunk diameter during the first year compared to wood chip mulch, but no other effect on growth was noted due to mulch type. During 1997, significant linear and quadratic trends in mulch area indicated that 4 sq. m. mulch area was similar to 9 sq. m. and better than 1 sq. m. for pecan tree growth. Leaf elemental concentration analysis in 1996 showed three-way interactions among irrigation, mulch type and mulch area size treatments for N, Ca, Zn, Fe, and Mn. In 1997, no interactions among treatments were noted for leaf elemental concentrations. Irrigation increased leaf N and Zn but decreased leaf Ca compared to no irrigation. Grass mulch increased leaf K compared to wood chip mulch. Most nutrients were similarly sufficient (N, P, Ca, Mg, and Mn) or insufficient (Zn and K) across all treatments both years. The differences in growth are more likely due to treatment rather than nutrition differences.

Introduction

Sod groundcover in orchards is advantageous in many respects. Groundcover reduces erosion, stabilizes soil structure, ameliorates vehicle travel, and relieves summer temperature compared to cultivated soil. However, vegetative groundcover surrounding trees has been shown to be detrimental to tree growth and yield (Bould and Jarrett, 1962; Fales and Wakefield, 1981; Foshee et al., 1995; Patterson et al., 1990; Smith, 1989; Smith et al., 1959; Todhunter and Beineke, 1979). This detrimental effect of surrounding vegetation may be due to competition for nutrients (Bould and Jarrett, 1962; Goff et al., 1991; Khatamian, 1984; Smith Et al., 1959; Worley and Carter, 1972), competition for moisture (Baker, 1941; Patterson et al., 1990; Ware and Johnson, 1958), or allelopathy.

Previous studies suggest that certain weeds may be allelopathic to orchard crops (Rink and Van Sambeek, 1985; Fales and Wakefield, 1981; Menges, 1987; Friedman and Horowitz, 1970; Meissner et al., 1989). Use of herbicides in orchards to maintain a weed-free area around the tree increases tree growth (Norton and Storey, 1970; Pool et al., 1990; Merwin and Ray, 1997). Current recommendations are to maintain a vegetation-free strip within tree rows while allowing turf to grow between rows (Carroll et al., 1994). The methods of eliminating turf and weeds within tree rows vary from physical cultivation (disking or hoeing) to herbicide applications, to mulch. Herbicides are recommended (McCraw et al., 1994) due to the ease of application and effectiveness. For mature trees, the danger of herbicide damage to pecan trees is low. In an orchard with very young trees, however, the risk of tree injury is greater. Alternative weed control during the early years of orchard establishment may eliminate the risk of tree injury while optimizing the growth of young pecan trees.

Mulch conserves soil moisture (Gartner, 1978; Himelick and Watson, 1990; Mage, 1982; Merwin et al., 1994; Parfitt et al., 1980; Teasdale and Mohler, 1993; Watson, 1988). Greater growth in mulched plants compared to non-mulched plants has been documented (Foshee et al., 1996; Green and Watson, 1989; Lord and Vlach, 1973; Mage, 1982; Parfitt et al. 1980; Pool et al., 1990). Drawbacks to the use of mulch include competition for N (Allison, 1965), pest harboring (Merwin et al 1994), potential allelopathic leachate (Still et al 1976), and expense of application.

For Oklahoma pecan growers, two types of easily available mulch are grass hay and wood chips. Grass hay may be cut from adjacent pastures and moved to the orchard. Wood chips are often available free from local power companies or contractors clearing under power lines. The purpose of this study is to examine effects of irrigation on pecan tree growth using two mulches and three mulch area sizes compared to herbicide weed control and to no weed control, and to detect interactions (if any) between irrigation and these treatments.

Materials and Methods

One-year-old container-grown 'Colby' pecan trees were planted at Oklahoma State University Pecan Research Station at Perkins in Fall, 1993 on a 10.7 m x 10.7 m spacing. Soil at the site is a Teller fine-loamy, mixed, thermic Udic Argiustoll. By spring 1996, the trees ranged in height from 30 to 120 cm tall. Treatments were irrigation at two levels, irrigated and not irrigated, in factorial combination with two mulch types (wood chip and grass) applied 15 cm deep in three different size areas (1 sq. m., 4 sq. m., and 9 sq. m.), plus a weed-free control (herbicide-strip 2.5 m wide), and a weedy control (no weed control). The experimental design was a split-plot with irrigation as the main plot and mulch type and mulch size as the subplots. Each treatment combination was replicated seven times with two trees per replication. Preemergent weed control was with norflurazon (4-chloro-5-methylamino-2-(α-α,α-trifluouro-m-toyl) pyridazin-3(2H)-one), at the rate of 2835 $g \bullet ha^{-1}$, applied before budbreak with a tractor-mounted boom. Simazine (6-chloro-N,N'-diethyl-1,3,5-triazine-2,4-diamine) was applied during late May at a rate of 1134 $g \bullet ha^{-1}$ before budbreak with tractor-mounted boom. Post-emergent herbicide was glyphosate (N-(phosponomethyl)glycine) at the rate of 16.4 $g \bullet L^{-1}$, applied to early-season weeds before pecan budbreak with a tractor-mounted boom sprayer, and applied by hand after budbreak, intermittently throughout the growing season. Irrigation was applied to the irrigated subplot with a traveling gun, delivering 5 to 7 cm water per application, whenever tensiometers in weedy control plots reached 40 kPa soil matric potential. Trees received split applications of fertilizer as recommended for Oklahoma orchards (McCraw et al., 1994). Foliar zinc application was 30.5 $kg \bullet L^{-1}$ ZnSO4, applied to run-off. Insecticides were applied as needed.

In July 1996, the first year of treatment application, and July 1997, leaf tissue samples were collected and analyzed to determine foliar elemental concentrations. Leaflets were collected from the middle of compound leaves attached to the middle of current-season's shoots of each tree. In 1996, there were not enough leaflets within each replication for a sufficient analysis quantity, so leaf tissue samples from each treatment within each irrigation treatment were pooled into three samples. Leaflets were rinsed briefly in tap water, then rinsed in 0.1N HCl solution, agitated gently in water containing 2% (v/v) detergent to remove surface contaminants, then rinsed twice in deionized water, for a total washing time not exceeding one minute. Leaflets were dried, ground to pass a 20-mesh (850-μm) screen and stored in airtight containers until analysis. Leaf elemental concentrations of N were determined using the macro-Kjeldahl method (Horowitz, 1980). Phosphorous was determined colorimetrically (Olsen and Sommers, 1982). Potassium, Ca, Mg, Zn, Fe, and Mn were analyzed using atomic absorption spectroscopy (Model #2380, Perkin-Elmer, Norwalk, Conn.).

Wood chip mulch originated from the local electric company as they cleared vegetation under electric lines. Typical trees included in the chips were Eastern redcedar (Juniperus virginiana L.), Bois d'arc (Maclura pomifera (Raf.) C. K. Schneid.), Siberian elm (Ulmus pumila L.), redbud (Cercis canadensis L.), and cottonwood (Populus deltoides Bartr. ex Marsh.). In 1996, grass hay was cut from sites on the research station and immediately applied as the grass mulch. This grass hay included bermudagrass (Cynodon dactylon (L.) Pers.), other grasses, and forbs. Perimeters of all mulch areas (wood chip and grass) were sprayed by hand with glyphosate three times during the 1996 summer. In 1997, grass mulch was re-applied in early spring using bales of hybrid sudan (Sorghum vulgare var. sudanese). Mulch area perimeters were not treated with herbicide in 1997.

Tensiometers were installed 30 cm deep and 30 cm from the trunk of two trees per treatment. Soil tension values were recorded from May to October in 1996 and 1997.

Tree growth data recorded during dormancy each year included survival, height increase, and trunk cross-sectional area increase.

Results

Soil moisture records of non-irrigated treatments only are shown since the irrigation treatment was watered to field capacity when soil tension reached 40 kPa. In both 1996 and 1997, weedy controls showed more soil moisture fluctuations than weed-free controls (Fig. 3.1 and 3.2). In 1996, wood chip mulch retained more moisture than the weedy control, but slightly less than weed-free controls. In 1997, wood chip mulch and weedy controls had similar soil moistures, while weed-free controls had greater soil moisture. Grass mulch retained more moisture than wood chip mulch, but both mulch types' soil tension values were similar during both years (Fig. 3.3 and 3.4). Rainfall during the 1996 and 1997 growing seasons (Figure 3.5) varied month to month but the average of each year over the growing season was similar to the mean.

There were no significant interactions among irrigation, mulch type and mulched area for tree growth in height and diameter. Therefore, main effects of each treatment are presented. Tree growth was increased by irrigation (Table 3.1). In 1996 both trunk diameter and tree height were greater when irrigated, regardless of mulch treatment. In 1997, trunk diameter increase was not affected by irrigation, but height was increased 48% by irrigation. Trunk diameter increase was greater for trees mulched with wood chip than grass in 1996; otherwise, mulch type did not affect other measured growth parameters. Tree growth was greater in weed-free controls than in weedy controls. In 1996, a positive linear relationship between mulch area and trunk diameter increase was observed. The largest mulch area (9 sq. m.) had a larger height increase than the weedy control. In 1997, increasing mulch area was curvilinearly related to tree height and trunk diameter increases. This indicates that a 4 sq. m. mulched area around the tree would provide near maximum growth.

Leaf elemental concentration in 1996 showed three-way interactions among irrigation, mulch type and mulched area for N, Ca, Zn, Fe, and Mn (Table 3.2). Under irrigation, pecan leaf N concentration increased quadratically as wood chip mulch area increased. With no irrigation, leaf N concentration of trees in wood chip mulch treatments responded linearly to increasing mulch area size. Trees in grass mulch under irrigation showed a linear increase in leaf N concentration to increasing mulch area. Without irrigation, pecan leaf N concentration with grass mulch showed an increasing curvilinear response to mulch area. Grass mulch resulted in higher pecan leaf N concentration than the wood chip mulch in both irrigation treatments. In most instances, leaf N concentration was higher in trees without irrigation than in trees with irrigation. Irrigated wood chip mulch treatments had higher leaf N concentration than the irrigated weedy control, as did irrigated grass mulch treatments. Leaf N concentration was lower in trees within irrigated 1 sq. m. and 9 sq. m. areas than trees in irrigated weed-free controls. With no irrigation, trees in 1 sq. m. and 4 sq. m. areas had lower leaf N concentration than trees in the weedy control, while trees in all sizes of the non-irrigated grass mulch had higher leaf N concentration than those in the weedy control or weed-free control.

Leaf P concentration of irrigated and non-irrigated trees in wood chip mulch increased linearly with increasing mulch area (Table 3.2). For trees in grass mulch, there was no significant trend of leaf P concentration with mulch area. Under irrigation, trees with 1 sq. m. wood mulch had lower leaf P concentration than trees in the weed-free control. Leaf P in trees with 9 sq. m. wood chip mulch was higher than the weedy control. With no irrigation, leaf P was higher in trees in weed-free controls than in trees in any area with wood chip mulch and in trees in the smallest grass mulch area. The trees in the two largest grass mulch areas without irrigation had higher leaf P than trees in the weedy control. Non-irrigated wood chip mulch resulted in less pecan leaf P than irrigated wood chip mulch, except in the 4 sq. m. area where pecan leaf P concentration was the same in both irrigation treatments. Leaf P concentration in trees in grass mulch was similar across irrigation treatments. The trees in the largest irrigated wood chip mulch areas had higher leaf P concentration than the trees in the largest irrigated grass mulch areas. There was no difference in leaf P concentration between the two smallest size irrigated wood chip and grass mulch areas. Without irrigation, there was no difference in leaf P between trees with any size of grass mulch compared to trees with equally sized wood chip mulch.

Pecan leaf K concentration trends were not significant in irrigated wood chip mulch and non-irrigated grass mulch treatments (Table 3.2). Pecan leaf K concentration increased linearly with increasing grass mulch area when irrigated. Pecan leaf K in irrigated mulch treatments was similar to both controls, except for trees in the largest grass mulch area, which had higher leaf K than trees in either control. Leaf K concentration in non-irrigated mulched trees was similar to both controls except for the trees with 4 sq. m. grass mulch; these trees had lower leaf K than the trees in the weed-free control. Leaf K was no different for trees in the smallest size irrigated wood chip compared to trees in similar areas of grass mulch, but for the larger size mulch areas, leaf K concentration was higher in trees with grass mulch. When not irrigated, grass mulch resulted in higher leaf K concentration for the trees in 4 sq. m. areas compared to trees in wood chip mulch of the same size. Trees in non-irrigated grass mulch areas had similar leaf K concentration as the similarly-sized non-irrigated wood chip mulch areas. Effects of irrigation on leaf K concentration for trees in wood chip mulch treatment varied by mulch area. Leaf K concentration was higher in irrigated trees than trees not irrigated for the smallest and largest size wood chip mulch areas, but lower in irrigated trees than non-irrigated trees for the 4 sq. m. wood chip mulch. For grass mulch, leaf K concentration was higher in the trees in irrigated 1 sq. m. and 4 sq. m. areas than trees in the same size non-irrigated grass mulch. In contrast, trees in the 9 sq. m. grass mulch areas had higher leaf K concentration when irrigated than when not irrigated.

