# MESQUITE LEAF DIFFUSIVE RESISTANCE UNDER VARIOUS ENVIRONMENTAL CONDITIONS

by

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# CHAPTER I

## INTRODUCTION

Water has become one of man's most valuable resources, especially in arid and semi-arid regions where the problem of water supply is critical because of increasing demands being placed on the limited quantity available. Under these circumstances, every facet of the supply and demand situation should be carefully examined. When a water waster is found, the outcry is loud and often emotional. Range plants with no apparent economic value are often classified as water wasters. Rechenthin and Smith (1967) described noxious brush as insidious thieves that steal more water than the amount that is consumed by all the towns and factories in Texas. They attribute a loss of 38% of the annual average rainfall to woody plant invaders and weeds, indicative that the greatest single waste of water in Texas is the host of worthless, water-robbing weeds, woody shrubs, and trees that have infested most of the grasslands of the state. They estimated an annual saving of 10 million acre-ft in Texas by brush control. Decker (1966) estimated that in arid areas of the United States, 90% of the annual precipitation is returned to the atmosphere through evapotranspiration.

Other researchers have estimated total water used by phreatophytes. Robinson (1965) estimated the consumptive waste of water by phreatophytes in the West and Southwest to be 25 million acre-ft. The effects of phreatophyte clearing is becoming more important. But, because of increased interest in the preservation or development of these resources, saving water by phreatophyte destruction can no longer be done so casually. Instead, more detailed information is needed on actual evaporation losses of individual plants and types of dover. This information can be used to establish alternate management practices and to better predict the results of methods now in use. Thus, careful consideration and evaluation of water use by native vegetation will help to determine the most beneficial use of water within a resource area.

Since mesquite (*Prosopis glandulosa*) occupies approximately 34 million acres of rangeland in Texas. Most often mesquite is considered to use water extravagantly. Therefore, this study was designed to measure the diffusive resistance of mesquite growing under various environmental regimes. Relative transpiration rates can then be calculated from diffusive resistance measurements. The information gained can be used to better evaluate the need and/or effectiveness of mesquite control in relation to the saving of soil water.

# CHAPTER II

# LITERATURE REVIEW

## Soil Water

Since transpiration is the chief means by which water is lost from the soils, an understanding of factors influencing transpiration is necessary if one is to successfully predict or evaluate the water loss from a given environment. The major external factors are soil water, soil temperature, relative humidity, air temperature, wind, and solar radiation. Of these soil water has received the most attention and has often been considered the most important. The controversy continues with some scientists maintaining that evapotranspiration continues at a potential rate, so long as the soil water content of the root zone is above the wilting point (Veihmeyer and Hendrickson, 1955). Others found that a decrease in soil water necessitates a decrease in water use (Thornthwaite and Mather, 1955; Kramer, 1956). Eagleman and Decker (1965) found a negative linear relationship ($r = -0.74$) between the soil water potential and the relative evapotranspiration rate. Recently it has been stressed that the soil, the plant and the atmosphere form a continuum through which water moves.

It is, therefore, the interaction of the three components of the system, not their absolute values, which influences the growth and behavior of plants (Lemon et al., 1957; Haas and Steger, 1965).

Beardsell et al. (1972) studied water stress of soybeans (*Glycine max*) in controlled conditions. Under four degrees of stress a decline in transpiration rate was closely correlated with increased water stress. At -0.4 bar soil water potential the transpiration rate became independent of atmospheric conditions. In controlling soil water content in three species of eucalyptus, Grendel (1971) determined that quantity of available soil water and inherent biological properties of the species determined the rate of transpiration. Denmead and Shaw (1962) observed transpiration rates in relation to soil water content and meteorological conditions. They found that at field capacity the transpiration rate was determined primarily by the meteorological conditions. But, the transpiration rate always decreased as soil water decreased. Still, the decline in transpiration rate occurred at higher soil water contents as the potential rate increased.

Lety and Blank (1961) studied sunflowers (*Helianthus annus*) and green beans (*Phaseolus* sp.) at various soil water suctions. They noted a corresponding transpiration rate decrease as soil water potential decreased. In their study, the reduction was greater under conditions of high evapotranspiration. Water loss by transpiration in several coniferous species was also found to decline as soil water potential decreased. The degree of reduction of transpiration rate differed with the species, but the transpiration rate decrease began in all species at a soil water potential of -1 to -2 bars (Lopushinsky and Klock, 1974).

Martin (1940) found that growth rate of sunflowers grown at 11, 14, 17, and 20% soil water content was affected by differences in soil water before any effect on transpiration rate per unit area could be detected. The transpiration rate was ordinarily effected only when about two-thirds of available soil water had been removed. Others have found no significant differences in the transpiration rates of mesquite grown at different soil water levels (Wendt et al., 1967). They grew mesquite seedlings at suctions of -15, -6.3, -1.5, and -0.1 bars and found the transpiration rate increased curvilinearly as vapor pressure differences (VPD) increased. But, they found that mesquite seedlings do not increase their transpiration rate proportionally with increasing evaporative demands of the atmosphere. Wendt (1966) conducted a similar study with mesquite in a controlled environment, using the pot weight method to estimate the influence of

VPD, soil water, and soil temperature on water use. But, no insight was gained into the influence of soil water levels as a single factor on water use. Instead, he concluded that water use was a function of more than one factor. In a recent study of transpiration, Lemon et al. (1957) reported that soil water tension does not solely govern water loss by plants. Nor can evapotranspiration be predicted strictly on the basis of meteorological variables, as the plant itself exerts variable restrictions on the system of water transfer.

In a study of the response of water potential in several irrigated crops, Cary and Wright (1968) noted large differences between water potential levels in different kinds of plants growing under similar conditions. By monitoring daily the soil water conditions and potential evapotranspiration they found the individual plant water potential to be influenced more by the evaporative demand of the atmosphere than by the increased soil water potential after irrigation. Daytime changes in plant water potential generally correlated more closely with the changes in potential evapotranspiration than with changes in soil water content. Shreve (1923) concluded that transpiration of desert plants varies with both the evaporating power of the air and the soil water content. However, the native species studied showed an ability to increase their resistance of water loss with increasing aridity. Nkemdirim and Haley (1973) found that evapotranspiration from "prairie grass" decreased with a decrease in soil water content. Soil water of 18% (by volume) supported actual evapotranspiration equivalent to the potential evapotranspiration. But, when the soil water content fell below 11%, the grass became quiescent and water loss occurred directly from the soil surface.

## Solar Radiation

Other environmental factors are not less important than soil water, but they have received less attention. In a controlled environment study with corn the U.S.D.A. (Anonymous, 1962) reported that radiant energy had a marked effect on transpiration. Full, one half, and one quarter amounts of normal sunlight were used and in every case plants grown in the lower radiant energy treatment had a lower transpiration rate. Kanemasu and Tanner (1969) found that abaxial and adaxial stomata behave quite differently and independently of each other with respect to light. The stomatal resistances of the sunlit adaxial surfaces were much less than that of the shaded leaves in snap beans (*Phaseolus vulgaris*). Whiteman and Koller (1967) also found a decrease in the stomatal resistance of sunflower leaves when light was increased from 500 to 1000 ft-c. But, further increase in light resulted in an increase in the stomatal resistance. On the other hand, Grendel (1971) found that the transpiration rate of Eucalyptus (woody xerophytes) grown in water deficient soil under arid conditions was not determined by the intensity of solar radiation.

## Relative Humidity and Air Temperature

Relative humidity is another controversial factor in soil-plant-atmosphere water relationships. It is often studied concurrently with air temperature. Sucoff (1969) found that leaf water potential in red pine (*Pinus resinosa*) was affected by both radiation and relative humidity when the total soil moisture remained the same. Yang and deJong (1972) studied the effect of aerial environment on the transpiration of wheat (*Triticum aestivum*) plants and found a decreasing plant resistance to water movement with increasing air temperature. Changes in relative humidity had no consistent effect on the transpiration rates. Beardsell et al. (1972) controlled VPD and air temperature in soybeans and found a lower transpiration rate for lower temperatures until the VPD reached 5 mb. At this point air temperature no longer had an effect on the transpiration rate. Research to determine moisture absorption by plants from the atmosphere was conducted by Breazale (1950). He found that leaves of tomato (*Lycopersicon* sp.) plants can absorb moisture from fog and

100% relative humidity atmosphere. It was believed that this water could be transported to the roots and even be deposited in the soil because water was exuded from the roots during the study. Stone (1965) repeated this experiment with pine (Pinus ponderosa) seedlings and some added controls to make sure that the exuded water was actually being transported through the plant. He found that plants with tops killed could transport water from a saturated atmosphere to the roots. He concluded that dew was important for the survival of pine seedlings, but that conditions did not exist in nature for actual movement of water through the plant into the soil.

In a study of evapotranspiration in woody phreatophytes earthen tanks were used as evapotranspirometers (Robinson, 1970). For a given phreatophyte species, annual transpiration rate was affected by climatic conditions of which air temperature was considered to be the most important.

## Wind

Effects of wind on transpiration have also been somewhat neglected, but it can be an important factor in evapotranspiration. Taylor and Ashcroft (1964) completed a study wherein evapotranspiration appeared to be influenced more by night winds than day winds. During the day the energy supplied by direct solar radiation was enough that soil and plant factors limited evapotranspiration. Additional advective energy brought in by winds would have little influence. At night the wind could cause evapotranspiration to continue. Winds in salt cedar (*Tamarix pentandra*) thickets were found to be turbulent with irregular inversions which could be important to water loss (Van Hylckama, 1969).

