INFLUENCE OF SITE PREPARATION ON SOIL MOISTURE IN SEMI-ARID PLANTING[3]

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A site preparation technique utilizing a synthetic weed barrier and rainfall harvesting has shown promise in establishing trees in semi-arid area with only one irrigation at time of planting. The objectives of this experiment were to determine the effect of two site preparation techniques: v-ditch (rainfall harvesting) and synthetic weed barrier, alone and in combination, on soil moisture and temperature in the root zone of target trees. The planting was located at the New Mexico State University Los Lunas Agriculture Science Center. The planting site was irrigated once with 15 cm of water from a flood irrigation system. Soil moisture content was measured for each site preparation treatment at nine loci beneath the treatments for seven weeks following irrigation. Seedling survival and height were measured for Arizona cypress (*Cupressus arizonica*). The low power of the experimental design and high variability within treatments resulted in the failure to find significant (alpha=0.05) differences in seedling survival and soil moisture even though over two-fold differences existed. Two-year height improved as site preparation intensity increased. Even though no significant differences were detected, the observed improved survival, growth, and soil moisture retention indicate the combination of rainfall harvesting and weed barrier is sufficient to established windbreak in the Middle Rio Grande Valley with minimal irrigation.

INTRODUCTION

Arid and semi-arid lands are defined as areas where the amount of available water for normal crop growth and development is limited (White 1960), or areas with an average annual rainfall of less than 200 mm and between 200 and 500 mm, respectively (West 1983). Arid and semi-arid lands comprise approximately 35% of the earth's land surface (Walton 1969) and support a population of 850 million people (Nierenberg 1995). The increase in demand for food and fiber production has necessitated dependence upon arid and semi-arid land surfaces to satisfy the needs of the expanding world population.

The highly erodible soils in many semi-arid regions further compounds the limitations of semi-arid climate on plant growth. In New Mexico, for example, over 340,000 hectares of soil eroded in a seven month period from November 1983 through May 1984 (Huszar and Piper 1986). In some areas of the state, including including Albuquerque and Las Cruces, soil loss by wind erosion is estimated to be 2,727 kilograms per hectare per year (Huszar and Piper 1986).

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Increasing demands on a finite quantity of irrigation water have resulted in many agriculture enterprises failing to utilize tree crops or windbreaks as a means of reducing wind erosion. Site preparation techniques utilizing a synthetic weed barrier and rainfall harvesting has shown promise in establishing trees in semi-arid areas with only one irrigation at time of planting (Maiers 1997). These windbreak establishment techniques have been evaluated for evergreen species and also shows promise in applications using fruit and nut trees. The preliminary effects on seedling survival and growth are now being monitored but little information exists on the effect of using a synthetic weed barrier and rainfall harvesting on soil moisture in the root zone of the trees.

Arizona cypress, along with other members of the genus *Cupressus* has shown characteristics which are promising afforestation plantings in both arid and semi-arid areas (Long 1977). Arizona cypress is drought resistant once it is established and can be grown in alkaline soils. Arizona cypress is found in both the canyons and mountains of southeast and central Arizona and southwest New Mexico and is found at an elevation of between 1200 and 2000 meters (Tidestrom and Kittell 1941). Traditionally, the genus *Cupressus* has been used for landscaping and Christmas trees and, more importantly, for erosion control and windbreaks (Young and Young 1992).

The objectives of this study were to evaluate the effect of two site-preparation techniques: v-ditch (rainfall harvesting) and synthetic weed barrier, alone and in combination, on soil moisture in the root zone of target trees.

MATERIALS AND METHODS

Study Site

This study utilized an established windbreak planting in Los Lunas, New Mexico. The planting site was part of a state wide windbreak establishment project conducted in 1994 and 1995 (Maiers 1997). The original study examined the influence of different site preparation techniques and stock sizes of container grown Arizona cypress (*Cupressus arizonica*) and eldarica pine (*Pinus brutia* var. *eldarica*). Only those treatment combinations involving the largest, (656 ml Deepot; Steuwe and Sons, Corvalis, OR) Arizona cypress in combination with the four site preparation treatments were used in the present study.