Leaf Ca concentration showed no significant trend except for a curvilinear response in the irrigated grass mulch (Table 3.2). When irrigated, trees in 9 sq. m. wood chip mulch had higher leaf Ca concentration than trees in the weed-free control, and trees in 4 sq. m. of grass mulch had higher Ca concentration than trees in either weedy or weed-free control. Without irrigation, leaf Ca concentration was similar for trees in mulch treatments as the trees in the controls. Irrigated grass mulch resulted in higher pecan leaf Ca concentration than irrigated wood chip mulch in the two largest mulch areas. Without irrigation, leaf Ca concentration was inconsistent. Trees in the smallest area grass mulch had higher leaf Ca than trees in the smallest area wood chip mulch, but trees in the two largest area of grass mulch had lower leaf Ca than trees in the two largest wood chip mulch areas. Pecan leaf Ca concentration in wood chip mulch treatments was the same or higher than trees in grass mulch treatments with similar irrigation.

Pecan tree leaf Mg concentration decreased linearly with increasing grass mulch area under irrigation (Table 3.2). No other significant trends in leaf Mg concentration were noted for mulch area size. Leaf Mg concentration in trees in irrigated wood chip mulch was higher than for trees in the weed-free control, but no different from trees in the weedy control. Irrigated grass mulch had higher pecan leaf Mg than trees in either control, except for trees in the largest mulch area, which had leaf Mg no different from either control. When irrigated, no difference in leaf Mg concentration was seen between trees in any mulch treatment and trees in either control. Differences among leaf Mg concentrations for trees within similar irrigation treatment but with different type of mulch were inconsistent or insignificant. Trees in both types of mulch responded similarly when comparing the effect of irrigation on leaf Mg concentration. Leaf Mg was higher for trees in the irrigated smallest mulch area than trees in the same area with no irrigation, but for the largest mulch area, results were reversed (leaf Mg was higher in the non-irrigated trees than in the irrigated trees).

Irrigated mulch treatments showed negative linear and quadratic trends of pecan leaf Zn concentration in response to increasing wood chip mulch area and grass mulch area, respectively (Table 3.2). No trends were significant without irrigation. In irrigation, trees in all mulch treatments had lower leaf Zn concentration than the trees in weedy controls, and trees in 9 sq. m. wood chip mulch had lower leaf Zn concentration than trees in both controls. Without irrigation, trees in all mulch treatments had lower leaf Zn than trees in the weed-free control, while trees in all sizes wood chip mulch and the 9 sq. m. grass mulch had lower leaf Zn than trees in both controls. The 4 sq. m. irrigated wood chip mulch resulted in higher pecan leaf Zn than the 4 sq. m. grass mulch, but irrigated 9 sq. m. wood chip mulch resulted in lower pecan leaf Zn than the 9 sq.m. grass mulch area. Without irrigation, trees in the smallest area wood chip and grass mulch treatments had similar leaf Zn concentration , while trees in the two larger area wood chip mulch treatments had lower leaf Zn concentration than similarly-sized grass mulch treatments. Trees in all mulch treatments had higher leaf Zn concentration without irrigation than mulched trees with irrigation.

Pecan leaf Fe concentration increased linearly with wood chip mulch area in both irrigation treatments, but while the irrigated treatment showed a negative linear and curvilinear trend, the non-irrigated treatment showed a positive linear trend (Table 3.2). No leaf Fe concentration trends were detected for trees in grass mulch area. With irrigation, trees in all mulch treatments had higher leaf Fe concentration than trees in the weedy control. Trees in the two irrigated smallest mulch areas and the largest wood chip mulch had higher leaf Fe than trees in the weed-free control. Without irrigation, pecan leaf Fe of trees in all mulch treatments were similar to trees in the controls, except for trees in the 1 sq. m. wood chip mulch, which had higher leaf Fe than trees in the weedy control. Trees in the irrigated wood chip mulch treatments had higher or similar pecan leaf Fe than those in the irrigated grass mulch treatments. Without irrigation, higher leaf Fe occurred in trees in the two smallest grass mulch areas compared to trees in similarly-sized wood chip mulch, but when comparing leaf Fe in trees of different mulch types of 9 sq. m. size, higher leaf Fe was found trees in the wood chip mulch. Leaf Fe concentration was generally higher or the same for trees in the non-irrigated treatments when comparing effects of irrigation on similar mulch types, but trees in the 1 sq. m. wood chip mulch had higher leaf Fe concentration than trees in the 1 sq. m. grass mulch.

Trends in pecan leaf Mn concentration were negatively linear in irrigated wood chip mulch and positively linear in irrigated grass mulch (Table 3.2). Without irrigation, pecan leaf Mn concentration increased curvilinearly with increasing wood chip mulch area , while leaf Mn for trees in grass mulch had no significant trend. Trees in irrigated 4 sq. m. and 9 sq. m. wood chip mulch had higher leaf Mn than trees in the weedy control, while trees in the 1 sq. m had higher leaf Mn than trees in the weed-free control. Trees in the two largest irrigated grass mulch areas had higher leaf Mn than trees in the weed-free control, while trees in the 1 sq. m. grass mulch had lower leaf Mn than trees in the weedy control. Without irrigation, trees in all mulch treatments had lower leaf Mn than trees in the weedy control, and trees in the 4 sq. m. wood chip mulch and the 1 sq. m. grass mulch had higher leaf Mn than trees in the weed-free control. Effects on pecan leaf Mn due to mulch type within similarly sized area and similar irrigation were inconsistent. Effects on pecan leaf Mn concentration of different irrigation treatments on trees within similar mulch types and size areas were also inconsistent.

In 1997, no interactions occurred so main effects are presented (Table 3.3). Irrigation increased pecan leaf N and Zn concentrations but decreased leaf Ca concentration. Trees in grass mulch had higher leaf K concentration than trees in wood chip mulch, while all other elemental concentrations were unaffected by the type of mulch. Both types of mulch increased leaf Ca concentration in pecan leaves, while most other elemental concentrations were no different from weedy or weed-free controls. The trees in 1 sq. m. mulch had higher leaf Mg concentration than the trees in the weed-free control, and trees in the 9 sq. m. mulch had lower leaf Mg concentration than trees in the weedy control. There were no significant trends in mulch area on leaf elemental concentrations.

Discussion

Lack of interaction between irrigation and mulch treatment indicates that mulch did not effectively substitute for irrigation. The benefits of mulch and irrigation are additive; a grower can achieve best growth with both mulch and irrigation. Evidently, the benefits of mulch go beyond soil moisture retention.

In 1996, mulch conserved soil moisture as well as the weed-free area, but in 1997 soil moisture in mulched areas was similar to the weedy control. This may be due to the mulch area perimeter weed control in 1996, while weeds were allowed to grow unchecked at mulch area perimeters during 1997. Roots of weeds growing at the edge of the mulch invaded the area under the mulch, depleting soil moisture. Also, the wood chip mulch was not re-applied in 1997, and some weeds germinated on the mulch surface during this year. Previous studies show that mulch conserves moisture better than bare soil (Appleton et al., 1990; Merwin et al., 1994). Results from this study indicate that a 4 sq. m. or 9 sq. m. area of mulch surrounding a tree conserved moisture as well as the weed-free control, as long as the mulch area perimeter is periodically treated to prevent weed encroachment adjacent to the mulch.

In 1996, both trunk diameter and height were significantly greater in irrigated trees than non-irrigated trees, while only height was significantly greater in irrigated over time when mulch is present (Merwin et al., 1994). While 4 sq. m. may be optimal for young pecan trees, mulch area may need to be extended over a greater area as the trees grow.

In both years, leaf elemental concentration analysis indicated that N, P, Ca, Mg, and Mn were at or above sufficiency ranges for pecan in Oklahoma (Smith, 1991). Only in irrigated weedy control trees of 1996 was Fe found to be insufficient. Leaf Zn concentrations were below the 60 μg/g minimum in trees of all treatments for both years. Leaf K concentration exceeded the 0.75% minimum sufficiency in trees within irrigated 9 sq. m. grass mulch treatments during 1996. Trees in all other treatments in both years had insufficient leaf K.

Leaf elemental concentrations during 1996 showed interactions among irrigation, mulch type and mulch areas, which makes the 1996 data difficult to interpret. Results from 1996 may be less reliable than the data from 1997, because of the pooled leaf samples due to poor growth, especially in the non-irrigated section. In 1996, leaf N in the non-irrigated mulch treatments was higher or no different than the irrigated mulch treatments. Elevated N concentrations in leaves of non-irrigated trees may be due to similar N uptake with less leaf expansion. This would result in more N per unit mass of leaf tissue. Results from 1997 are the opposite; leaf N was higher in irrigated treatments than in the non-irrigated treatments. These two years results of leaf N are inconsistent with each other. I have no explanation for the inconsistency. Goff et al. (1991) found no difference in leaf N of pecan tree due to irrigation treatments.

Previous studies show increased leaf K in trees mulched with straw or hay (Baker 1941, Lord and Vlach 1973). Similarly, leaf K was higher in pecan with grass mulch compared to wood chip mulch in 1997. Results from 1996 also show higher pecan leaf K in grass mulch compared to wood chip mulch particularly using the 4 sq. m. mulch area. Goff et al. (1991) found that pecans with weed control had higher leaf K than pecan trees with weeds present. Data of this study does not support his finding.

Leaf Ca was lower in the irrigated plot than the non-irrigated plot. This may be due to a dilution effect, where the increased growth of irrigated trees distributed the Ca throughout more leaf tissue. Goff et al. (1991) found that leaf Ca concentration was higher in herbicide-treated plots than weedy plots. Similar results are seen in the 1997 data from this study.

In 1997, the only other elemental concentration to be affected by treatment was Zn, and it was higher in the irrigated trees than in the non-irrigated trees. Similarly, Goff et al. (1991) found increased leaf Zn concentration with irrigation compared to no irrigation.

While the increased growth in irrigated trees coincides with higher leaf N of irrigated trees during 1997, it is unlikely that higher leaf N was responsible for the increased growth. Because leaf N was sufficient in all treatments and other leaf elemental concentrations were similar in most treatments, soil moisture and other unmeasured parameters of soil conditions appear to have been responsible for the increased growth. Organic mulch of any type appears to be an excellent method for conserving soil moisture and optimizing growth of young pecan trees.

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Table. 3.1. Effects of irrigation, mulch type, and size of mulch area on the growth of nonbearing pecan trees.

	1996		1997	
	Trunk dia. Increase (mm)	Tree ht. Increase (cm)	Trunk dia. Increase (mm)	Tree ht. Increase (cm)
		Irrigation effect		
Not irrigated	2.9	30	8.1	27
Irrigated	4.2*	46**	8.6	40**
		Mulch type effect		
Wood chip mulch	4.2	41	9.3	35
Grass mulch	2.9*	37	7.4	34
		Mulch area main effect		
Weedy control	1.4	37	2.9	18
Weed-free control	3.3	32	7.5	30
1 sq. m.	2.7	38	5.5	24
4 sq. m.	3.8	37	10.6***	39***
9 sq. m.	4.3	42#	9.1***	39***
Significance	L**	NS	L**,Q**	L***,Q*

*, **, ***, # Main effects of irrigation significantly different at 5% (*) or 1% (**), or mulch size main effect significantly different from the weedy control at 5% (*) or 0.1% (***), or from the clean control at 5% (#).

Table 3.2. Pecan leaf elemental concentrations, 1996.

			Dry mass (%)					Dry mass (ppm)		
Irrigation	Mulch type	Mulch area size (sq. m.)	N	P	K	Ca	Mg	Zn	Fe	Mg
Irrigated	Weedy control	-	2.53#	0.13#	0.57	2.21	0.39	45#	46#	1108#
Irrigated	Weed free	-	2.71*	0.17*	0.55	2.18	0.35	35*	54*	688*
Irrigated	Wood chip	1	2.56*#	0.14#	0.57	2.54*#	0.45*#	38*#	90*#	964*#
Irrigated	Wood chip	4	2.73*#	0.15*#	0.55	2.18	0.41#	35*	62*#	810*#
Irrigated	Wood chip	9	2.65*#	0.16*	0.55	2.63*#	0.40#	25*#	68*#	644*
Significance			Q*	L*	NS	NS	NS	L**	L**,Q*	L**
Irrigated	Grass	1	2.72*#	0.13#	0.57	2.38*#	0.46*#	38*#	69*#	651*
Irrigated	Grass	4	2.86	0.14#	0.63*#	2.76*#	0.44*#	29*#	63*#	932*#
Irrigated	Grass	9	2.91	0.14#	0.77*#	2.24	0.35*	36*	60*#	1159#
Significance			L**	NS	L**	Q*	L**	Q**	NS	L**
Not irrigated	Weedy control	-	2.87	0.12#	0.58#	2.14	0.46	50#	75	1459#
Not irrigated	Weed free	-	2.87	0.17*	0.82*	2.23	0.46	53*	72	497*
Not irrigated	Wood chip	1	2.74*	0.12#	0.60#	1.87*#	0.42*#	43*#	60*#	344*#
Not irrigated	Wood chip	4	2.73*	0.14*#	0.51*#	2.18	0.42*#	40*#	63*#	829*#
Not irrigated	Wood chip	9	2.88*#	0.14*#	0.63*#	2.28*	0.45	40*#	82*#	479*
Significance			L*	L*	NS	NS	NS	NS	L**	Q**
Not irrigated	Grass	1	2.93*#	0.14*#	0.59#	2.09#	0.41*#	45*#	78#	774*#
Not irrigated	Grass	4	3.16*#	0.15*#	0.70*#	1.94*#	0.44	44*#	70*	670*#
Not irrigated	Grass	9	2.93*#	0.15*#	0.66*#	2.05#	0.44	43*#	69*	601*#
Significance			Q**	NS	NS	NS	NS	NS	NS	NS
$\text{LSD}_{0.05}$ for mulch type with same irrig'n trts			0.02	0.01	0.04	0.13	0.02	2	4	57
$\text{LSD}_{0.05}$ for mulch type with different irrig'n trts			0.02	0.01	0.01	0.04	0.01	1	2	21