Tests winds of 1, 9, 19, and 33 mph caused considerable anatomical and morphological differences in sunflowers (Whitehead, 1961). Plant growth was reduced with increasing wind speeds (smaller leaf area accompanied by reduction of internode length). There was a distinct reduction of transpiration rate per unit area of leaf with increasing wind speed. In general the phenotype became more xeromorphic with increasing wind speed.

## Total Use and Efficiency

Many of the studies of water use by phreatophytes have been estimates rather than actual measurements since the areas involved are often so large. The density of the canopy is determined; then, using relationships between measurements of transpiration rate at field capacity and the evaporation of open water surface computed from observations of net radiation, air temperature, humidity, and wind speed (Penman, 1956) total water use estimate can be calculated. However, when an entire plant community is considered, physical and biological factors are influenced by the stand so that the total water demand of the community may be different from the sum of the individuals considered separately. The entire system must be considered when studying the water demand of a particular type of plant. Van Hylckama (1963) found a decrease in growth and development in salt cedar to parallel a diminishing use of water, even though water seemed freely available. He speculated that as plants reach a certain density, water use must decline, so optimum density for water use is not necessarily equal to maximum density. In another study, Van Hylckama (1970) determined by a 6 year observation of salt cedar that thinned stands use nearly as much water as the unthinned control. Densities were decreased by 50%, and as new growth appeared the water use was only 10-15% less than in uncut stands. This means that water use extrapolation from a 100% density can lead to serious over estimation of water use. He concluded that with a water table at 4 m, salt cedar may thrive but use comparatively little water, thus, the quantity of water potentially saved by their eradication could be overestimated. This is in contrast to an earlier work in which Gatewood et al. (1950) found water use by salt cedar, cottonwood (Populus deltoides), and baccharis (Baccharis sp.) to vary directly with volume density. Campbell and Pase (1972) noted little effect on plant-moisture stress after removal of 22 and 86% of the leaf mass on mountain mahogany (Cercocarpus montanus). But, removal of 41 and 66% leaf mass caused decreases of 6 and 8 bars plant moisture tension. Because of the reduced internal plant-moisture stress they assumed that water would not be removed from soil as rapidly or in amounts as large as occurred before pruning.

Rich (1952) reported that consumptive use of water by forest and range vegetation depends on the distribution and occurrence of precipitation, the amount of water held by the soil, and the character and type of the vegetation. For instance, consumptive use in the chaparral zone was found to be 81% of the annual precipitation for grasses and 84% for shrubs. By using earthen tanks as evapotranspirometers, Robinson (1970) measured water use by greasewood (Sarcobatus vermiculatus), rabbitbrush (Chrysothamnus nauseosus), willow (Salix sp.), and wild rose (Rosa woodsii) over a period of 5 years. Evaporation from bare soil was less than half the evapotranspiration from the vegetated tanks. The annual water use increased during growing seasons with high temperatures and ranged from 1.2 ac-ft/ac (greasewood) to 3.0 ac-ft/ac (willow). On the average, 70% of this was supplied by ground water and only 10% by soil water. Several studies have been designed to measure the efficiency of water use by various kinds of vegetation and what effect substitution of grasses for shrubs has on the ground water supply. Degarmo (1966) compared the efficiency of water use by four grasses and four woody species while controlling soil moisture levels at field capacity, one half, one third, and one fourth of field capacity. Fourwing saltbush (Atriplex canescens) seedlings required 735 g of water to produce 1 g of dry matter (most efficient of the shrubs studied). Creosote bush (Larrea tridentata) and mesquite (Prosopis juliflora) seedlings required 1629 and 1432 g of water respectively, to produce 1 g of dry matter. Bush muhly (Muhlenbergia porteri) used 409 g of water to produce 1 g of dry matter. Maximum productivity of shrubs and grasses occurred at field capacity, but water use efficiency was also lowest at this soil water level. The most efficient level was one third field capacity. Degarmo concluded that shrubs require at least twice as much water as grasses to produce a unit of dry matter and that desert species inefficiently use soil water at field capacity. McGinnes and Arnold (1939) found the differences between grasses and shrubs to be even greater. They found velvet mesquite (Prospopis velutina) to use 1725 lb of water to produce 1 lb of dry matter which was more than four times the amounts calculated for perennial grasses such as blue grama (Bouteloua *gracilis*) and curly mesquite (*Hilaria belangeri*).

These and other plant water use studies have led to investigations of water yield increase by replacing woody phreatophytic vegetation with grasses and forbs. Hibbert et al. (1974) reported that chapparral shrubs depleted soil water to a greater depth than shallow-rooted grasses and forbs. Soil moisture records were obtained for several years from California rangelands with natural woody brush vegetation and from adjacent plots which were denuded by burning (Veihmeyer, 1953). In every case, all soil water available to plant growth was used on the undisturbed plots. But there were appreciably larger amounts of water remaining in the burned plots. Annual and perennial grasses did not deplete the water supply for as long as, nor as deeply as the shrubs so that some available water was left in the soil. Thus, less water was required to replenish the ground water. Differences in the surface layers between burned and unburned plots were slight; removal of all vegetation resulted in the greatest water savings. Hill and Rice (1963) found that grass covered plots required less rainfall to recharge the soil than brush covered plots. Grass allowed more water to percolate through the soil to recharge the water table. Deep rooted summer-growing forbs reduced soil water as much as the brush. They concluded that to increase water yield by vegetation control the soil must be deeper than 3 ft and the surface must be kept free of weeds. With studies on plots cleared of scrub oak (*Quercus* sp.) and mountain mahogany and reseeded with grass, Rowe and Reimann (1961) found a greater carryover of water below the 30 inch depth since brush in uncleared plots used water from deeper depths. This increased yield continued only when forbs were controlled. However, evapotranspiration loss was actually more on the grass plots than the brush plots during the rainy season. Thus, on a shallow soil brush to grass conversion could lead to a lower water yield. Vegetation management to increase water yield depends on: sufficient rainfall to penetrate the canopy layers, depth of soil, density of grass cover, and amount of mulch on soil.

# CHAPTER III

## METHODS AND PROCEDURES

This study was designed to evaluate the leaf diffusive resistance and to estimate the relative transpiration rate of honey mesquite (*Prosopis glandulosa var. glandulosa*) growing in various environments. One study area was located on the Texas Tech University campus at Lubbock while three other areas were selected for study on the Post-Montgomery Estate ranch 15 miles east of Tahoka, Texas. The average annual precipitation for this area of the high plains is 18 to 20 inches. Summers are hot and most of the precipitation occurs as thundershowers that are most frequent during late spring-early summer and late summer-early fall.

The area on the Texas Tech campus, a sandy loam range site with an Amarillo fine sandy loam soil, was divided into two areas (Figures 1 and 2). One of the areas was irrigated bi-weekly throughout the growing season and periodically during the remainder of the year to maintain a constant supply of soil water. The other area received only natural precipitation. Five trees were randomly selected and permanently marked for study on both the

Fig. 1. Honey mesquite trees on the non-irrigated area, Texas Tech University campus.

Fig. 2. Honey mesquite trees on the irrigated area, Texas Tech University campus.

irrigated and non-irrigated area. Also, a portion of the root system was excavated to a depth of approximately 30 inches and the tap root was cut (at approximately the 26 inch depth) on two trees from both the irrigated and non-irrigated area (Figure 3). A jar lid was placed between the severed portions of the root to prevent root grafting.

Three environmental situations were selected for study on the Post-Montgomery ranch. One situation involved a comparison of the transpiration rates and leaf diffusive resistances of trees growing near the edge of a spring-fed reservoir and trees growing on a clay loam range site on a dry hillside (Figures 4 and 5). The hillside soil consisted of an Acuff loam and that around the reservoir was also an Acuff loam. Five trees on each area were randomly selected and permanently marked for study. During the second summer, a third site was added to this location. Three trees were marked for study in an adjacent area that was characterized by a dense stand of salt cedars which indicated an adequate supply of ground water (Figure 6). The soil of the third area was a Yaholla fine sand which is often a water bearing sand.

The influence of density and the location of trees growing within a stand of approximately 1000 trees/acre was the third environmental situation selected for study (Figures 7 and 8). The soil of this area was Amarillo fine

Fig. 3. Excavated tap root of a mesquite tree on the non-irrigated area with the jar lid visible between the severed portions of the root.

Fig. 4. Permanently marked trees on a shallow upland hillside site near Spring Tank, a spring fed reservoir.

Fig. 5. Trees selected for study along the edge of Spring Tank, a spring fed reservoir.

Fig. 6. Dense stand of salt cedar growing on a site with shallow ground water, located near Spring Tank, a spring fed reservoir.

Fig. 7. Permanently marked trees on the perimeter of a dense (1000 trees/acre) stand of mesquite.

Fig. 8. Permanently marked trees in the interior of a dense (1000 trees/acre) stand of mesquite

sandy loam. Four trees around the perimeter of the stand and four trees within the interior of the stand were randomly selected and permanently marked for study.

At Spring Tank trees were selected on which the diffusion resistance of abaxial and adaxial leaf surfaces was measured. Two trees were selected randomly from the marked trees on 6 different days and diffusive resistance readings were taken at 1000 and 1400 (CDT) from both surfaces of a leaflet.