This study was conducted at the New Mexico State University - Los Lunas Agricultural Science Center in Los Lunas, New Mexico (latitude 34° 46", longitude 106° 45"). Average annual precipitation ranges from 22 to 25 cm (Hooks 1996). The soil of the planting site is a loamy sand (87.2% sand, 4.6% silt, 8.2: clay; Maiers 1997). Average monthly soil temperature ranges from 3.3°C in January to 29°C in July (Hooks 1996). The site was leveled using a laser level prior to the initial planting in 1995. The site was initially dominated by sagebrush (*Artemesia filifolia*) prior to leveling.

Site Preparation Treatments

Four site preparation treatments were monitored in this study. These treatments included an undisturbed control, a shallow V-ditch, a synthetic weed barrier, and a combination of the V-ditch treatment with the weed barrier laid over the V-ditch. The V-ditch treatment makes use of a shallow trench two meters wide. The base of the "V" is one meter in from each edge of the trench. The V-ditch treatment was installed using a blade on the back of a farm tractor.

The weed barrier consists of a tightly woven synthetic burlap which allows for water penetration and prevents weed growth. To accommodate the seedlings, slits were cut into the weed barrier. All seedlings were planted one meter in from the edge of all site preparation treatments. All treatments were two meters wide and 15 meters long.

The current study began on June 20, 1997 and ran through August 1, 1997. On the first day of the study the entire plot was irrigated with a minimum of 15 cm of water from a flood irrigation system. The experimental design was a randomized complete block design with three blocks.

Plant Measurements

Seedling height was measured from the ground to the tallest growing tip of the established Arizona cypress seedlings remaining in the study. Height was measured to the nearest centimeter using a meter stick. Seedling height and survival were measured only for those seedlings planted as 656 ml Deepots. Height and survival data were analyzed using analysis of variance (PROC GLM; SAS Institute, 1990). Treatment separation was done using the LSD means separation procedure (PROC GLM; SAS Institute 1990).

Soil Moisture Measurement

Soil moisture content was measured for each site preparation treatment at three depths at three points relative to the center of the site preparation treatment. The three points relative to the center were 0, 30 and 60 cm from the center of the treatment. At each point, samples were taken from depths of 10, 20 and 30 cm. This sampling design generated a grid of nine soil moisture measurements per site preparation treatment per block. Soil samples were taken using a bucket style sand auger. Samples were removed from the auger and placed into pre-weighed, ointment cans. Lids were immediately placed onto the cans following filling with samples. Cans were then transported to the laboratory where they were weighed to the nearest milligram using a top loading balance. Lids were then removed and the cans containing the samples were placed into a drying oven at 105°C for 24 hours or until a constant weight was achieved. Samples were then removed from the oven and placed on a laboratory bench until they cooled to room temperature and were re-weighed as described above. Soil water content (w) was calculated as the mass of water per unit mass of dry soil using the following equation:

$$w = \frac{\text{mass of wet soil - mass of dry soil}}{\text{mass of dry soil}}$$

Soil moisture content was measured twice weekly throughout the duration of this study (34 days). Measurement of soil moisture was terminated due to heavy rainfall prior to the eleventh sample date. No other appreciable (> 5 mm) precipitation occurred prior to this rain episode.

To prevent sample contamination with backfill, sampling was conducted using both sides of the treatment. On alternating days, samples were taken from opposite sides of the treatment. Samples were taken at 20 cm intervals along the axis of the treatment. The final sample (tenth sample date) was located approximately two meters from the initial sample point. Upon reviewing the data, this technique was found to be sufficient in minimizing sample contamination. A total of twelve samples had to be discarded due to contamination.

Soil water content was then converted to soil moisture pressure potential by using a pressure release technique (Klute 1986; Smith and Mullins 1991). Appendix A contains the three pressure release equations for the three soil moisture sampling blocks used in this study. Due to the low power of this sampling design, only summary data (mean and standard error) are presented.

RESULTS

Survival and Growth

Two-year survival was not influenced by site preparation treatment (Table 1, Figure 1). Two-year height was influenced by site preparation treatment (Table 2). Two-year height improved as site preparation intensity increased (Figure 2). Seedlings growing in the combined V-ditch, and weed barrier treatment had two-year heights greater than either treatment alone and two-fold taller than seedlings growing in the control treatment. The two intermediate site preparation treatments had two-year heights exceeding control seedlings in excess of 52% (Figure 2).