*,# significantly different at 5% level from weedy control and weed-free control, respectively, within same irrigation treatment

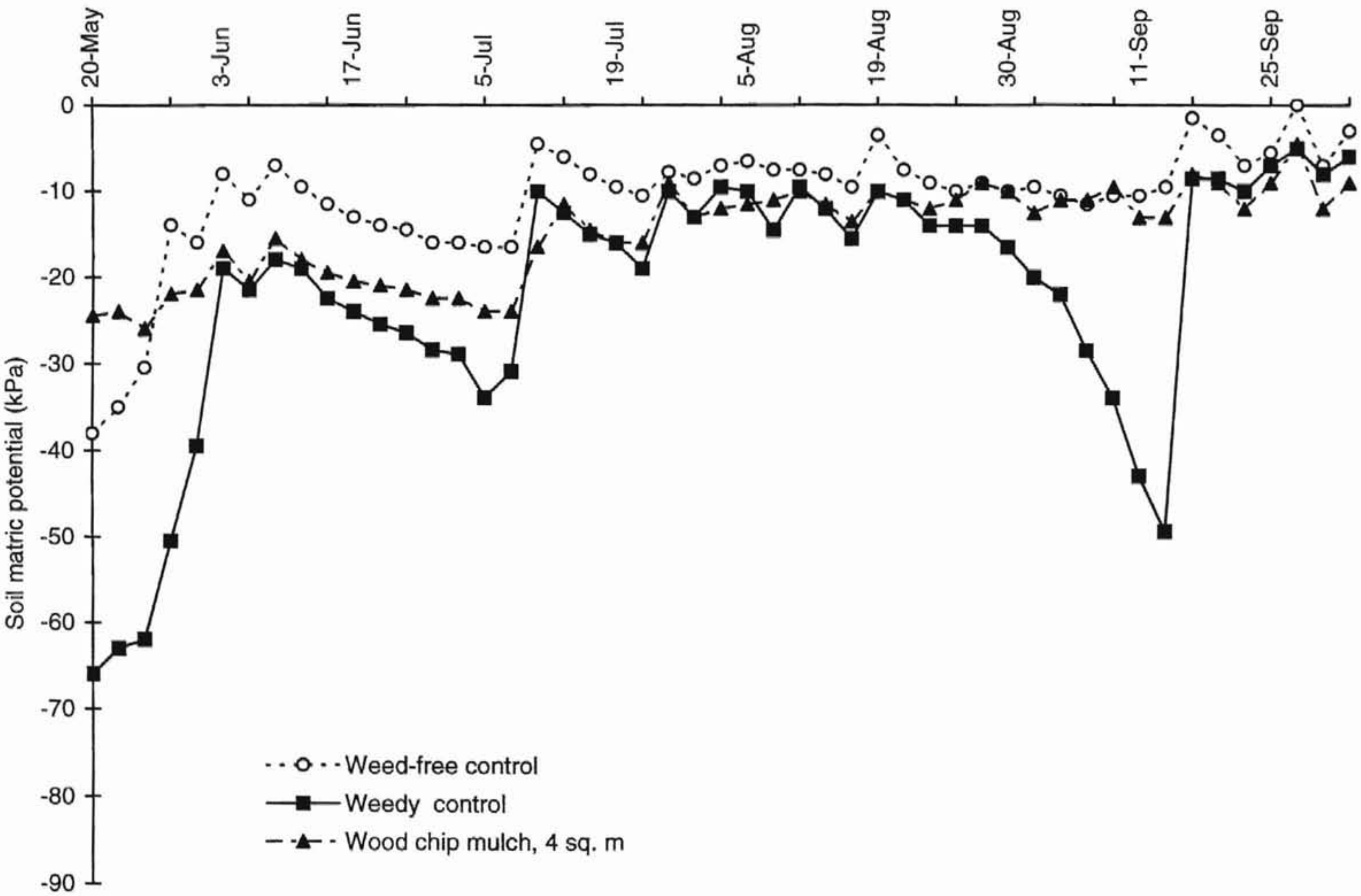
Table 3.3. Pecan leaf elemental concentrations, 1997.

	Dry mass (%)					Dry mass (ppm)		
	N	P	K	Ca	Mg	Zn	Fe	Mn
				Irrigation effect				
Not irrigated	2.52	0.13	0.60	1.45	0.43	32	78	1459
Irrigated	2.75***	0.14	0.60	1.23**	0.44	39*	75	1274
				Mulch type effect				
Wood chip mulch	2.59	0.14	0.53	1.42	0.44	36	76	1272
Grass mulch	2.67	0.13	0.67***	1.27	0.44	35	77	1465
				Mulch area effect				
Weedy control	2.57	0.12	0.64	1.04	0.45	40	74	1489
Weed-free control	2.56	0.12	0.65	1.29	0.43	38	70	1243
1 sq. m.	2.62	0.13	0.57	1.31*	0.46#	37	75	1235
4 sq. m.	2.62	0.13	0.56	1.37*#	0.44	35	80	1482
9 sq. m.	2.65	0.14	0.65	1.36*#	0.42*	34	75	1404
Significance	NS	NS	NS	NS	NS	NS	NS	NS

*,**,***,# Main effects of irrigation significantly different at 5% (*), 1% (**), or 0.1% (***), or treatment main effect different at 0.1% (***), or mulch size significantly different from weedy control at 5% (*) or from the weed-free control at 5% (#).

Figure 3.1. Soil moisture records of non-irrigated weed-free control, weedy control, and 4 sq. m. wood chip mulch, 1996.

1996


20-May
3-Jun
17-Jun
5-Jul
19-Jul
5-Aug
19-Aug
30-Aug
11-Sep
25-Sep
0
-10
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-30
-40
-50
-60
-70
-80
-90
Soil matric potential (kPa)
Weed-free control
Weedy control
Wood chip mulch, 4 sq. m

1997

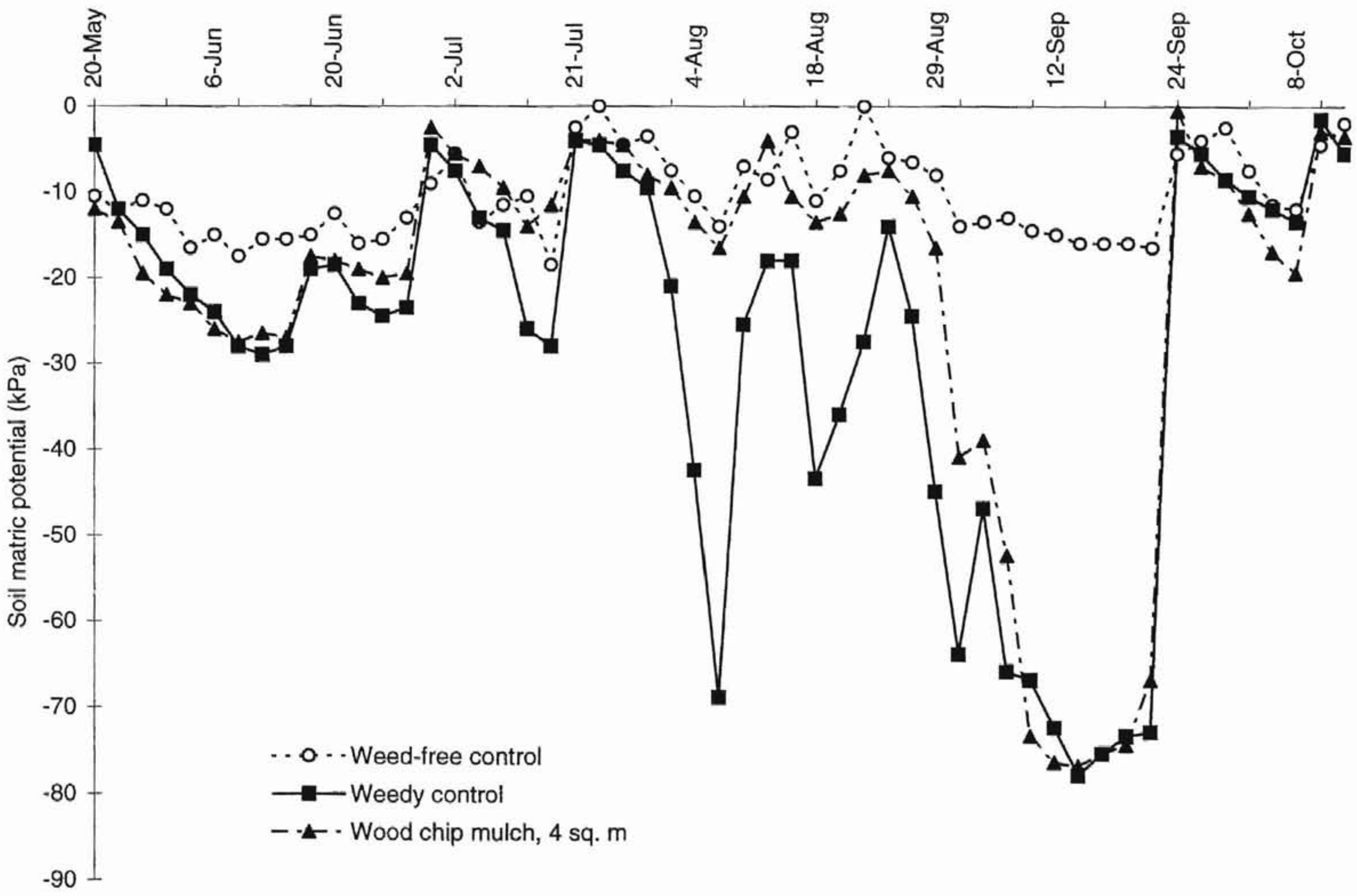

20-May
6-Jun
20-Jun
2-Jul
21-Jul
4-Aug
18-Aug
29-Aug
12-Sep
24-Sep
8-Oct
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Soil matric potential (kPa)
Weed-free control
Weedy control
Wood chip mulch, 4 sq. m

Figure 3.3. Soil moisture records for non-irrigated 4- and 9- sq. m. wood chip and grass mulch treatments, 1996.