A study concerning the influence of canopy cover (percent) on transpiration rates and leaf diffusive resistance was conducted on a clay loam range site with Olton clay loam soil where the mesquite trees had been thinned to various densities. One tree was randomly selected and permanently marked within the center of a stand of trees varying in density and canopy cover (7.5, 15, 22.5, and 30%). Stands of trees were 1 acre in size, and each treatment consisted of three replications arranged in completely randomized design.

Leaf diffusive resistances of trees growing in each environment were measured weekly throughout the growing season (May through August) during 1974 and 1975. Measurements were made at approximately 0800, 1200, and 1600 (CDT). Periodically diurnal cycles of diffusive resistance were measured from pre-dawn through post-dusk, and during one 24 hour period. During each of these periods measurements were made at 2 hour intervals.

Diffusive resistances of the leaves were measured with a diffusive resistance porometer (Kanemasu et al., 1969; and Van Bavel, 1965). Actual transpiration rates are inversely related to diffusion resistance and may be calculated according to Van Bavel (1965). Prior to use in field measurements, the porometer (Lamda Instruments Corp.) was calibrated at different diffusive resistances at temperatures ranging from 15 to 40 C. Field use procedures recommended by Morrow and Slayter (1971) such as shading the sensor cup and keeping the time that the leaf remained inside the cup to a minimum were followed.

Soil temperature (6, 12, 18, and 24 inch depths), soil water content (0 to 6, 6 to 12, 12 to 18, and 18 to 24 inches), air temperature, wind speed, and relative humidity were measured at the time of the diffusive resistance measurements. Soil temperature was measured by inserting a glass laboratory thermometer into a hole in the ground made by driving a 1/2 inch steel shaft to the prescribed depth. A oil water content was measured gravimetrically from core samples taken in 6 inch increments. Relative humidity was measured with a standard Weather Bureau type sling psychrometer. Air temperature was measured with a standard glass thermometer. Wind speeds were measures with a hand held wind gage. Leaf temperatures and solar radiation were measured simultaneously with diffusive resistance measurements. Leaf temperatures were measured with a thermistor in the sensor cup of the porometer. Solar radiation was measured with a Lambda light meter.

# CHAPTER IV

# RESULTS AND DISCUSSION

## Texas Tech University Campus

Honey mesquite trees on this location were subjected to two soil water regimes and the resulting leaf diffusion resistances were measured. On the irrigated area the amount of water in the soil in the top 24 inches remained relatively constant during both the 1974 and 1975 growing seasons. In 1974 the average soil water content (by weight) was 12.3% while in 1975 the average was 12.5%. Because less than 2 inches of precipitation was measured during the 1974 study period and greater than 8 inches during a similar period in 1975, there was greater variation in the average soil water content in the non-irrigated area. In 1974 soil water in the non-irrigated area averaged 5.9% while in 1975 the average soil water increased to 7.9%, more than 35% over 1974. This variation in natural precipitation allowed a comparison of leaf diffusion resistances between a wet and a dry year as well as the planned comparison between irrigated and naturally watered areas.

During 1974 there was a significant difference in diffusion resistances at the various times of day and between the irrigated and non-irrigated areas (Figure 9). However, in 1975 only the time of day significantly affected the diffusion resistances (Figure 10). In 1974, trees growing on the non-irrigated area had markedly higher diffusion resistances throughout the day. The difference in diffusion resistance between areas was less in the morning at 0800; increased by 1200; and was very large by 1600. Generally, the irrigated trees continued to transpire (as indicated by low diffusion resistances) throughout the day with only a slight decrease by 1600. In 1975 there was very little difference in the diffusion resistances of the trees growing on both areas; consequently transpiration rates were similar, with a maximum rate being reached by noon and a gradual decrease thereafter.

Each year the measured variables were analyzed by a multiple regression to determine which factors were most important in influencing transpiration rates at each time of day. In 1974 (the dry year) on the irrigated area, air temperature and relative humidity were the most important factors throughout the day (R = .583). On the non-irrigated area, the same two factors were most important at 1600 (R = .904), but soil water and soil temperature were also highly correlated (R = .758). In 1975 (wet year)

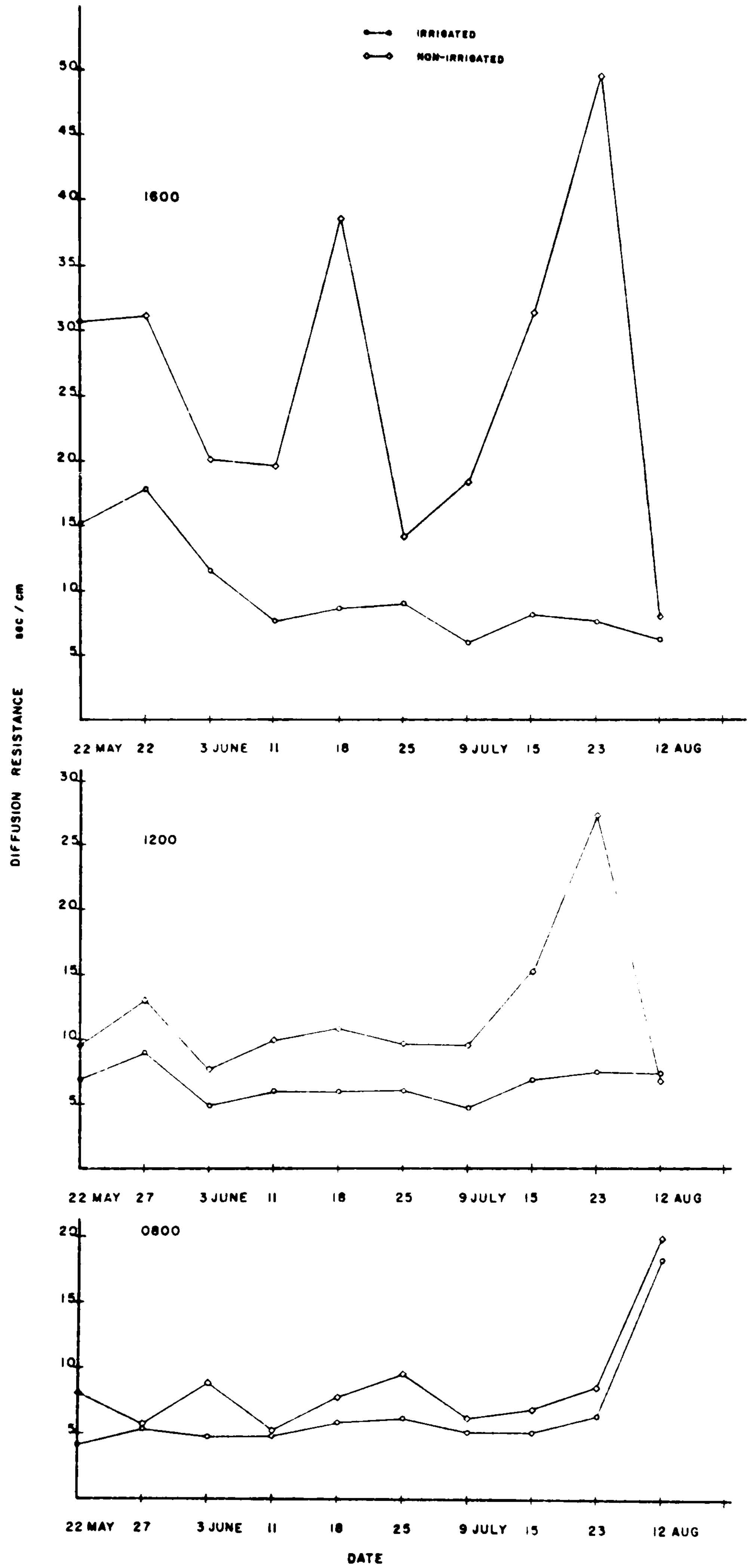


Fig. 9. Diffusive resistances of mesquite trees growing on irrigated and non-irrigated areas on the Texas Tech University campus at three times of day during 1974.