Soil Moisture

The initial irrigation completely wetted all loci evaluated in the study (Figure 3). All loci in all site preparation treatments remained moist through the fourth collection date or 13 days into the dry down period. The upper three loci, loci 1, 4, and 7 began to show signs of drying by the fifth collection date or day 17 into the dry down period in all but the V-ditch, weed barrier combined treatment (Figure 3). The most intensive site preparation treatment, the combination of V-ditch and weed barrier, did not show signs of appreciably (>0.3 Mpa) drying until 24 days after the last irrigation. The second tier of loci (20 cm below the surface) began drying down much later, with the V-ditch treatment alone appearing to dry down faster than the other two site preparation treatments and the control. However, it was not until the eighth collection period or 27 days into the dry-down period, that any appreciable drying occurred in the V-ditch alone treatment. Only on the last collection date or 34 days since the last irrigation, that any appreciable drying occurred in the second tier loci of the control plots. Soil drying never exceeded 0.3 Mpa in the second or third tier loci in the weed barrier alone or combined V-ditch and weed barrier treatments. In the control and weed barrier treatments alone, the lowest tier of loci (30 cm) were not dried below 0.3 Mpa.

Drying in the upper loci began at the center and periphery loci (loci 1 and 7) and moved inward toward loci 4. This drying trend was most rapid in the two intermediate site preparation treatments (Figure 3). This pattern of drying started at collection date 5,

Table 1. Analysis of variance for 2-year survival percent of Arizona cypress (*Cupressus arizonica*) seedling growing under four site preparation treatments in Los Lunas, NM.

Source	df	Sums of Squares	F value	Pr > F
Block	2	316.67	0.32	0.7365
Site Preparation	3	3825.00	2.59	0.1379
Error	6	2950.00		
Corrected Total	11	7091.67		

Table 2. Analysis of variance for 2-year height of Arizona cypress (*Cupressus arizonica*) seedling growing under four site preparation treatments in Los Lunas, NM.

Source	df	Sums of Squares	F value	Pr > F
Block	2	118.96	0.33	0.7334
Site Preparation	3	44973.60	82.34	0.0001
Slock x Site Prep.	6	1092.37	0.31	0.9285
Error	61	35628.74		
Corrected Total	72	82047.04		

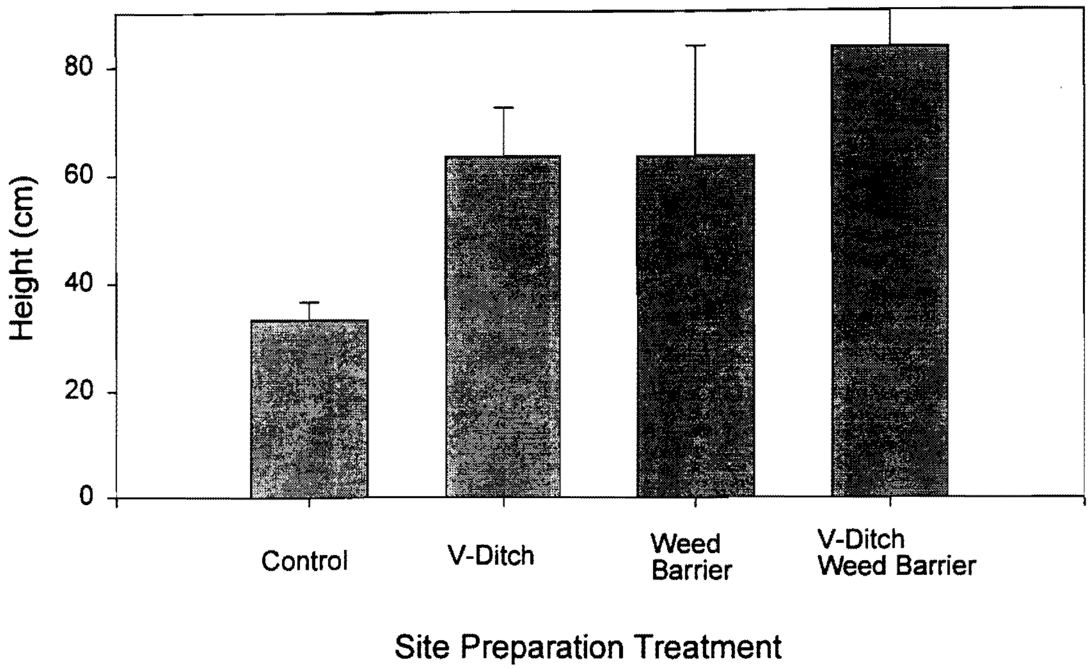

Figure 1. The effect of site preparation on 2 year survival of Arizona cypress (*Cupressus arizonica*) growing in Los Lunas New Mexico (mean ± SE).