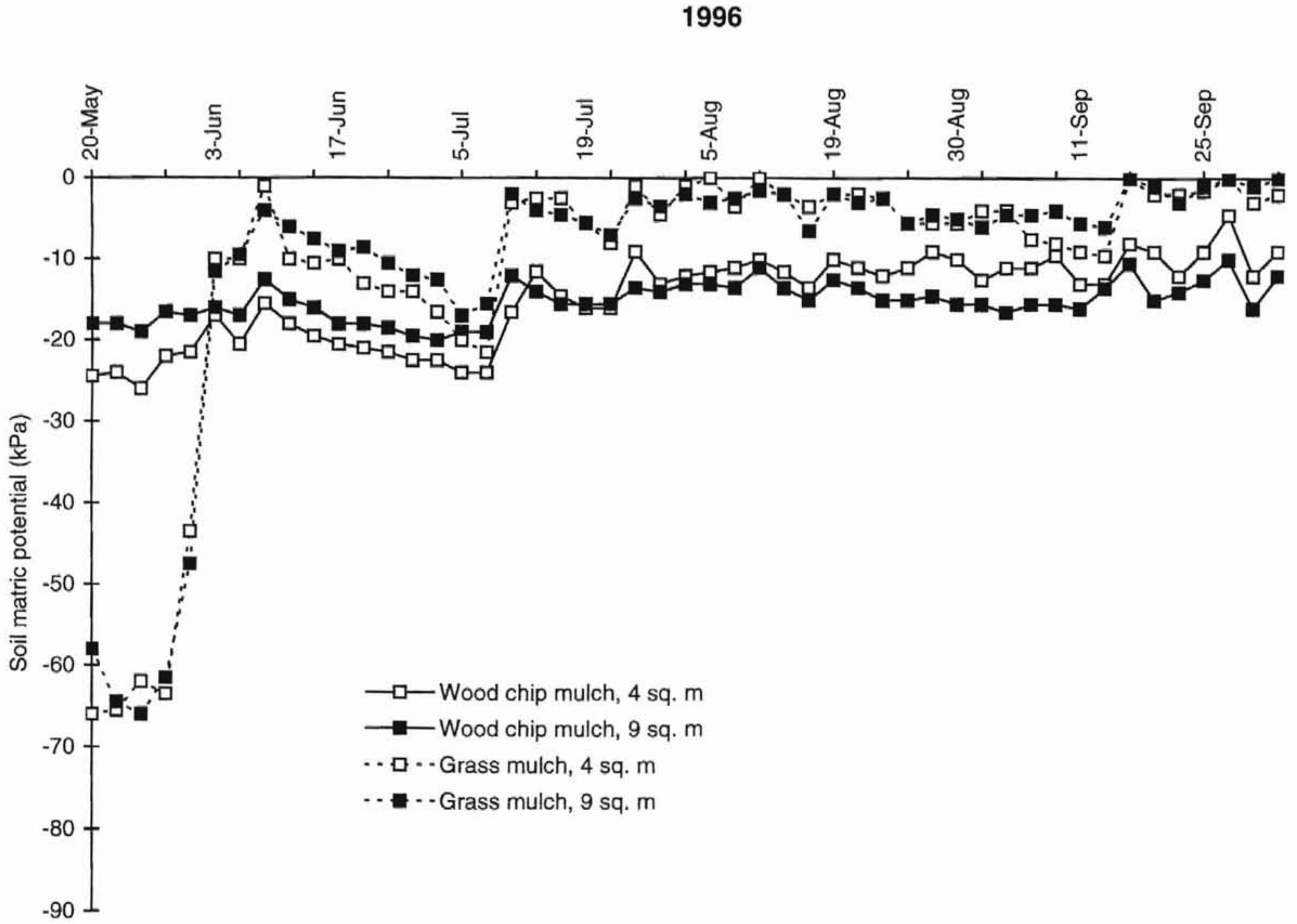
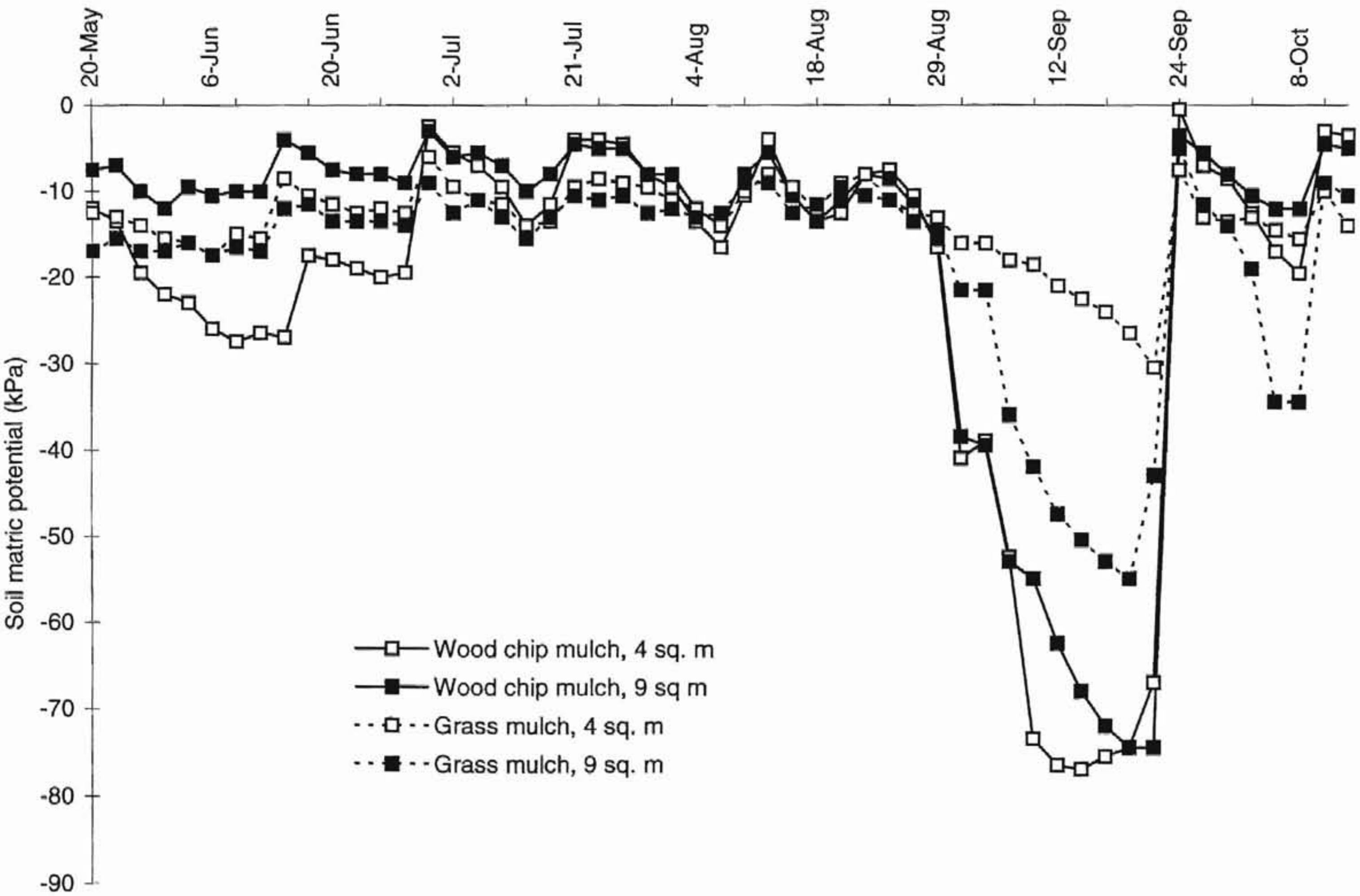

1996
Soil matric potential (kPa)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
20-May
3-Jun
17-Jun
5-Jul
19-Jul
5-Aug
19-Aug
30-Aug
11-Sep
25-Sep
Wood chip mulch, 4 sq. m
Wood chip mulch, 9 sq. m
Grass mulch, 4 sq. m
Grass mulch, 9 sq. m

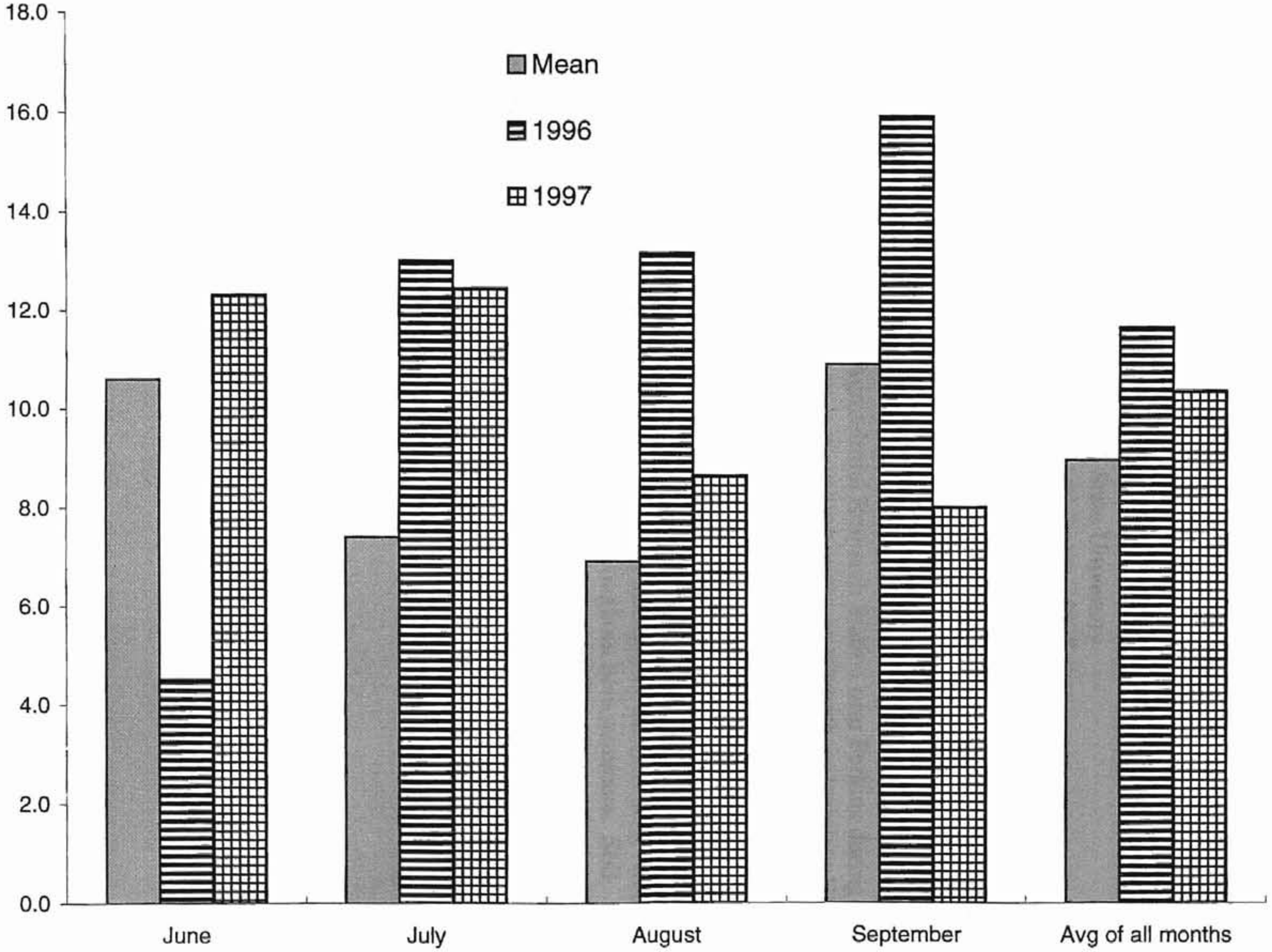
Figure 3.4. Soil moisture records for non-irrigated 4- and 9- sq. m. wood chip and grass mulch treatments, 1997.



1997

Soil matric potential (kPa)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
20-May
6-Jun
20-Jun
2-Jul
21-Jul
4-Aug
18-Aug
29-Aug
12-Sep
24-Sep
8-Oct
Wood chip mulch, 4 sq. m
Wood chip mulch, 9 sq m
Grass mulch, 4 sq. m
Grass mulch, 9 sq. m

Figure 3.5. Rainfall recorded during 1996 and 1997 growing season and long-term monthly averages at Oklahoma State University Pecan Research Station at Perkins, Oklahoma.


18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
▨ Mean
▤ 1996
▦ 1997
June
July
August
September
Avg of all months

CHAPTER IV

EFFECT OF WEED DENSITY AND WEED SEASON ON GROWTH OF NONBEARING PECAN TREES

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Additional index words: Carya illinoinensis, Cynodon dactylon, Amaranthus sp., Oenothera speciosa, weed, competition, tree, transplant, bare-root, trunk diameter, height, allelopathy, leachate.

Abstract: Bareroot 'Apache' pecan (Carya illinoinensis (Wangenh.) K. Koch) trees were planted at the Oklahoma Agricultural Research Station near Perkins during May 1996. Treatments were 1) one cut-leaf evening primrose (Oenothera laciniata Hill) (1CEP), 2) two cut-leaf evening primrose (2CEP), 3) one pigweed (Amaranthus sp.)(1PW), 4) two pigweed (2PW), 5) one cut-leaf evening primrose succeeded by one pigweed (1CEP+1PW), 6) two cut-leaf evening primrose succeeded by two pigweed (2CEP+2PW), and 7) no weed (control). Weeds were planted 30 cm from the tree trunk. Tensiometers were installed 30 cm deep and 30 cm from the tree in two replications of each treatment and were monitored throughout the summers. Controls had greater soil moisture than other treatments throughout both summers. Soil moisture was lowest in 2PW and 2CEP+2PW treatments each summer. Tree height increases in 1996 were greater in pigweed treatments than in cut-leaf evening primrose treatments. In 1997, tree height and trunk diameter increases were greater in CEP treatments than PW treatments. In both years, height increase was greater for weed-free trees than for other treatment trees. In 1997, trees with 1CEP+1PW grew taller than trees with 2CEP+2PW treatments.

Introduction

One of the most important cultural practices in orchards is weed control. Many studies have shown detrimental effects of weed interference on orchard tree growth and yield (Anderson et al. 1992, Bould and Jarrett 1962, Fales and Wakefield 1981, Foshee et al. 1995, Norton and Storey 1970, Patterson et al. 1990, Pool et al. 1990, Smith 1989, Todhunter and Beineke 1979). Early season weeds may affect tree growth more than late season weeds (Merwin and Ray 1997, Patterson et al. 1990). Few studies have been conducted examining the relationship between tree growth and the density of surrounding weeds (Merwin and Ray 1997, Welker and Glenn 1989), but studies involving agronomic crops show that increasing weed density decreases yield (Klingaman and Oliver 1994, Knezevic 1994, Schrefler et al. 1994).

Cut-leaf evening primrose is a cool season annual common in orchards. Seed of cut-leaf evening primrose germinate in autumn and the plant grows as a prostrate rosette form until spring, then it grows more rapidly and flowers. Pigweed, a warm season annual, germinates in late spring at about the same time as cut-leaf evening primrose matures. Additional pigweed seed germinates throughout summer. Together, these weeds present a temporal succession of weed interference commonly found in orchards. Effects of these weeds and their density are examined in this study.

Materials and Methods

In February 1996, seventy 1.5 to 2.0 m tall 'Apache' bareroot trees were planted on 3.1 m x 6.1 m spacing at the Oklahoma Pecan Research Station near Perkins. The soil is a Teller, fine-loamy, mixed, thermic Udic Argiustoll. Each root system was pruned to about 40 cm long and tops were pruned to 80 cm tall. Trees were watered after transplanting. The experiment was a completely randomized design with ten single-tree replications. Treatments included 1) control (weed-free), 2) one cut-leaf evening primrose (CEP), 3) two CEP, 4) one pigweed (PW), 5) two PW, 6) one CEP succeeded by one PW, 7) two CEP succeeded by two PW. In 1996, weeds were planted 30 cm from the tree and 180° from each other in treatments with more than one weed. In 1997, most treatments had volunteer weeds emerging near the tree; these were left according to plan and other weeds were removed physically or hand-sprayed with glyphosate (N-(phosponomethyl)glycine) at the rate of 16.4 $g \bullet L^{-1}$. Controls were maintained weed-free by hand application of glyphosate as needed throughout both growing seasons. Fertilizer was applied in split applications as recommended to Oklahoma pecan growers (McCraw et al, 1994). The trees were not irrigated, except for initial hand watering at time of transplant, and hand watering during the first two months after transplant due to lack of rainfall.