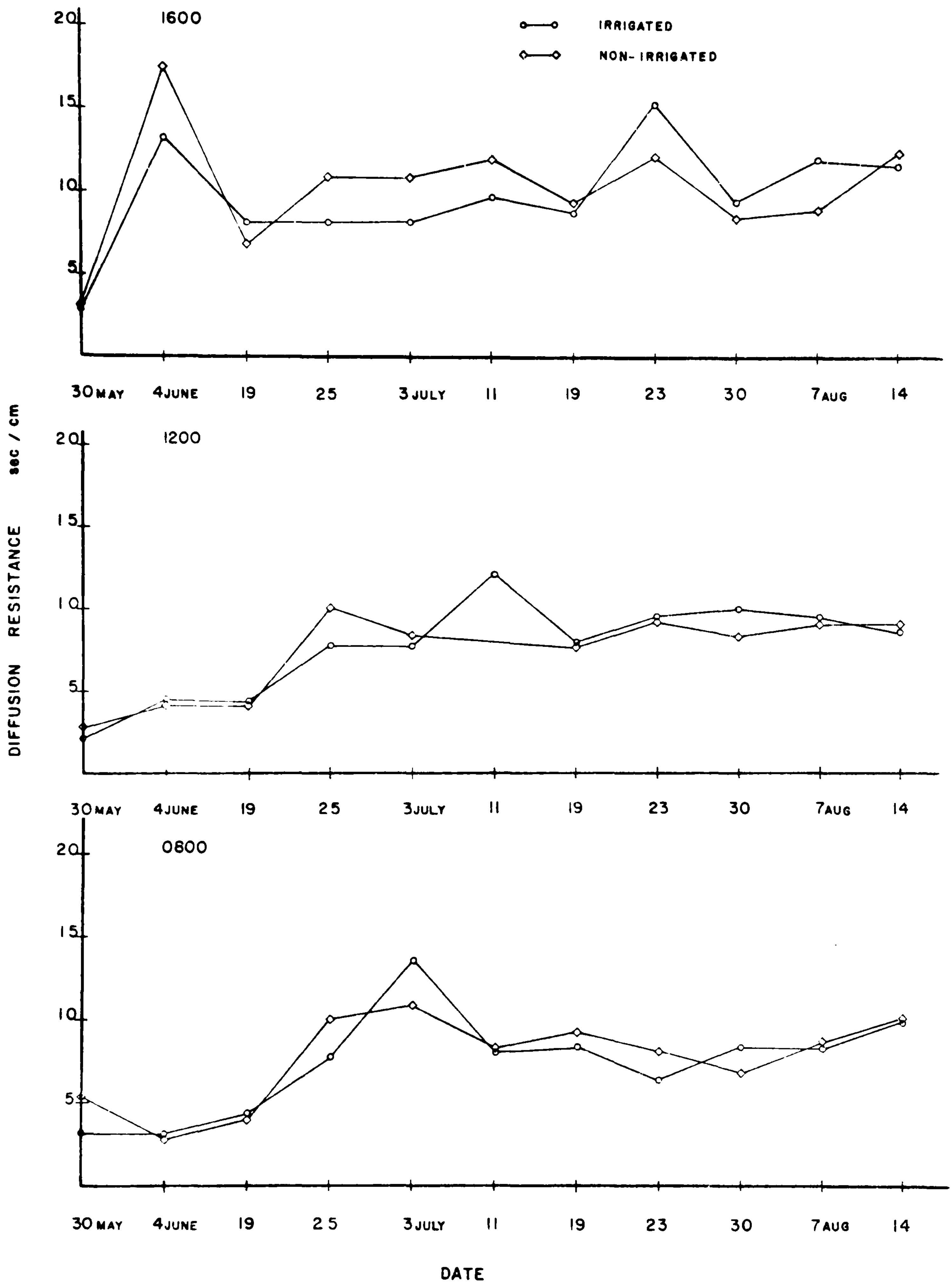


Fig. 10. Diffusive resistances of mesquite trees growing on irrigated and non-irrigated areas on the Texas Tech University campus three times of day during 1975.

the highest correlation for diffusion resistance of trees on the irrigated area was obtained from leaf temperature and relative humidity at 1200 (R = .848) and leaf temperature and soil water content (R = .814) at 1600. Leaf temperature and relative humidity also appeared to be most important on the non-irrigated area at 1200 in 1975 (R = .783). Thus it seems that leaf temperature and relative humidity are the most important environmental factors contributing to diffusive resistance when soil water is plentiful. However, when soil water is limiting as on the non-irrigated area in 1974 other factors assume greater importance and the total relationship of these factors to diffusion resistance becomes more complex.

Mesquite trees growing on the irrigated area used water much more extravagantly during 1974 than the trees growing on the non-irrigated area. On days when evaporative demand was high the non-irrigated trees reduced their water use to a very low rate while irrigated trees continued using water at a high rate. In 1975 when precipitation provided abundant water for the non-irrigated trees, their rate of water use paralleled the rate of the irrigated trees. Thus, mesquite trees on this location used water extravagantly when available, but were able to drastically curtail the rate of use when supply could not meet evaporative demands.

## Mesquite Tap Root Dependence

To establish the contribution to transpiration of the central tap root of honey mesquite, tap roots of four trees (two on each the irrigated and non-irrigated areas) were severed at about the 26 inch depth. During 1974 both trees on the non-irrigated area evidenced some apparent physiological shock in the form of defoliation that was at least partially continued throughout the summer. The two trees on the irrigated area, however, showed no outward signs of additional stress. During 1975, one of the trees on the non-irrigated area seemed to recover completely while the other, the smallest tree marked, was hampered further by insects and did not "leaf out" entirely at any time.

Analysis of the differences in diffusion resistances between trees with cut and uncut tap roots showed significant differences between trees on the irrigated and non-irrigated areas and between trees with cut and uncut roots. When these data were further analyzed by Duncan's New Multiple Range Test it was found that the significant difference between trees with cut and uncut roots was due to those trees on the non-irrigated area (Table 1). There was no difference between trees with cut and uncut roots when growing on the irrigated area. In 1975 the data were analyzed in the same manner, but this time there was no significant difference between any trees with cut and uncut

Table 1. Influence on the diffusive resistance (cm/sec) of honey mesquite leaves by cutting the taproot of trees growing with and without irrigation on the Texas Tech University campus during 1974.

| | Cut Root[1/] | Uncut Root |
|---|---|---|
| | A | A |
| Irrigated | 7.565 a | 7.205 a |
| | A | B |
| Non-irrigated | 17.418 b | 12.752 b |

[1/] Capital letters indicate differences in rows while lower case letters indicate differences in columns. Entries with the same letter are not significantly different at the 5% level.

roots nor even between trees growing on the irrigated and non-irrigated sites. It seems that as long as water is adequate, an excess of water does not necessarily result in a continued increase in the rate of water use. These results indicate that mesquite trees growing on the High Plains of Texas depend primarily on the roots in the upper two feet of soil for absorbing water. However, when soil water becomes limiting in the upper two feet, mesquite depends on the deeper tap root for its survival. A similar conclusion was reached by Easter and Sosebee (1975).

## Density Study

This area was selected for its dense stand of mesquite, approximately 1000 trees per acre. In 1974 diffusion resistances of trees growing on the perimeter of the stand showed no significant difference to those growing in the center of the stand (Figure 11). The apparent transpiration of the marked trees both inside and outside the stand varied in a similar manner throughout the day. Diffusive resistances were generally low in the morning and increased throughout the day as evaporative demands increased. The open bipinnately compound leaf of the mesquite tree results in low canopy density even in stands of high stem density. Solar radiation on the interior of the stand was generally not reduced more than 40%. This type of foliage is also not highly effective as a windbreak. Thus, environmental conditions such as air temperature and relative humidity tended to be similar inside the stand and on the perimeter. In addition there was no significant difference in soil water content between the interior and perimeter of the stand. Due to the similarity of response of trees both inside and outside the stand, this study was not continued in 1975.

## "Spring Tank" Location

This location provided comparison of diffusion resistances between mesquite trees assumed to have a constant supply of ground water because of their proximity (3 to 25 feet) to a spring fed reservoir and those exposed to

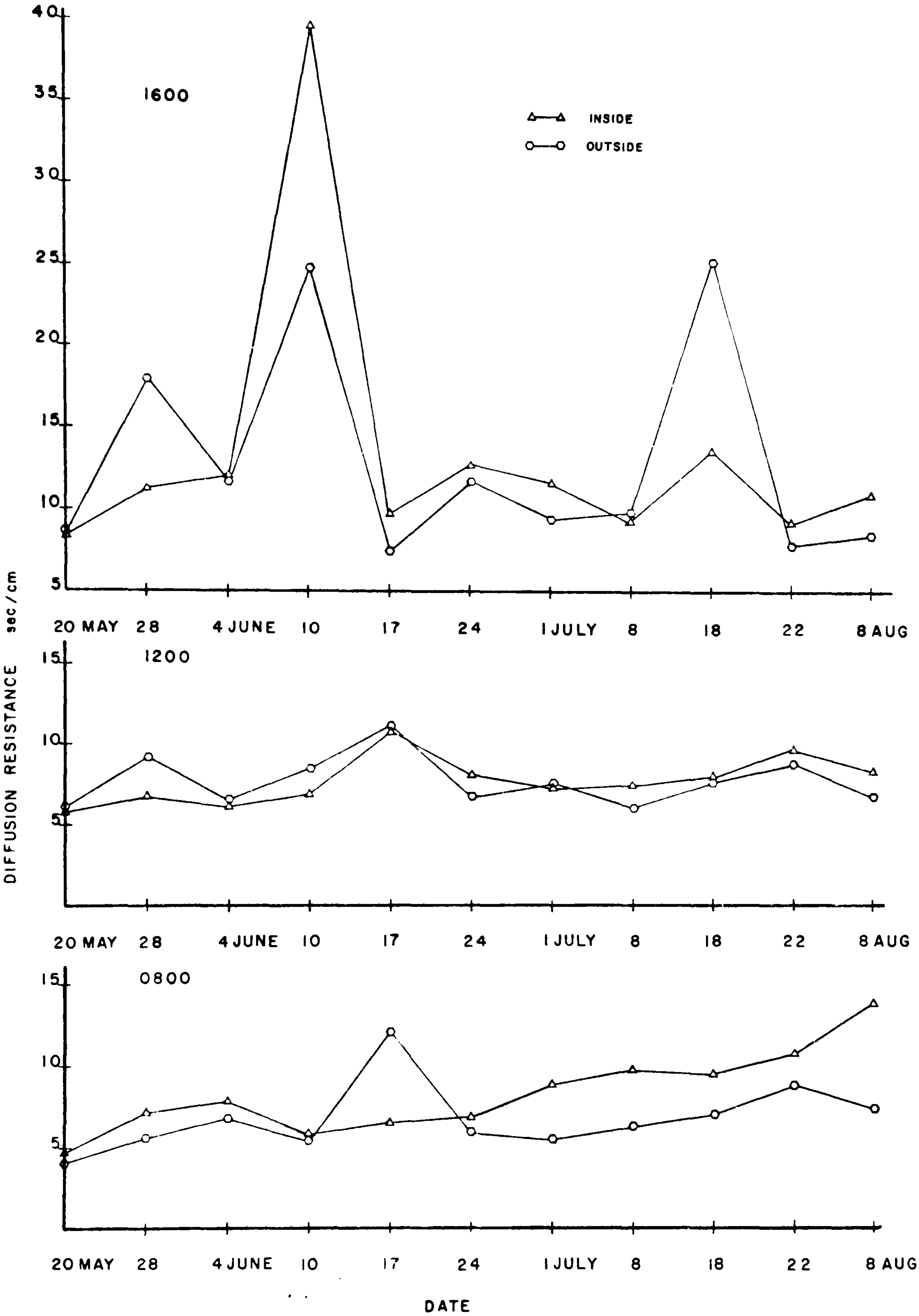


Fig. 11. Diffusive resistances of mesquite trees growing on the perimeter and in the interior of a dense stand of honey mesquite on the Post-Montgomery Estate ranch, 1974.