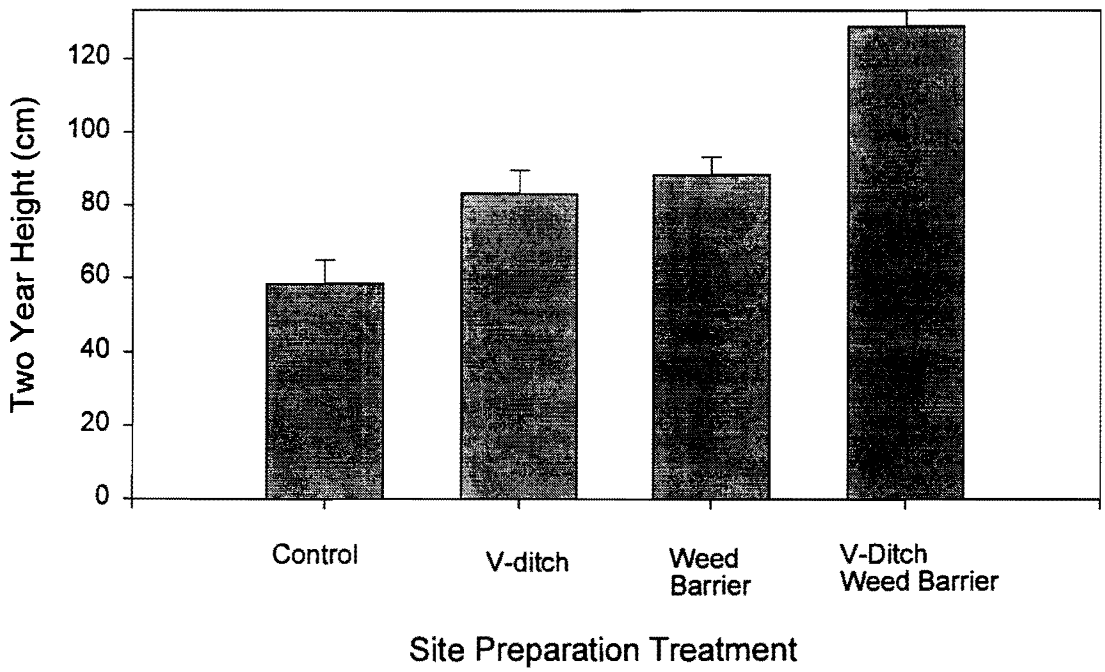

Figure 2. The effect of site preparation on 2-year hieght of Arizona Cypress (*Cupressus arizonica*) growing in Los Lunas, New Mexico (mean ± SE).