Tensiometers were used to monitor soil moisture in two replications of each treatment from May 1996 to October 1996 and May 1997 to October 1997. Tensiometers were placed 30 cm from the tree trunk and 30 cm deep. Soil moistures were recorded about three times per week. Data gathered for each tree at the end of the seasons included total new shoot growth, trunk diameter, and tree height. Data were analyzed with SAS's GLM procedure and with single-degree-of-freedom contrasts.

Results

Tensiometer averages for 1996 indicate that trees with no weeds experienced highest soil moisture throughout the season. Presence of cut-leaf evening primrose resulted in lowest soil moisture in late May and early July (Fig. 4.1), while pigweed treatments showed lowest moisture during early and late July. Soil moisture of multiple weed treatments resembles those of pigweed alone (Fig. 4.1). Two cut-leaf evening primrose followed by two pigweed resulted in lower moisture than 1CEP+1PW (Fig. 4.2). Except during early and late July, 2CEP soil moistures were very similar to 2PW and 2CEP+2PW treatments (Fig. 4.1). Soil moisture with one or two pigweed was similar (Fig. 4-3). Soil moisture with one cut-leaf evening primrose was similar to soil moisture with two cut-leaf evening primrose (Fig 4.4).

Tensiometer readings of 1CEP and 2CEP during 1997 showed higher soil moisture in these treatments than in the control (Fig. 4.5). Two pigweed treatments had considerably lower soil moisture than 1PW treatments (Fig. 4.6). The 2PW treatment average created most extreme fluctuations in soil moisture, and the 2CEP+2PW had less extreme fluctuations (Fig. 4.7). The 1CEP+1PW treatments had lower soil moistures than the 2CEP+2PW treatments (Fig. 4.8). Rainfall during the 1996 and 1997 growing seasons (Figure 4.9) varied month to month but the average of each year's growing season was similar to the mean.

Tree height increase in both 1996 and 1997 was greater for weed-free trees than for the average of all other treatments (Table 4.1 and Table 4.2). Tree height and new growth was less in trees with cut-leaf evening primrose than treatments with pigweed. Trees with only one weed species had more new growth than trees with a combination of cool and warm season weeds. There was no difference between 1PW and 2PW for height and trunk diameter increases, but trees with 2PW had more new growth than trees with 1PW. There was no difference in growth response for the 1CEP+1PW and 2CEP+2PW treatments (Table 4.1).

In 1997, weed-free trees were taller, had larger increases in trunk diameter, and had more new growth than the average of all other treatments (Table 4.2). Trees with pigweed were shorter and had less trunk diameter increase than trees with cut-leaf evening primrose. Trees with only one pigweed had a 45% greater trunk diameter increase than trees with two pigweed, although this difference was not significant at the 5% level. There was no difference between 1CEP and 2CEP treatments for the parameters measured. Treatments of single weeds (one species only) had more new growth than treatments with multiple weeds (two species). Trees with 1CEP+1PW were taller than trees with 2CEP+2PW.

Discussion

In 1996 and 1997, trees in the weed-free treatments grew taller than trees in the other treatments, indicating that the presence of cool season as well as warm season weeds is detrimental to the growth of pecan. Similarly, Foshee et al (1995) found that there was no difference in trunk cross-sectional increases of young pecan when comparing the effects of winter legumes to summer legumes, or when comparing the effects of grasses to legumes. Fales and Wakefield (1981) found that turf cover (primarily Kentucky bluegrass (Poa pratensis L.) and red fescue (Festuca rubra L.)) inhibited trunk diameter increases and internode growth of dogwood (Cornus florida L.) compared to dogwood growing in turf-free areas. Patterson et al. (1990) found that in three out of four years following transplanting, pecan trees increased in trunk diameter more with total weed control compared to grass-only weed control. Only during the first year after transplant was there no difference between these two treatments. Because the grasses infesting this experiment site were mostly crabgrass (Digitaria sanguinalis L. Scop) and bermudagrass (Cynodon dactylon L. Pers.), the grass-only weed control was mostly a warm-season weed control, and the total weed control is both cool-season and warm-season weed control. Since trunk diameters increased more with the total weed control, it appears that cool season weeds as well as warm-season weeds are detrimental to the growth of pecan. Results of other studies indicate that tree growth is affected differently by cool season versus warm season weeds. Bould and Jarrett (1962) compared effects of three types of cover crop (white clover (Trifolium repens L.), perennial ryegrass (Lolium perenne L.), timothy grass (Phleum pratense L.)) to effects of natural sod (primarily Poa annua L.) and clean cultivation on young apple (Malus sp.) trees. Their results showed that trunk diameter growth was greater where the natural sod and white clover were grown, compared to timothy and ryegrass. Worley and Carter (1973) found no difference in mature pecan tree terminal shoot growth over ten years in treatments of mowed sod compared to clean cultivation plus winter legume.

Height increases of woody species are typically dependent upon the energy reserve stored within the tree tissues. This energy, plus sufficient moisture at the beginning of the season, contributes to the first flush of growth. Thus the amount of new growth in 1996 was greatly determined by the trees' energy stores. Although the trees were watered several times after transplanting, lack of rainfall early in the season could have hindered optimal establishment of these trees. Data from 1996 may not reflect the full effect of weed presence, since the trees had just been transplanted.

Previous studies have similar inconsistencies with first-year data (Patterson et al. 1990, Foshee et al. 1995, Miller 1983, Norton and Storey 1970). Decomposition of weed root tissues may affect the tree growth during years subsequent to planting. Friedman and Horowitz (1970) found that bermudagrass tissue incubated in soil two to four months will inhibit radicle elongation in barley (Hordeum vulgare L.), mustard (Brassica juncea (L.) Czerniak.), and wheat (Triticum aestivum L.). Menges (1987) found similar inhibition of sorghum (Sorghum bicolor L. Moench.) and cabbage (Brassica oleracea var.capitata L.) in response to soil-incorporated tissues of Palmer amaranth (Amaranthus palmeri S. Wats).

Tensiometer records in 1997 indicate that pigweed competed more strongly for water than cut-leaf evening primrose, leading to less growth in height and trunk diameter for pigweed treatments compared to CEP treatments.

Trunk diameter increase was smaller for 2 PW than for 1PW, but height and new growth were not different for these two treatments This may be explained by the timing of pigweed growth in contrast to pecan growth. Pigweed presented competition stress during the latter part of the season, after pecan had made the initial growth flush in spring.

In the 1997 CEP+PW treatments, increased weed density inhibited all growth parameters, but only height was significantly decreased. The contrast between a single weed and multiple weeds showed that only new growth was significantly inhibited by multiple weed treatments, yet when the multiple weeds increased in density, new growth showed no significant difference. I have no explanation for these apparently conflicting results. It is very clear, nevertheless, that the presence of two or fewer weeds is detrimental to the growth of young pecan trees.

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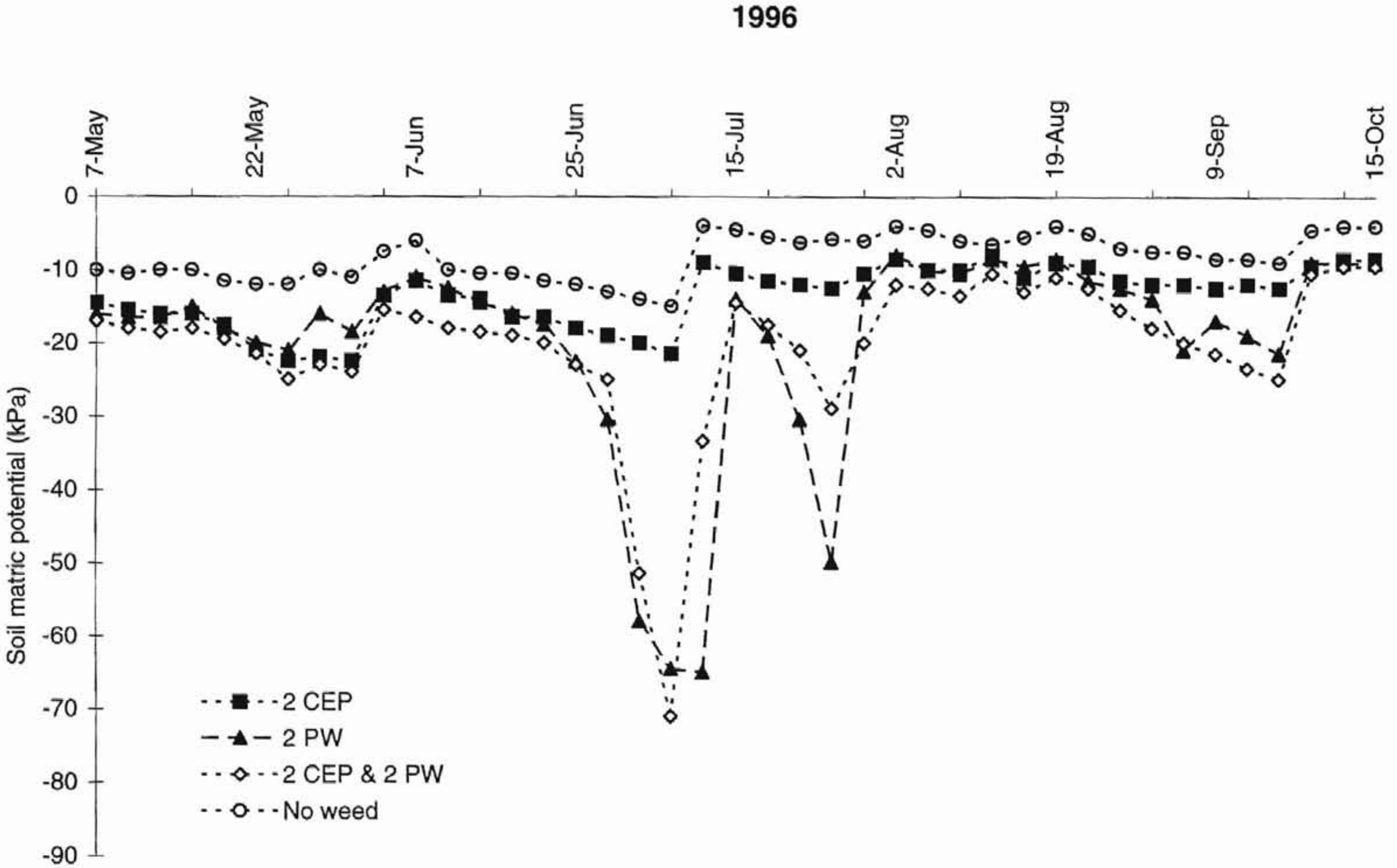
Table 4.1. Effects of weed species and density on the growth of nonbearing pecan, 1996.