limited soil water conditions, trees growing on a dry hillside. Precipitation varied greatly between years with the soil on the hillside having an average water content of 2.8% (by weight) in 1974 and increasing to 6.3% in 1975. The soil along side of Spring Tank varied as much, going from an average water content of 6.1% in 1974 to 8.5% in 1975.

At 0800 there was very little difference in the diffusive resistances of trees growing on either area. At noon the trees on the hillside had an increased diffusion resistance (lower apparent transpiration). The trees near Spring Tank also experienced slower apparent transpiration rates; however, the diffusion resistances had not increased as much as in the trees growing on the hillside. During the afternoons when evaporative demands were high the trees on the hillside seemed to stop transpiring almost completely as indicated by high diffusion resistances (Figure 12). In 1975 the difference between areas was slight at all times during the day (Figure 13). In fact, the trees on the hillside had a lower diffusive resistance in the morning than the trees near Spring Tank. Apparently the more exposed trees on the hillside received energy adequate for transpiration sooner and thus began to use water earlier in the day. Trees on both areas responded typically with an increase in diffusive resistance through-

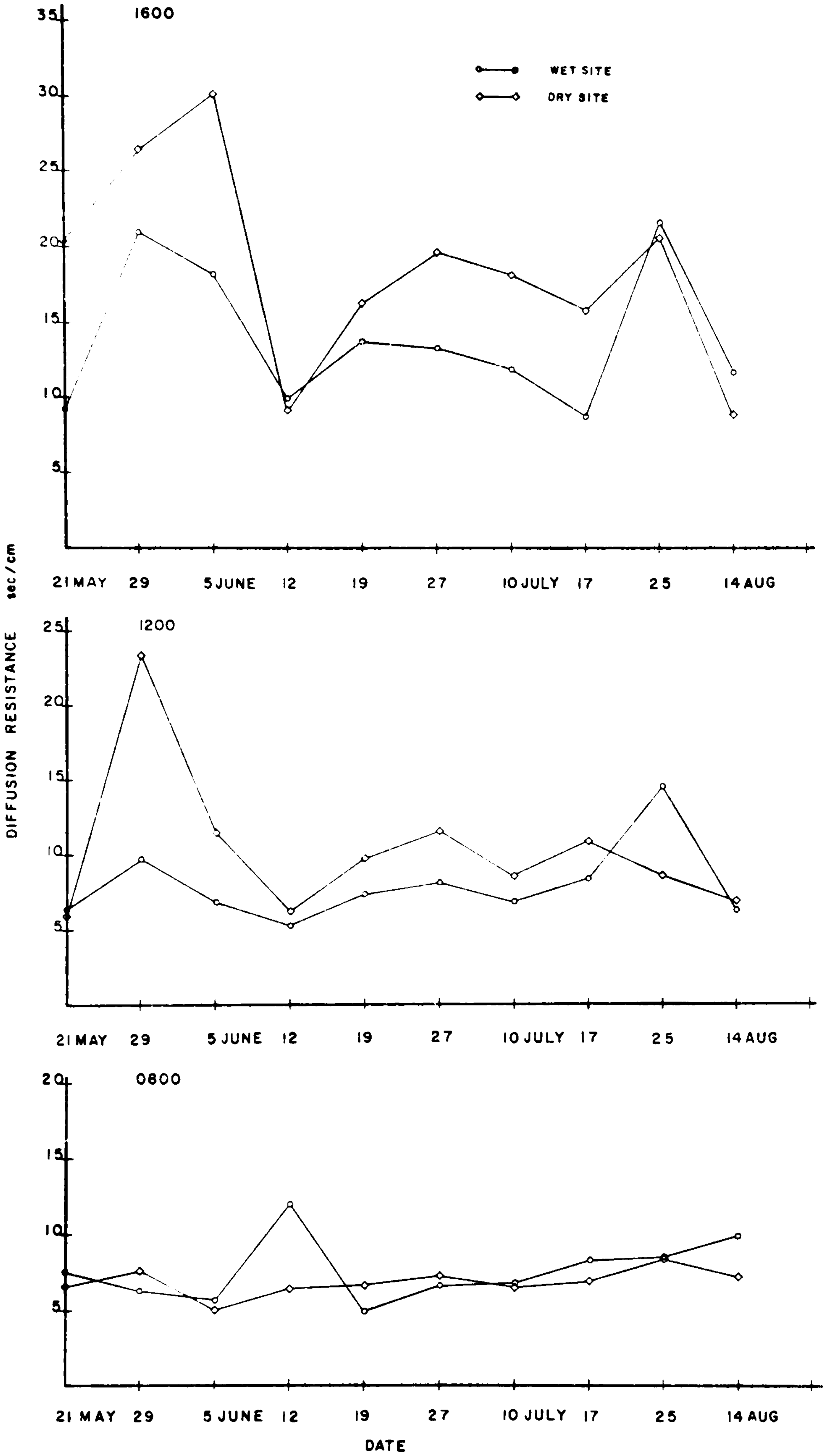


Fig. 12. Diffusive resistances of mesquite trees growing beside Spring Tank (wet site) and on a nearby hillside (dry site) on the Post-Montgomery Estate ranch in 1974.

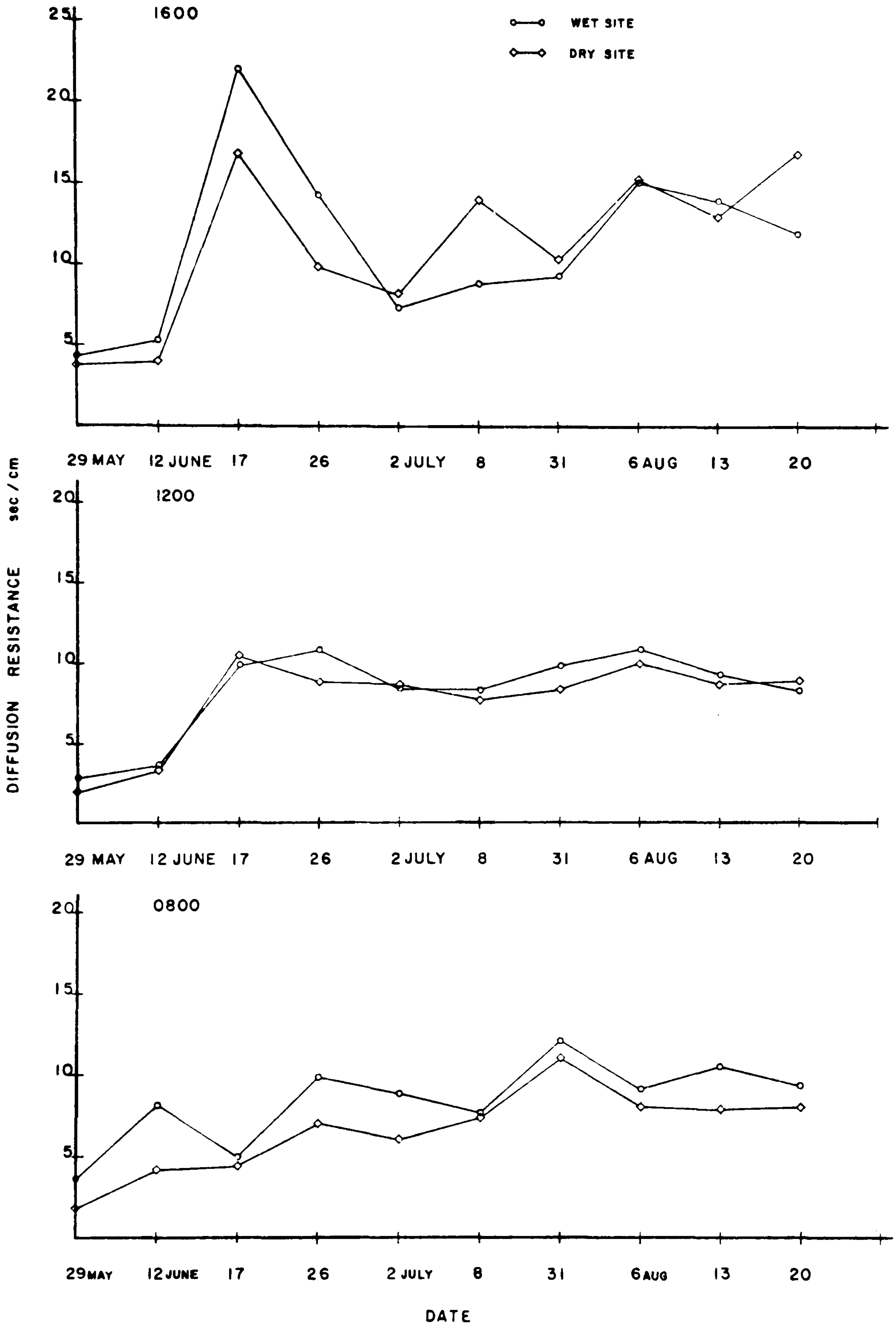


Fig. 13. Diffusive resistances of mesquite trees growing beside Spring Tank (wet site) and on a nearby hillside (dry site) on the Post-Montgomery Estate ranch in 1975.

