WATER YIELD IMPROVEMENT FROM RANGELAND WATERSHEDS

Annual Progress Report

to

Texas Water Development Board
Contract No. IAC (86-87) 0940

and

Texas Agricultural Experiment Station Expanded Research
Project No. 15570 6190-2140

W. H. Blackburn, Professor, Coordinator
R. W. Knight, Assistant Professor
C. A. Call, Assistant Professor
R. K. Heitschmidt, Associate Professor
R. J. Ansley, Post-Doctoral Research Associate
D. L. Price, Visiting Assistant Professor
J. W. Holloway, Professor
M. A. Weltz, Graduate Research Assistant
J. D. Franklin, Graduate Research Assistant
R. A. Hicks, Graduate Research Assistant
P. A. Julien, Graduate Research Assistant
G. L. Holmstead, Graduate Research Assistant
T. A. Wright, Technician
S. L. Dowhower, Research Associate
B. O. Spoonts, Research Associate

Data presented in this report have not been completely analyzed and are subject to change, results are preliminary and should be interpreted as such.

January 1987

TABLE OF CONTENTS

INTRODUCTION

Approximately 66% of Texas lands are classified as rangelands. These rangelands are often dominated by a mixture of shrub species which have been estimated to transpire and evaporate approximately 38% of the state's available water. It is hypothesized that water yields from these rangelands will increase following removal of shrubs. It is also hypothesized that water yields can be dramatically altered as a function of type of herbaceous plant community. Previous research has shown that both runoff and sediment production are greater in shortgrass dominated communities than in midgrass dominated communities. Research has also shown that various grazing management strategies can alter the species composition of plant communities relative to the abundance of short- and midgrasses. This research project is designed to evaluate the influence of vegetation manipulation on the hydrologic processes of Texas rangelands, with emphasis on off- and on-site water yields.

The research objectives are: 1) to determine the water balance of shrub/grass dominated sites as influenced by vegetation manipulation; 2) to determine the water use efficiency of brush and grass species on managed/mixed grass sites; and 3) to quantify aboveground herbaceous growth dynamics and belowground biomass of shrub/grass dominated sites.

The following research report represents the progress made during FY 1986. Results are reported from four study locations: 1) Wagon Creek Spade Research Areas located 5 km north of the Texas Experimental Ranch in Throckmorton County; 2) Lyles Ranch located 30 km west of Uvalde; 3) Annadale Ranch located 32 km northeast of Uvalde near Concan; and 4) the La Copita Research Area located 20 km south of Alice.

During 1986 the following professionals were brought to campus to take part in our distinguished lecture series and review this expanded research effort: 1) Ron Hibbert, Hydrologist, USDA-FS, Tempe, AZ; 2) James Patric, Hydrologist, USDA-FS, retired; 3) Merrill Kaufmann, Plant Physiologist, USDA-FS, Ft. Collins, CO; 4) Ross Wight, Range Scientist, USDA-ARS, NWRC, Boise, ID; and 5) Leonard Lake, Hydrologist, USDA-ARS, Tucson, AZ. The inputs of these scientists were used to solidify and guide the program's research objectives and approach. All reviewers were very complementary of this research effort.

This project is presently active in the data collection phase. Great care should be taken with the actual interpretation of results presented in this report and by no means should they be considered final.

WAGON CREEK SPADE STUDY AREA

The research area is part of the Rolling Plains Resource area which consists of 6.3 million hectares of rolling to nearly level uplands and broad valleys. The research site is located on a Nuvalde silty clay loam (1-3% slopes) soil series normal precipitation for the area is 679 mm. The dominant midgrasses are sideoats grama (Bouteloua curtipendula), a warm season midgrass, and Texas wintergrass (Stipa leucotricha), a cool season midgrass. The shortgrass interspaces are dominated by common curly mesquite (Hilaria belangeri) and buffalograss (Buchloe dactyloides). A dense stand of single stemmed honey mesquite (Prosopis glandulosa) trees encompass most of the research area as well as the rolling plains.

The Influence of Vegetation on the Water Budget

J.D. Franklin, R.W. Knight, W.H. Blackburn, R.K. Heitschmidt and T.A. Wright

Summary

Soil water, surface runoff and deep drainage in both weighing and non-weighing lysimeters was determined for each soil profile from September 1985 through September 1986. In the weighable lysimeters, four treatments were compared: bareground, common curlymesquite-buffalograss (a warm season shortgrass mixture), sideoats grama (a warm season midgrass) and Texas wintergrass (a cool season midgrass). Total soil water content varied seasonally between treatments. Bareground treatments maintained higher soil water content across all horizons analyzed. Soil water content in the bareground treatments were greater for all soil layers at the end of the study period than at the beginning. Soil water content in the sideoats grama lysimeters were consistently lower than the other treatments considered, except for February and March when soil water was the lowest in the Texas wintergrass lysimeters.