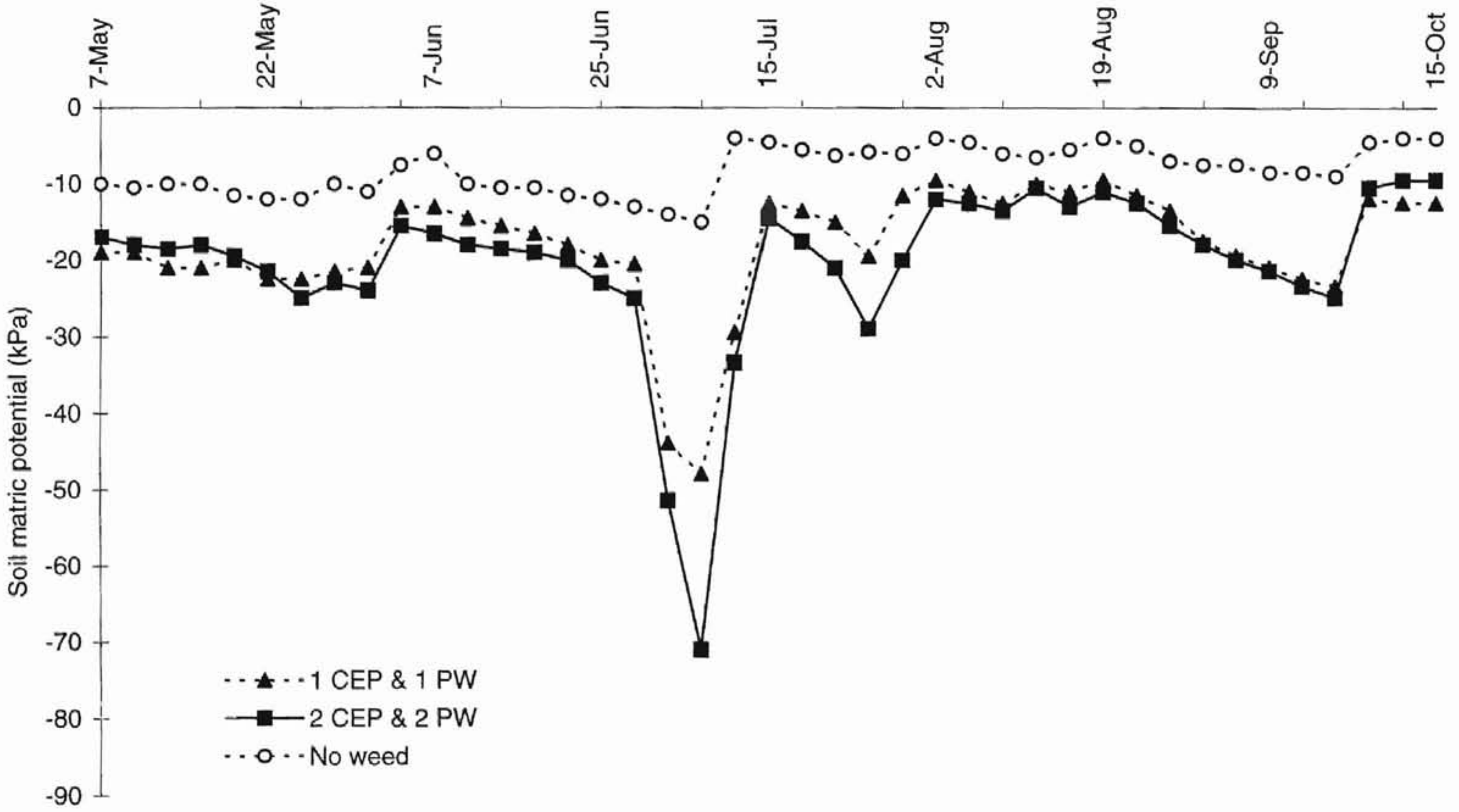
Treatment	Ht. increase (cm)	Trunk dia. increase (mm)	New stem growth (cm)
Weed-free	22.3	3.2	79.0
1 Cut-leaf evening primrose	9.9	1.6	53.5
2 Cut-leaf evening primrose	8.3	3.6	49.5
1 Pigweed	16.6	2.6	65.7
2 Pigweed	24.7	1.6	97.3
1 Cut-leaf evening primrose + 1 pigweed	12.1	1.6	48.0
2 Cut-leaf evening primrose + 2 pigweed	6.3	1.5	40.4
Contrasts P>F			
Weed-free v. other	0.025	0.283	0.101
PW v. CEP	0.003	0.582	0.009
1 PW v. 2 PW	0.136	0.450	0.048
1 CEP v. 2CEP	0.764	0.145	0.799
Single weed v. multiple weeds	0.084	0.337	0.023
(1CEP+1PW) v. (2CEP+2PW)	0.275	0.983	0.630

Table 4.2. Effects of weed species and density on the growth of nonbearing pecan, 1997.

Treatment	Ht. increase (cm)	Trunk dia. increase (mm)	New stem growth (cm)
Weed-free	67.1	13.9	361.8
1 Cut-leaf evening primrose	48.6	11.1	310.0
2 Cut-leaf evening primrose	54.2	10.2	272.2
1 Pigweed	44.0	9.4	249.8
2 Pigweed	30.1	5.2	196.7
1 Cut-leaf evening primrose + 1 pigweed	47.3	8.2	189.1
2 Cut-leaf evening primrose + 2 pigweed	27.1	4.4	97.6
Contrasts P>F			
Weed-free v. other	0.002	0.002	0.005
PW v. CEP	0.046	0.045	0.139
1 PW v. 2 PW	0.168	0.071	0.412
1 CEP v. 2CEP	0.578	0.709	0.554
Single weed v. multiple weeds	0.253	0.061	0.005
(1CEP+1PW) v. (2CEP+2PW)	0.047	0.102	0.159

Figure 4.1. Soil moisture records for two cut-leaf evening primrose [2CEP], two pigweed [2PW], two CEP succeeded by two PW [2CEP + 2PW], and control [No weed], 1996.


1996
7-May
22-May
7-Jun
25-Jun
15-Jul
2-Aug
19-Aug
9-Sep
15-Oct
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Soil matric potential (kPa)
2 CEP
2 PW
2 CEP & 2 PW
No weed



1996

Soil matric potential (kPa)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
7-May
22-May
7-Jun
25-Jun
15-Jul
2-Aug
19-Aug
9-Sep
15-Oct
1 CEP & 1 PW
2 CEP & 2 PW
No weed

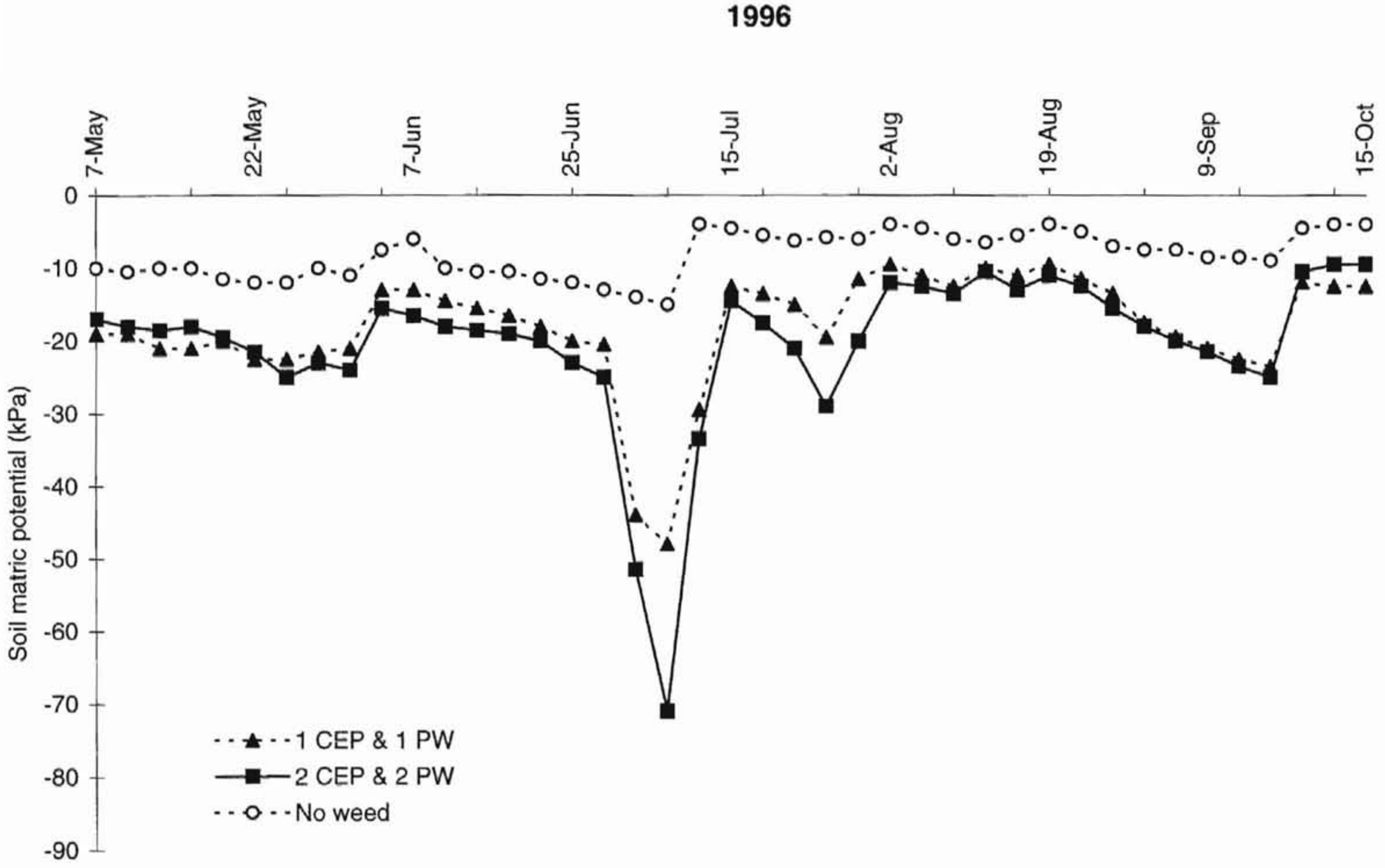
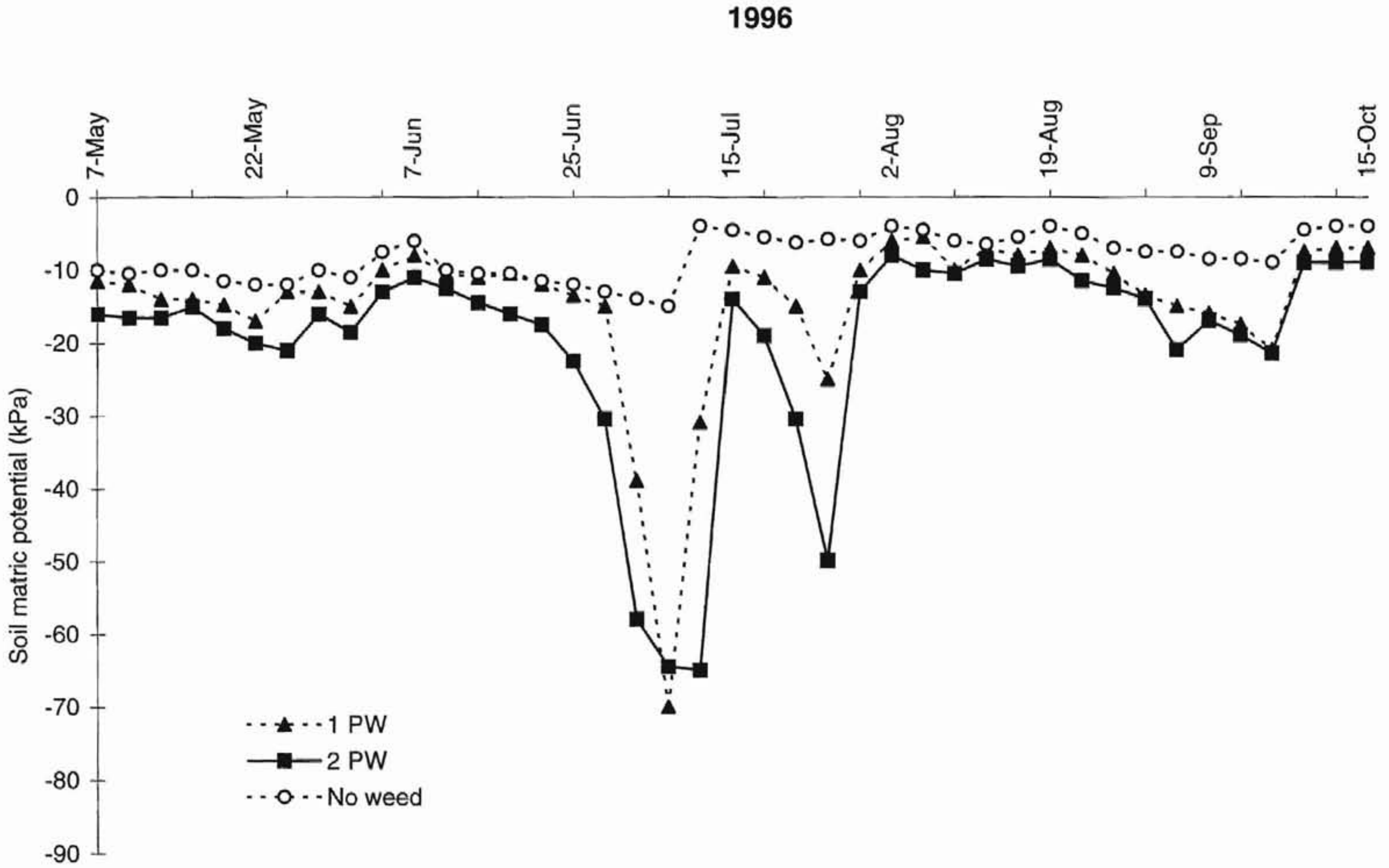
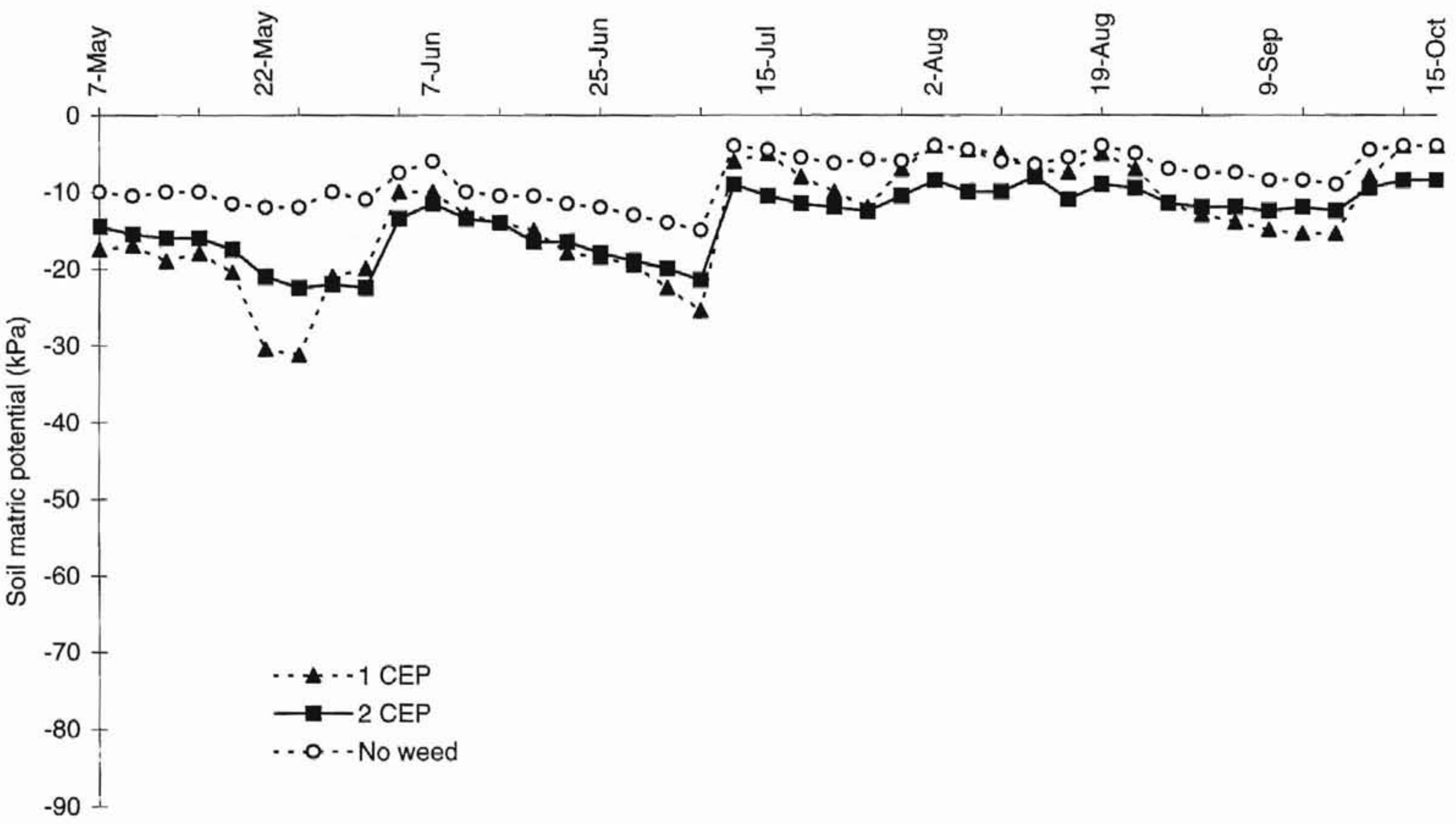