out the afternoon as the evaporative demand reached a peak. Trees on the hillside had less water available both in 1974 and 1975 and were exposed to greater evaporative demands than the trees at water's edge. Their response was to greatly reduce the rate of water use during the afternoon. In 1975 when the average soil water content on the hillside was about equal to that beside the reservoir in 1974, the hillside trees reacted in much the same manner as the trees near the water in 1974. In 1975, trees on both areas responded similarly. Trees beside the reservoir reduced the rates of water use during the afternoons in both 1974 and 1975 and did not use water as extravagantly as the irrigated trees on the Texas Tech campus. Thus water supply seems to be a limiting factor concerning rate of water use. If sufficient water is not available, evaporative demand can cause large fluctuations in the rate of water use. Conversely when water supply is adequate evaporative demand does not always cause the same type of fluctuations.

Multiple regression analysis indicated the factors with the highest correlation to diffusion resistance may change during the day. On the hillside in 1974 leaf temperature and soil water ($R = .629$) had the highest correlation to diffusion resistance at 0800, but by 1600 leaf temperature and relative humidity were the most important factors (= .894). Beside Spring Tank, air temperature and relative humidity accounted for most of the variation in diffusion resistance at 1600 (R = .857) while air temperature and soil temperature accounted for 66% of the variation in diffusion resistance at noon (R = .815). In 1975, the relative importance of environmental factors beside Spring Tank was unchanged. However, the correlation of air temperature and soil temperature at noon was slightly higher (R = .873) and exactly the same (R = .815) for air temperature and relative humidity at 1600. On the hillside, a different pair of factors assumed importance at each time of day: leaf temperature and soil water content (R = .849) at 0800, air temperature and soil temperature at 12 inches (R = .928) at 1200, and leaf temperature and relative humidity (R = .828) at 1600. These data indicate that various natural factors influencing diffusion resistance may fluctuate in relative importance as conditions change throughout the day.

One additional area was checked at this location in 1974, a site characterized by ground water at a shallow depth. The diffusion resistances of three mesquite trees were measured, and even when the evaporative demand was very high these trees responded very much like the trees near Spring Tank in that transpiration continued throughout the afternoon. Observations of these trees were continued in 1975, but there was no significant difference between diffusion resistances of the trees at this location and the trees near Spring Tank. It appears that even the trees with a source of ground water limit the rate of water use as evaporative demand increases.

## Thinning Study Location

Trees were marked and diffusion resistances were measured at this location to determine the effect of density and canopy cover on transpirational water loss by mesquite.

Early in the summer of 1974 the trees on this site were heavily damaged by hail with as much as 75% defoliation up to 80% by insects. However, the insect damage was not as extensive throughout the stand as the hail damage had been and most trees recovered from the insect defoliation by mid-summer, aided by abundant rainfall. This defoliation may have affected transpiration rates, but measurements were continued throughout both summers. Trees in the four thinning treatments showed no significant differences in diffusion resistances. Daily transpiration patterns were typical of other sites, i.e. declining rates (indicated by increasing diffusive resistances) from noon to 1600 with amount of decline depending upon evaporative demand and soil water supply. The comparisons between thinning treatments supported the density study results of the other location in that no significant differences were observed between different densities. Therefore, the amount of water lost from mesquite per unit leaf area is not necessarily dependent upon density of the stand.

## Diffusive Resistance of Abaxial and Adaxial Surfaces

In order to determine the total water loss of a leaf of leaflet by transpiration it is necessary to know if transpiration occurs at the same rate from both surfaces. Two trees were selected at Spring Tank in 1974 and diffusion resistances of abaxial and adaxial leaf surfaces were measured at 1000 and 1400. There was no significant difference between the diffusion resistances of the two surfaces in the morning. In the afternoon the differences were noticeably increased with the adaxial surfaces having the greater diffusion resistances (less apparent transpiration). However, the differences were not significant. Thus, there would seem to be no real difference between water loss by transpiration of abaxial and adaxial surfaces.

## Diurnal Transpiration Patterns

Diurnal transpiration patterns of mesquite, alfalfa (*Medicago* sp.), corn (*Zea mays*), and vine mesquite (*Panicum obtusum*) were observed during the summer and fall 1974. As long as soil water was available mesquite transpired most actively between 2 hours after sunrise until about 2 hours before sunset with the rates generally declining gradually from a peak around mid-day (Figures 14 and 15). A sharp decrease usually started about 2 hours prior to sunset. However, when soil water was limited the sharp decline began by mid-morning and transpiration nearly ceased by 1800 as indicated by the July 15, 1974 observations (Figure 14). The field crops and native grasses observed were all irrigated, thus their response to dry soil was not measured.

All species studied tended to start transpiring earlier, to maintain a higher rate during the day, and to continue longer than any of the mesquite trees. In the 24 hour observation made in 1975 it was noted that alfalfa had an especially long period of transpiration, starting earlier and continuing longer than any of the other species. None of the species had measurable activity during the night except alfalfa which start transpiring about 2 hours before sunrise (Figure 16). The observations taken in late October 1974 indicated that transpiration had begun 1 hour after sunrise and continued at a more or less constant rate until sunset (Figure 14). On this date alfalfa had a higher transpiration rate throughout the day, but the pattern was similar to that of mesquite. It appears that as day length becomes shorter mesquite transpires during a greater percentage of the hours of actual sunlight.

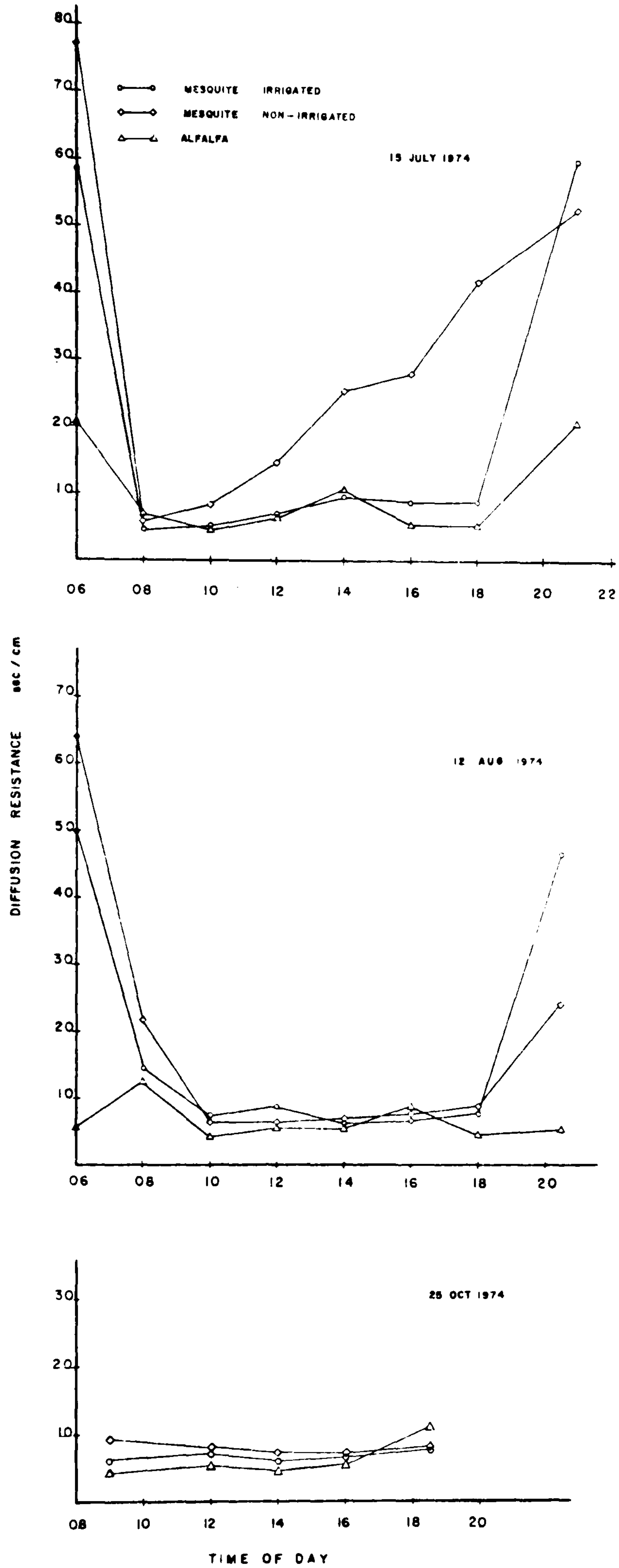


Fig. 14. Diffusive resistances of irrigated and non-irrigated mesquite trees and irrigated alfalfa during pre-dawn to post-dusk observations of plants growing on the Texas Tech University campus.