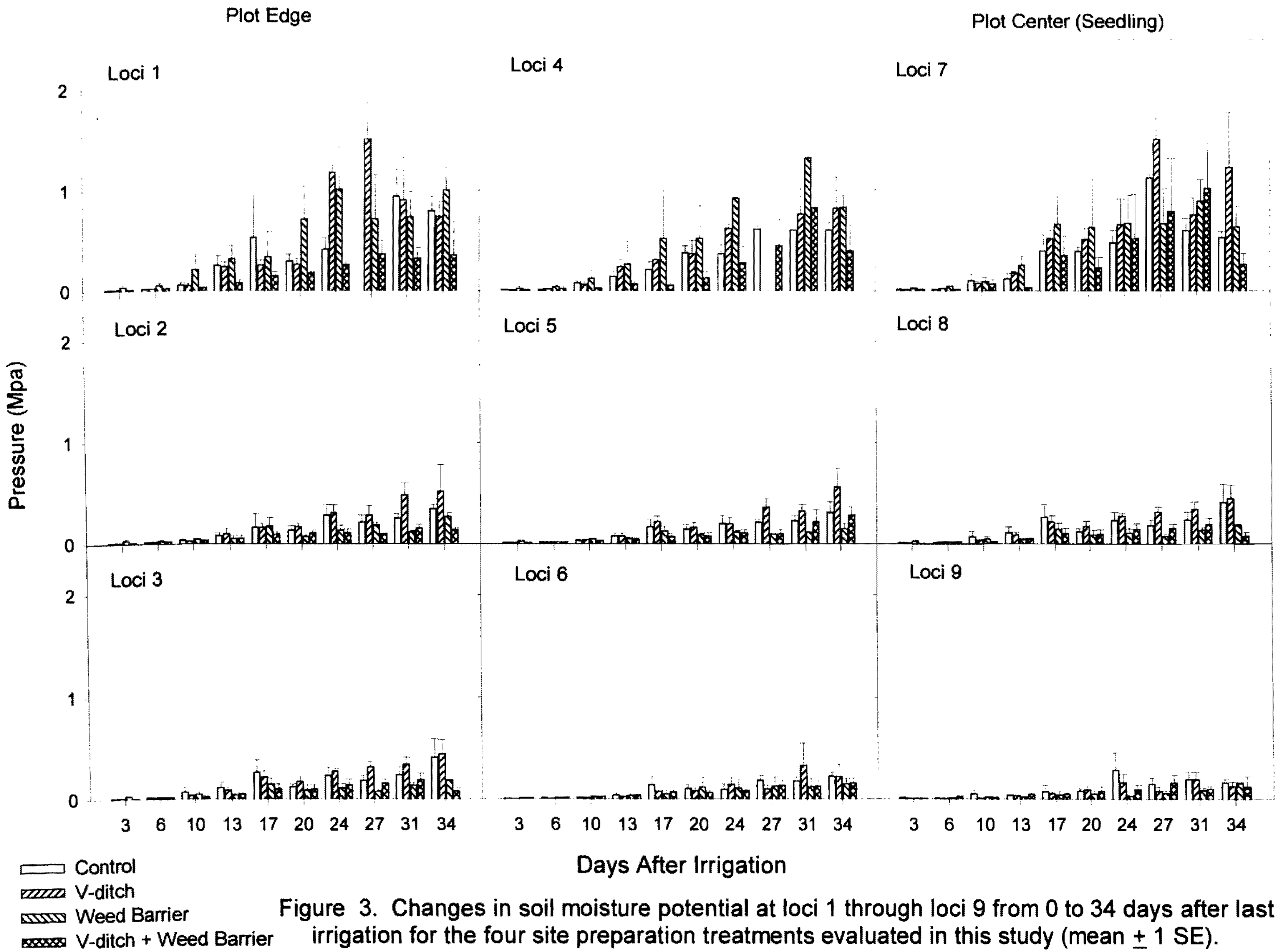

Figure 3. Changes in soil moisture potential at loci 1 through loci 9 from 0 to 34 days after last irrigation for the four site preparation treatments evaluated in this study (mean ± 1 SE).

with the exception of the combined V-ditch, and weed barrier treatment where the trend began 7 days later. At the seventh collection date when signs of appreciable drying (at loci 7) in the most intensive treatment were beginning, the other two site preparation treatments and control had appreciable drying in all the loci in the upper tier (Figures 3).

DISCUSSION

In the present study none of the site preparation treatments evaluated improved two-year survival of Arizona cypress. Even though there appeared to be over a two-fold improvement in survival for the combined V-ditch. and weed barrier treatment relative to the control, the overall variability among the blocks prevented detection of this difference. In previous studies using plastic mulches, mulches have been shown to improve survival (Lopushinski and Beebe 1976). However, the 30% improvement in survival due to the weed barrier alone treatment in this study was twice the survival improvement found in the same treatment by Loupushinski and Beebe (1976). Others have found a lack of detectable difference in survival when comparing plastic film mulches to untreated controls (Van Sambeek et al. 1995, Traux and Gagnon 1993, McDonald et al. 1994).

Studies using scalping or mechanical vegetation removal have found these techniques to improve early, two-year, survival (Capo-Arteaga and Newton 1991). However, the wide range of variability between blocks resulted in the inability of the over 30% improvement in survival to be significant. However, mechanical and/or chemical removal of competing vegetation has been shown to be a factor in improving survival of seedlings planted in dry sites (Capo-Arteaga and Newton 1991).