1996
7-May
22-May
7-Jun
25-Jun
15-Jul
2-Aug
19-Aug
9-Sep
15-Oct
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Soil matric potential (kPa)
1 CEP & 1 PW
2 CEP & 2 PW
No weed

Figure 4.3. Soil moisture records for one pigweed [1PW], two pigweed [2PW], and control [No weed], 1996.


1996

Soil matric potential (kPa)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
7-May
22-May
7-Jun
25-Jun
15-Jul
2-Aug
19-Aug
9-Sep
15-Oct
1 PW
2 PW
No weed

Figure 4.4. Soil moisture records for one cut-leaf evening primrose [1CEP], two cut-leaf evening primrose [2CEP], and control [No weed], 1996.



1996

Soil matric potential (kPa)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
7-May
22-May
7-Jun
25-Jun
15-Jul
2-Aug
19-Aug
9-Sep
15-Oct
1 CEP
2 CEP
No weed

Figure 4.5. Soil moisture records for one cut-leaf evening primrose [1CEP], two cut-leaf evening primrose [2CEP], and control [No weed], 1997.

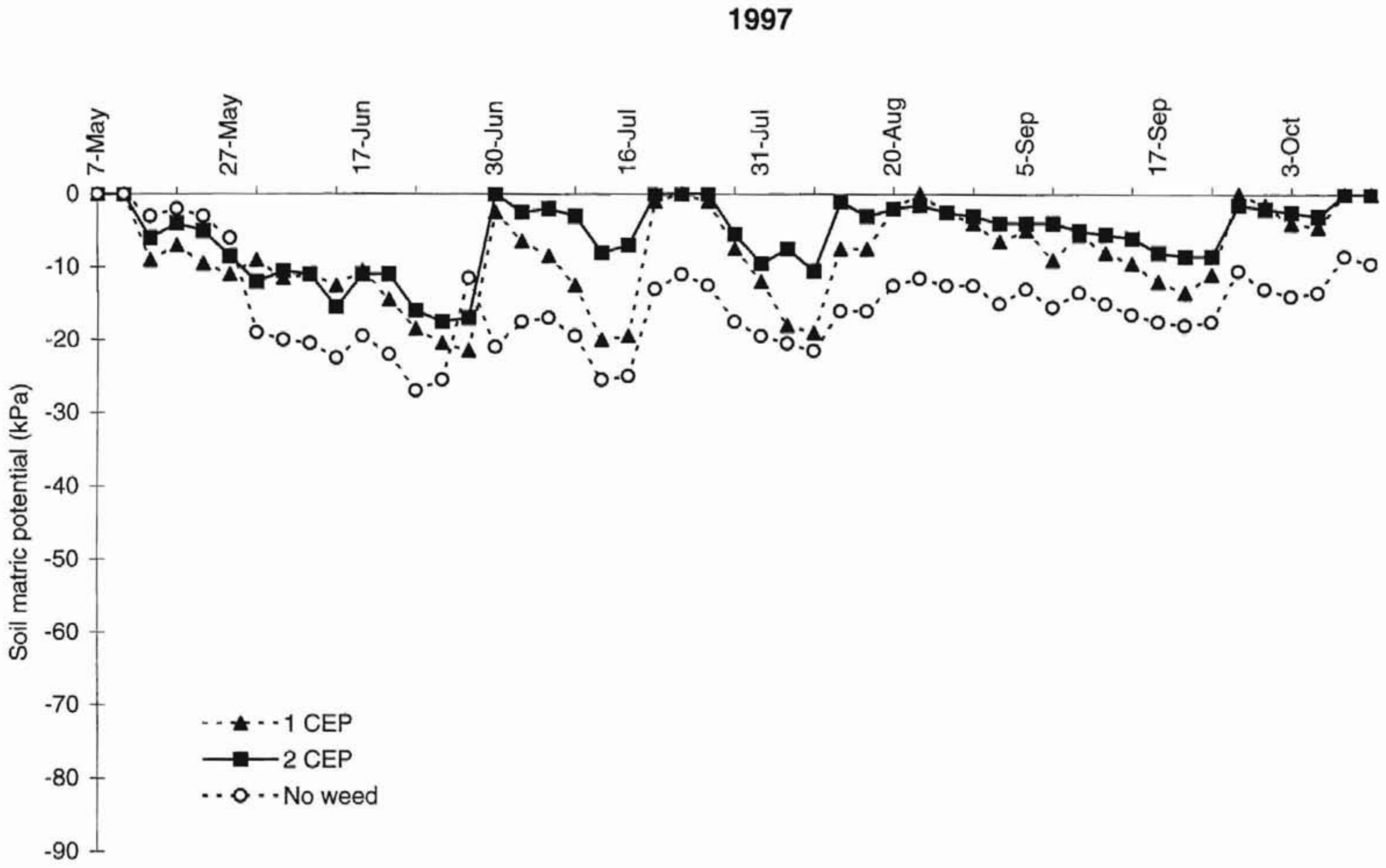

1997
Soil matric potential (kPa)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
7-May
27-May
17-Jun
30-Jun
16-Jul
31-Jul
20-Aug
5-Sep
17-Sep
3-Oct
1 CEP
2 CEP
No weed

Figure 4.6. Soil moisture records for one pigweed [1PW], two pigweed [2PW], and control [No weed], 1997.

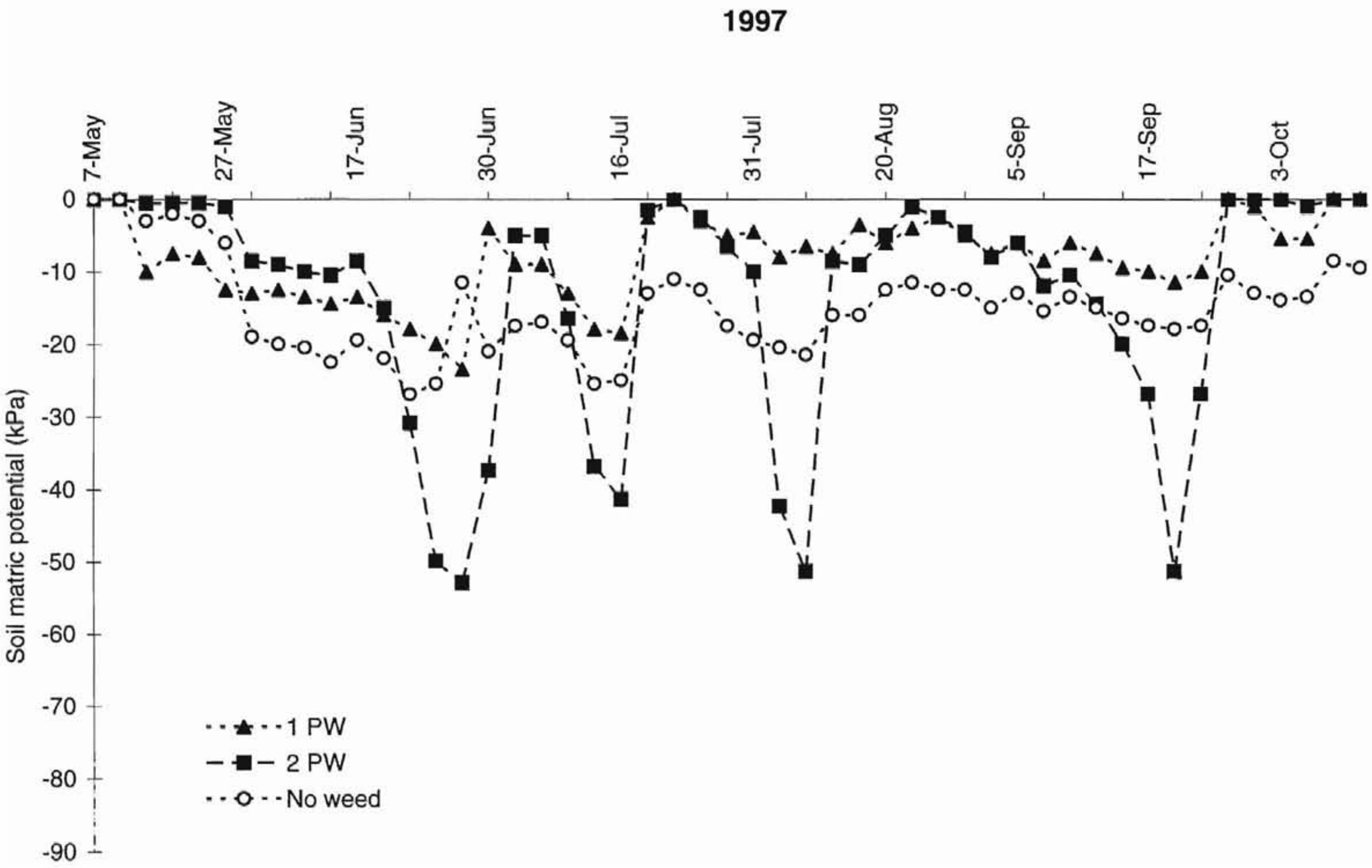
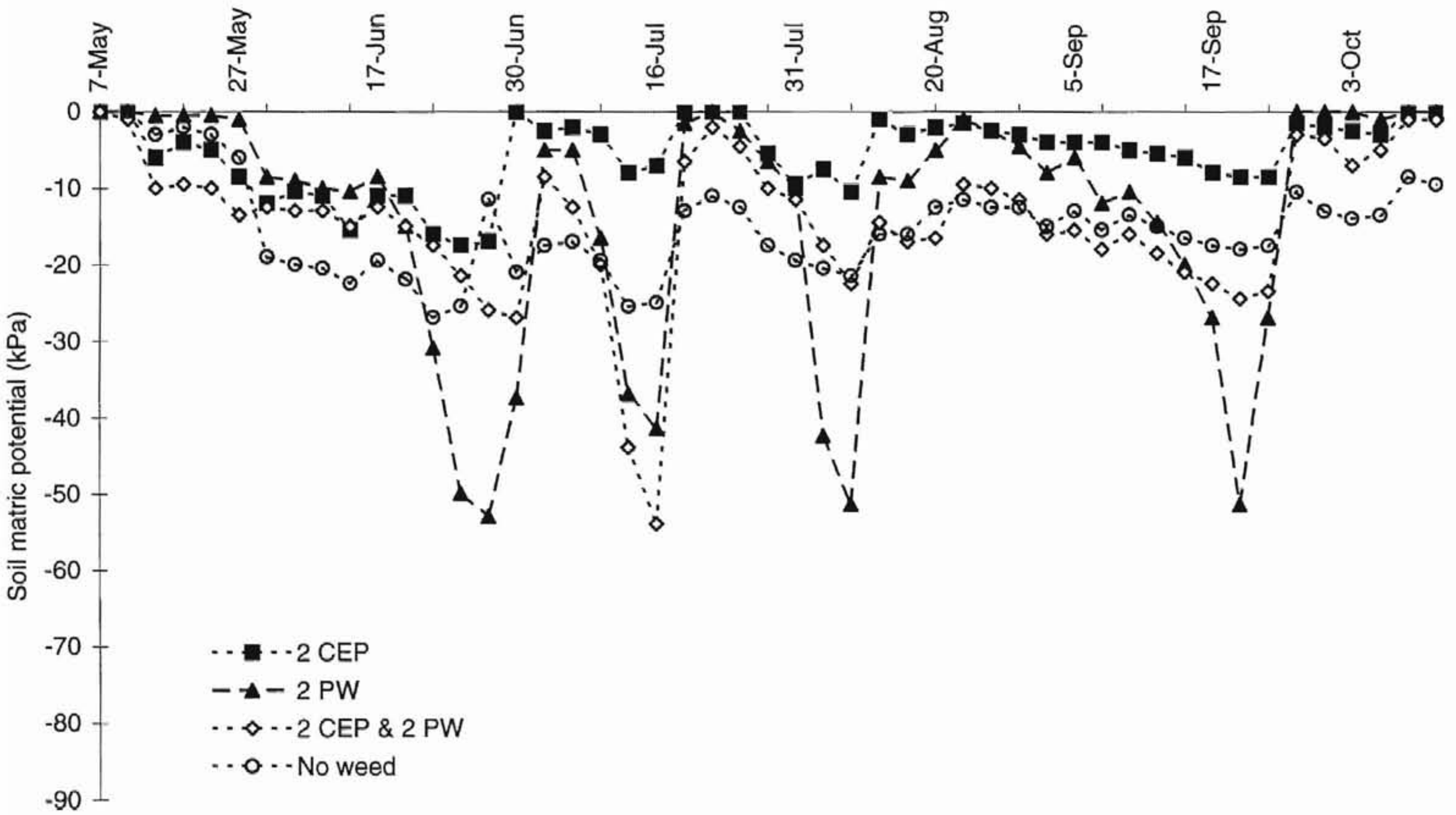