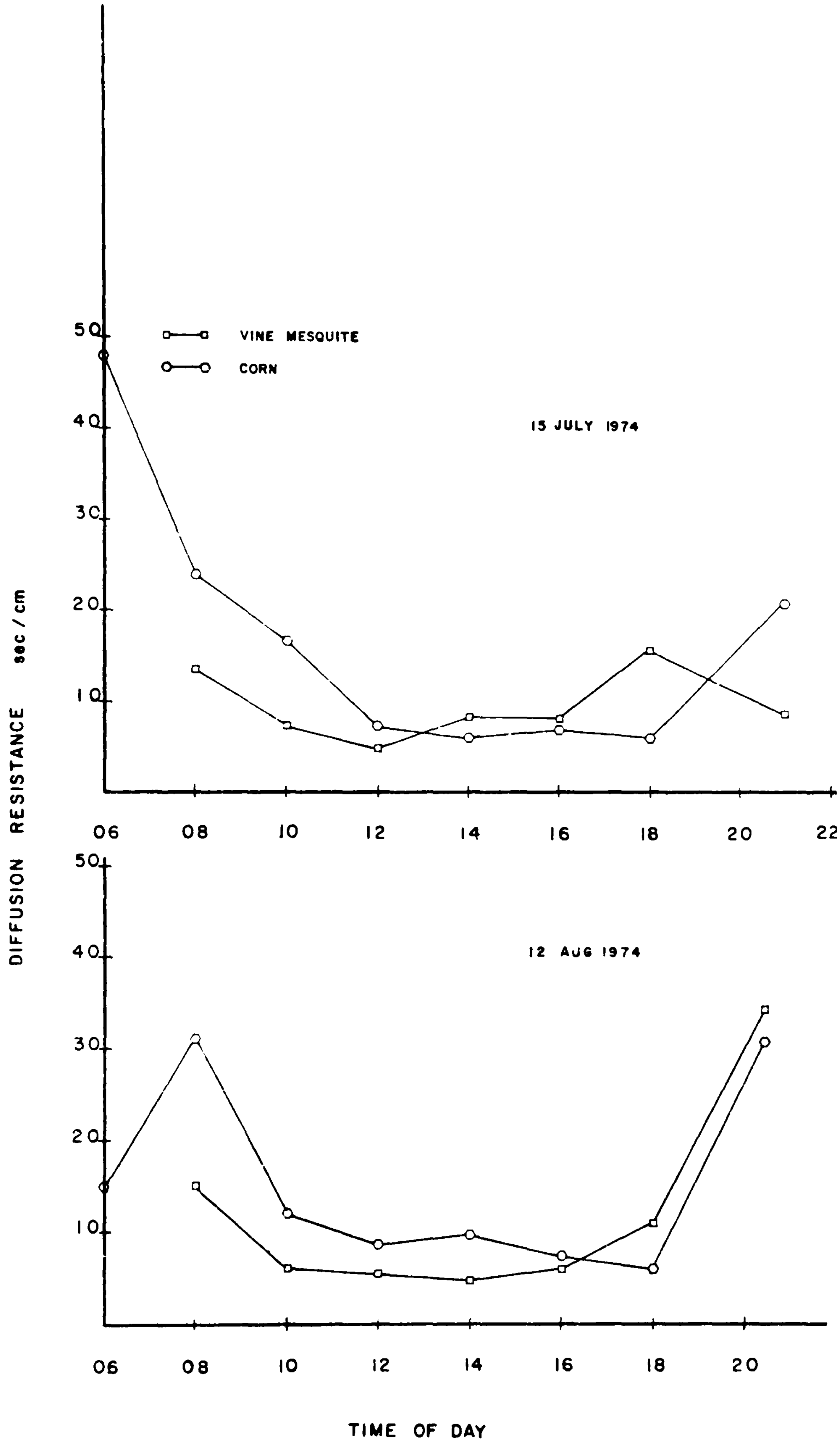


Fig. 15. Diffusive resistances of native grass and field corn during pre-dawn to post-dusk observations of plants growing on the Texas Tech University campus.

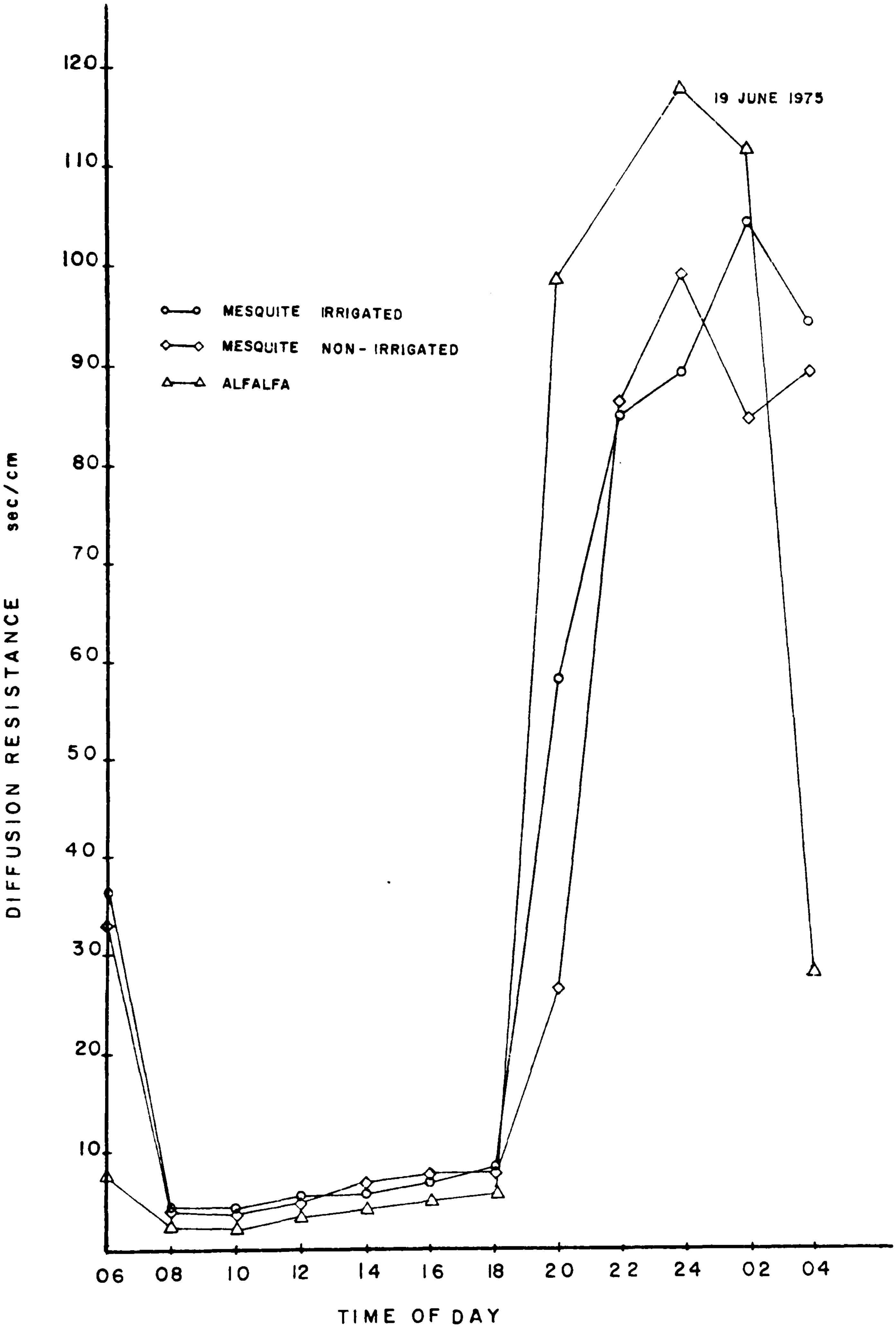


Fig. 16. Diffusive resistances of irrigated and non-irrigated mesquite trees and irrigated alfalfa during a 24 hour period of plants growing on the Texas Tech University campus.

# CHAPTER V

# SUMMARY AND CONCLUSIONS

Increased water yield is often expected as a result of mesquite control. Yet, information is lacking concerning the influence of site characteristics on water loss by mesquite. Therefore, this study was designed to provide information about environmental factors which influence transpirational water loss by honey mesquite.

## Environmental Factors

The comparison of information from wet and dry sites, both naturally and artificially irrigated, indicates that mesquite transpiration varies with soil water content. During days when evaporative demand was greatest, diffusion resistance in trees on the dry sites would greatly increase, thereby reducing transpiration. On these same days, however, trees on the irrigated site continued transpiring at an almost constant rate. The diffusion resistances of trees near Spring Tank increased on these days, but not nearly as much as that of trees on the adjacent dry sites. During 1975 when precipitation was more plentiful there was very little difference between the diffusion resistances of trees on any site. In addition, stand density had no relationship to diffusion resistance. Trees in the center of the most dense stand available (1000 trees/acre) had diffusion resistances no different from those on the stand exterior. Also stands thinned to various percentages of canopy cover had no significant differences in diffusion resistances.