The improvement in two-year height growth as site preparation intensity increased in the present study is similar to that reported by others. Using a black plastic (polyethylene) mulch improved the height growth of butternut (*Juglans cinerea* L.), bur oak (*Quercus macrocarpa* Michx.), and white ash (*Fraxinus americana* L.; Traux and Gagnon 1993). Similar improvements in growth have been reported for other deciduous and evergreen species (VanSambeek et al. 1995; McDonald et al. 1994). Authors have attributed this improvement to several environmental modifications resulting from the site preparation used including improved nutrition (Traux and Gagnon 1993), improved moisture availability (VanSambeek et al. 1995; Fleming et al. 1994; 1996, Parfett et al. 1980) and improved root zone temperature before and after the growing season (Davies 1975).

Only the top two tiers of soil loci monitored in this study had any appreciable drying over the course of the study. In the case of the second tier of soil (20 cm below the surface) this drying occurred only in the control and V-ditch alone treatment on the last three sampling periods. Only the most intensive site preparation treatment, the V-ditch, weed barrier combined treatment, appeared to delay surface (10 cm) soil drying in this study. However, the two site preparation treatments applied independently did not forestall surface drying relative to the control treatment. While most reported studies show that use of a plastic mulch will improve soil moisture, no studies have examined the dry down scenario in either the absence of additional moisture or in a semi-arid environment as was done in this study.

In most reported studies illustrating the benefit of plastic mulches in retention of soil moisture, the material evaluated is a solid polyethylene sheet (VanSambeek et al. 1995; Fleming et al. 1994; 1996; Parfett et al. 1980). In the present study a woven (porous) polyethylene material was used. Appleton et al. (1990) using the same material, found the fabric reduced soil moisture deficit relative to bare soil. However, two important differences exist between the two studies. First, the reference point for soil moisture measurement used in the Appleton et al. (1990) study would have been located in the second tier of loci in the present study where differences were just beginning to become evident after 4 weeks. Secondly, the value reported in the Appleton et al. (1990) study was a season long average. Had the rain which occurred 35 days into the present study been delayed, we expect the soil moisture curves for the site preparation treatments, which were beginning to diverge, would have continued to diverge.

The pattern of dry down, regardless of time of initiation, seen in all three site preparation treatments and the control treatment may have been caused by the associated or adjacent weed competition. A likely explanation has to do with the build up of weed competition at the edges of the weed barrier treatments or within the V-ditch treatment. The weeds growing along the edge of the weed barrier treatment were larger in stature than individuals of the same species growing in the control and V-ditch treatments (personal observations). This phenomenon has been reported by others (Traux and Gagnon 1993, Davies 1988a, 1988b). The weed population adjacent to the treated area may have extended root systems growing under the weed barrier layer on the soil surface. This root mass would result in the depletion of the water in this portion of the soil. This theory is also supported by the pattern of soil depletion moving in from the edges towards the center of this upper tier of soil (Figure 3). The depletion from the center would be resulting from the seedlings and associated weeds growing through fabric openings made for the trees at the time of planting.

The large variability within each loci by treatment for a given sampling time is likely due to the nature of the sampling procedure. The systematic sampling procedure was adhered to regardless of the presence of vegetation. This may have resulted in some loci being sampled directly under a plant in one or two blocks while the other sample or samples may have been under minimal influence of a plant. This may have resulted in the large fluctuations in soil moisture observed in this study.

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APPENDIX A: PRESSURE POTENTIAL EQUATION

$$H = \frac{\left[\left(\frac{\theta_s}{\theta}\right)^{\frac{1}{m}} - 1\right]^{\frac{1}{n}}}{\alpha}$$

Where:

H = pressure head in Mpa;

θ_s = saturated moisture content;

θ = moisture content;

m = 1-1/n;

n = fitting parameter;

α = air entry potential.

Block parameters for pressure potential equation.

Block	θ_s	θ	m	n	α
1	0.350	0.148	0.237	1.306	1631.9
2	0.330	0.156	0.242	1.320	991.8
3	0.274	0.120	0.228	1.295	1500.0