1997
7-May
27-May
17-Jun
30-Jun
16-Jul
31-Jul
20-Aug
5-Sep
17-Sep
3-Oct
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Soil matric potential (kPa)
1 PW
2 PW
No weed

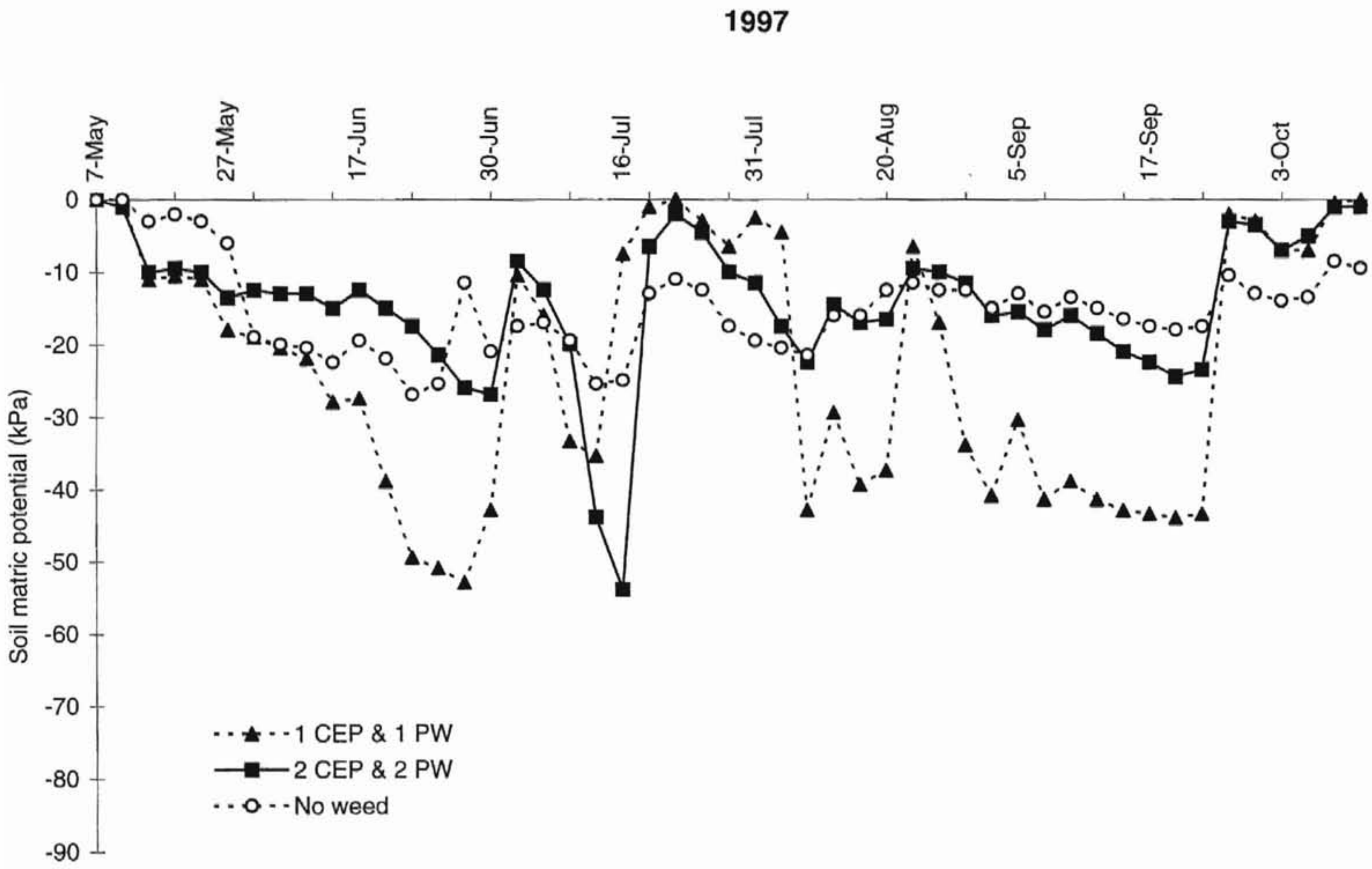
Figure 4.7. Soil moisture records for two cut-leaf evening primrose [2CEP], two pigweed [2PW], two cut-leaf evening primrose succeeded by two pigweed [2CEP + 2PW], and control [No weed], 1997.



1997

7-May
27-May
17-Jun
30-Jun
16-Jul
31-Jul
20-Aug
5-Sep
17-Sep
3-Oct
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Soil matric potential (kPa)
2 CEP
2 PW
2 CEP & 2 PW
No weed

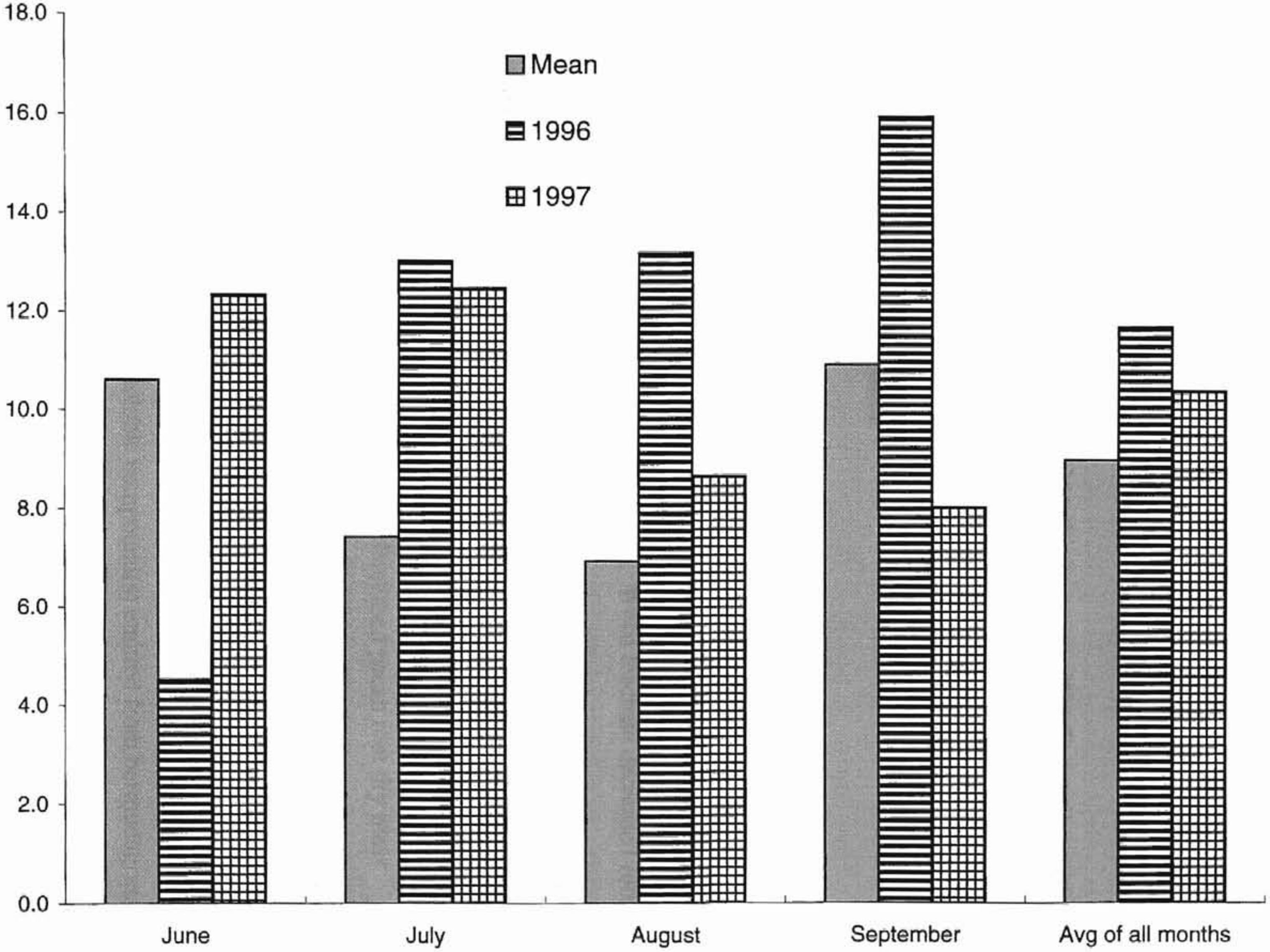
Figure 4.8. Soil moisture records for one cut-leaf evening primrose succeeded by one pigweed [1CEP + 1PW], two cut-leaf evening primrose succeeded by two pigweed [2CEP + 2PW], and control [No weed], 1997.



1997

Soil matric potential (kPa)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
7-May
27-May
17-Jun
30-Jun
16-Jul
31-Jul
20-Aug
5-Sep
17-Sep
3-Oct
1 CEP & 1 PW
2 CEP & 2 PW
No weed

Figure 4.9. Summer rainfall recorded at Oklahoma State University Pecan Research Station, 1996, 1997, and the long-term average rainfall.



18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Mean
1996
1997
June
July
August
September
Avg of all months

CHAPTER V

SUMMARY

Weed control in young pecan orchards is critical for optimal tree establishment and growth. Weeds compete for nutrients and soil moisture. Certain weeds also leach water-soluble compounds, which are allelopathic to pecan. Weeds must be completely eradicated from the young tree root zone to attain optimal tree growth. A sufficiently large area of organic mulch surrounding young pecan trees provides an effective alternative to herbicide weed control.

Leachate of bermudagrass and pigweed decreased leaf area compared to controls of one-year-old pecan trees as they broke dormancy and grew for 3 months. Bermudagrass leachate inhibited root growth compared to controls when applied to germinated seed as the seed grew for four months. Weed leachate decreased root growth when trees were grown in either a calcined clay medium or a peat/bark/perlite medium. When one-year-old pecan trees were grown in pots with either live weeds or incorporated dried weed tissue, no difference in growth was a detected comparing live weed versus dead weed tissue. Dried pigweed decreased pecan root dry mass compared to dried bermudagrass. Weed tissue at 6% w/w decreased tree height compared to 3% w/w. Leaf elemental concentration analysis indicated that nutrition is unlikely to have caused the inhibitions in growth. Results from these leachate experiments indicate that water-soluble compound(s) emitted from bermudagrass and pigweed inhibit growth of pecan. Inhibition of root growth is most easily detected when the leachate is applied to newly developing root systems.

Data from the field study examining the effects of weed density on young pecan trees indicate that complete weed control is necessary for optimal growth of the pecan. As few as one weed left to grow near the tree will decrease growth compared to controls. A succession of cool and warm season weeds is more detrimental to tree growth than a single weed species. Growth inhibition does not appear to be directly related to soil moisture competition.

Mulch performs well as an alternative to herbicide weed control in young pecan orchards. Grass mulch and wood chip mulch performed equally well for tree growth. Grass mulch retained more soil moisture than wood chip mulch, but decomposed more quickly. Grass mulch must be re-applied every year. A 4 sq. m. area of mulch resulted in optimal growth of three- to four-year-old pecan trees. Mulched areas of at least 4 sq. m. with perimeter weed control retained moisture as well as a weed-free control. Pecan trees surrounded by grass mulch had higher leaf K concentrations than trees surrounded by wood chip mulch. Other leaf elemental concentrations were similar or inconsistently different across treatments. Most elements were sufficient, except for Zn, which was deficient for all trees. Growth differences are more probably due to treatments than to the differences in nutrition.

Most pecan growers who are establishing a new orchard are interested in quick tree establishment. Greater tree growth rates will lead to earlier grafting and quicker economic returns. Complete weed control is critical to achieve optimal tree growth. Not only do weeds compete for soil moisture; they may also emit allelopathic compounds, which will inhibit growth of young pecan trees. Pecan growers may consider mulch as a viable alternative to herbicide weed control in their newly established orchards.

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