The environmental factors most related to transpiration varied with the time of day and with soil moisture. Thus, on a wet site, air temperature and/or leaf temperature plus relative humidity would be the most important throughout the day, but on the dry site, combinations of various environmental factors including soil temperature would be highly correlated with transpiration. Wind is a factor that tended to be more important in the morning but would lose significance as radiant energy and actual air temperature became excessive. Altogether, it would seem that the transpiration rate is not dependent on one factor alone but upon a combination of factors. This combination may vary throughout the day, and the relative importance of each single factor varies as conditions change. Soil water seems to be a dominant factor, but total transpiration is due to a complex interrelationship of all factors.

## Plant Factors

To help understand the response of mesquite to environmental influences, observations were taken to determine diurnal transpiration patterns, dependence on tap roots and transpiration from adaxial and abaxial leaf surfaces.

Transpiration rates followed a distinct daily pattern on both wet and dry sites. Transpiration started very slowly about sunrise, increased to a maximum rate about 1200 and decreased slowly the remainder of the day until a sharp decrease started around two hours prior to sunset. The transpiration of trees growing where soil water was limited peaked earlier than 1200 and the rate decreased much more rapidly throughout the remainder of the day. The diffusion resistances of mesquite with adequate moisture were higher and the periods of transpiration were shorter than the sampled field crops and grasses. When soil water was abundant mesquite apparently transpired most in early summer and thereafter decreased during the remainder of the summer. No noticeable transpiration was observed at night. Transpiration was approximately the same from both surfaces of the leaf.

It was difficult to determine dependence on a tap root in just two years. During the first year when soil water was limited there was a significant difference between the transpiration rates of trees with cut and uncut tap roots on the non-irrigated site. The next year there was more precipitation and there were no significant differences in apparent transpiration. Trees on the irrigated site never showed significant differences. This leads to the hypothesis that the tap root is not necessary during wet years, but in dry years it contributes significantly to drought tolerance and thus survival. If this is true mesquite may be categorized as a facultative phreatophyte.

The water use habits of mesquite appear to be such that thinning for water yield alone may not be feasible. Also, relative water loss per unit area of leaf surface indicates complete control of medium density stands on native, dry range sites may not yield an increase in soil water. However, in areas where mesquite is phreatophytic or has a supplemental source of water, control might be expected to increase water yield enough to be profitable.

## LITERATURE CITED

Anonymous. 1962. Research in plant transpiration. U.S. Dep. Agr. Production Research Report no. 87, 8p.

Beardsell, M., K. Mitchel, and R. Thomas. 1972. Effects of water stress under contrasting environmental conditions on transpiration and photosynthesis in soybean. J. Exp. Bot. 24 (80); 579-586.

Breazeale, E. L., W. T. McGeorge, J. F. Breazeale. 1950. Moisture absorption by plants from an atmosphere of high humidity. Plant Physiol. 25:413-419.

Campbell, C. J., and C. P. Pase. 1972. Pressure bomb measures changes in moisture stress of birchleaf mountain-mahogany after partial crown removal. U.S. Dep. Agr. Forest Service Res. Note RM-221. 6p.

Cary, J. W., and J. L. Wright. 1969. Response of plant water potential to the irrigated environment of southern Idaho. Agron. J. 63:691-695.

Decker, W. L. 1966. Potential evapotranspiration in humid and arid climates, p. 23-26. In, Evapotranspiration and its role in water resources management. Am. Soc. Agr. Eng. Conf., Proc.

Degarmo, C. H. 1966. Water requirement and production of desert plant species under four soil moisture levels. M.S. Thesis. New Mexico State Univ. Las Cruces, New Mexico. 63p.

Denmead, O. T., and O. T. Shaw. 1962. Availability of soil water to plants as affected by soil moisture content and meteorological conditions. Agron. J. 54:385-389.

Eagleman, J. R., and W. L. Decker. 1965. The role of soil moisture in evapotranspiration. Agron. J. 57:626-629.

Easter, S. J., and R. E. Sosebee. 1975. Influence of soil-water potential on the water relationships of honey mesquite. J. Range Manage. 28:230-232.

Grendel, I. 1971. Transpiration in three eucalyptus species as a function of solar energy, soil moisture, and leaf area. Physiol. Plant. 24:143-149.

Haas, R. H., and R. E. Steiger. 1965. Evaluation of environmental factors influencing growth of mesquite. Southern Weed Conf., Proc. 18:633-640.

Hibbert, A. R., E. A. Davis, and D. G. Scholl. 1974. Chaparral conversion potential in Arizona. Part I. Water yield response and effects on other resources. U.S. Dep. Agr., Forest Service Res. paper RM-126. 36p.

Hill, L. W., and R. M. Rice. 1963. Converting from brush to grass increases water yield in southern California. J. Range Manage. 16:300-305.

Kanemusu, E. T., and C. B. Tanner. 1969. Stomatal diffusion resistance of snap beans. II. Effect of light. Plant Physiol. 44:1542-1546.

Kanemusu, E. T., G. W. Thurtell, and C. B. Tanner. 1969. Design, calibration, and field use of a stomatal diffusion porometer. Plant Physiol. 44:881-885.

Kramer, P. T. 1956. Physical and physiological aspects of water absorption. Encyclopedia of Plant Physiology. 3:124-159.

Lemon, E. R., A. H. Glaser, and L. E. Satterwhite. 1957. Some aspects of the relationship of soil, plant, and meteorological factors to evapotranspiration. Soil Science Soc., Proc. 21:464-468.

Lety, J., and G. B. Blank. 1961. Influence of environment on the vegetative growth of plants watered at various soil moisture suctions. Agron. J. 53:151-153.

Lopushinsky, W., and G. O. Klock. 1974. Transpiration of conifer seedlings in relation to soil water potential. Forest Sci. 2:181-186.

Marrow, P. A., and R. C. Slatyer. 1971. Leaf resistance measurements with diffusion porometers; precautions in calibration and use. Agr. Meteorol. 8:223-233.

Martin, E. V. 1940. Effect of soil moisture on growth and transpiration in sunflower. Plant Physiol. 15: 449-466.

McGinnies, W. G., and J. F. Arnold. 1939. Relative water requirements of Arizona range plants, In Ariz. Agr. Exp. Sta. Tech. Bull., 80.

Nkemdirim, L. C., and P. E. Haley. 1973. An evaluation of grassland evapotranspiration. Agr. Meteorol. 11: 373-383.

Penman, H. L. 1956. Evaporation: an introductory survey. Neth. J. Agr. Sci. 4:9-29.

Rechenthin, C. A., and H. N. Smith. 1967. Grassland restoration: Effect on water yield and supply. U.S. Dep. Agr., Soil Conservation Service. 23p.

Rich, L. R. 1952. Forest and range vegetation. Am. Soc. Civil Eng. Trans. 117:974-990.

Robinson, T. W. 1965. Phreatophytes. Geological Survey water-supply paper 1423. 28p.

Robinson, T. W. 1970. Evapotranspiration by woody phreatophytes in the Humboldt river valley. Geological Survey Professional Paper 491-D. 14p.

Rowe, P. B., and L. F. Reimann. 1961. Water use by brush, grassforb vegetation. J. Forestry. 59: 175-180.

Shreve, E. C. 1923. Seasonal changes in the water relations of desert plants. Ecology. 4:266-292.

Stone, E. C. 1965. Role of dew in pine survival in soil below the wilting point and its measurement, p. 41, In F. Eckart (ed.). Methodology in Plant Ecophysiology. Proceedings of the Montpellier Symposium. p. 41.

Sucoff, E. 1969. Water potential in red pine. Ecology. 53:526-528.

Taylor, C. A. 1934. Transpiration and evaporation losses from areas of native vegetation. Amer. Geophys. Union, Trans. 1934:554-563.

Taylor, S. A., and G. L. Ashcroft. 1964. Influence of advective energy on transpiration. Agron. J. 56: 139-142.

Thornthwaite, C. W., and J. R. Mather. 1955. The water balance: published in Climatology. 8:1-104.

Van Bavel, C. H. M., F. S. Nakayama, and W. L. Ehrler. 1964. Measuring transpiration resistance of leaves. Plant Phys. 40:535-540.

Van Hylckama, T. E. A. 1969. Winds over salt cedar. Agr. Meteorol. 7:217-233.

Van Hylckama, T. E. A. 1963. Growth development and water use by salt cedar under different conditions of weather and access to water. Int. Assn. Sci. Hydrol., pub. 62. 12p.

Van Hylckama, T. E. A. 1970. Water use by salt cedar. Water Resources Res. 6:8-12.

Veihmeyer, F. J. 1953. Use of water by native vegetation versus grasses and forbs on watersheds. Amer. Geophys. Union, Trans. 34:201-212.

Veihmeyer, F. J., and A. H. Hendrickson. 1955. Does transpiration decrease as soil moisture decreases? Amer. Geophys. Union, Trans. 36:425-448.

Wendt, C. W. 1966. A study of techniques to measure and environmental variables influencing the water relations of mesquite. Ph.D. Diss. Texas A & M Univ., College Station, Texas 95p.

Wendt, C. W., R. H. Haas, and J. Runkles. 1967. Influence of selected environmental variables on the transpiration rate of mesquite. Agron. J. 60:382-384.

Whitehead, F. H. 1961. Experimental studies of the effect of wind on plant growth and anatomy. New Phytol. 61:59-62.

Whiteman, P. C., and D. Koller. 1967. Interactions of $CO_2$ concentration, light intensity, and temperature on plant resistances to water vapour and $CO_2$ diffusion. New York Phytol. 66:463-473.

Yang, S. J., and E. deJong. 1972. Effect of aerial environment and soil water potential on the transpiration and energy status of water in wheat plants. Agron. J. 64:574-578.