Non-weighable lysimeters were used to compare soil water content under three treatments. Treatments were bareground, herbaceous vegetation only, and honey mesquite with herbaceous vegetation. As found with the weighing lysimeters, the bareground lysimeters maintained greater soil water content than all other treatments and soil water was greater at the end of the study than at the beginning. Soil water content in the upper 1.30 m of the soil profile was generally less in the herbaceous lysimeters than in the mesquite lysimeters. However, soil water from 1.30 to 2.38 m in the profiles the mesquite lysimeters were lower in soil water content than the herbaceous lysimeters. The mesquite lysimeters contained less soil water content than the herbaceous lysimeters when the entire soil profile was considered. Soil

water content in the herbaceous lysimeters was greater than the other treatments in the soil layer below the bottom of the lysimeters (2.38 to 3.28 m). The mesquite and bareground lysimeters had very similar soil water content. Soil water content (0 to 3.28 m) in the mesquite lysimeters was lower than the herbaceous lysimeters, which was than the bareground lysimeters.

Runoff was greatest from the bareground lysimeters, intermediate from the shortgrass treatment and lowest in the warm and cool season midgrass lysimeters. Runoff from the non-weighable lysimeters was greater for the bareground treatment, intermediate for the mesquite treatments and least from the grass treatments.

Methodology

The water budget in a stand of plants and in the soil penetrated by their roots is expressed by the water balance equation:

$$WY = P - ET \pm S$$

where: WY = water yield of surface and subsurface flows, and any percolation to ground water, P = total precipitation received on the site, ET = evapotranspiration, including interception losses by vegetation and litter, S = change in soil water storage. Components of the water balance equation were collected for a characteristic brush-grassland site using weighable and non-weighable lysimeters.

Nine weighable and nine non-weighable lysimeters were instrumented on the Wagon Creek Spade Ranch located approximately 3 miles north of the Texas Experimental Ranch, in the spring and summer of 1985. An additional three weighing lysimeters were installed in January, 1986. Nine mature mesquite trees and associated grass vegetation were encircled with plastic sheets to form non-weighable lysimeters by trenching around an approximate 6x6 m area to a depth of 2 m. Mesquite trees in six of the non-weighable lysimeters were removed by hand slashing and the stumps treated with 1 l of diesel oil to prevent resprouting but allowing herbaceous growth. Three of these lysimeters were treated with tebuthiuron to maintain a bare soil surface. Three of the twelve weighing lysimeters contained common curly-mesquite and buffalograss (a warm season shortgrass mixture), three were sideoats grama (a warm season midgrass), and three were dominated by Texas wintergrass (a cool season midgrass).

A weather station on the study site records precipitation (mm), wind run (m/s), maximum and minimum atmospheric temperature (C), relative humidity (%), total radiation (mv/kw/m^2), and soil temperature (C) at 0.1 m and 0.5 m depths. A standard rain gauge was later installed to provide a check for the continuous recording tipping bucket.

Soil water content of each lysimeter was measured with a neutron probe. Soil moisture readings were taken twice monthly until January 1986 and weekly thereafter. Actual runoff from each lysimeter was measured after each precipitation event. Runoff in the non-weighing lysimeters was measured by pumping accumulated runoff from a reservoir through a water meter which measured gallons of runoff.

Deep drainage will be calculated for each lysimeter by determining the unsaturated hydraulic conductivity and then the flux of water movement between the bottom two layers of the lysimeter.

Soil texture, soil structure, desorption curves, hydraulic conductivity, bulk density, aggregate stability, air dry, and organic matter was determined for each horizon in the lysimeters. Soil texture was determined by particle size distribution (Bouyoucas, 1962). Desorption curves were determined using a pressure plate apparatus (Klute 1965a). Hydraulic conductivity was determined by methods outlined by Klute (1965b). Aggregate stability was determined by the wet sieve method (Kemper 1965). Organic matter content was determined by the Degtjareff method (Walkley and Black, 1934).

Volumetric water contents were measured at five different depths in the weighing lysimeters and ten in the non-weighing lysimeters. One access tube for soil moisture readings was placed in each weighing lysimeters and four tubes were installed in each non-weighing lysimeter. Later, a fifth tube was installed in each non-weighing lysimeter. The fifth tube was placed as close as possible to the mesquite tree to determine if soil water was lower near the tree versus in the grass interspace. Volumetric water content on a per period basis and by tube was plotted against depth to determine any differences between tubes on the non-weighing lysimeters. Mean volumetric water content from each lysimeter was then determined. Volumetric water content was plotted by period against depth on a treatment basis to determine differences between replications, and finally treatments were plotted with volumetric water content against depth.

Total soil water (mm) in the lysimeter profiles was determined by weighting each volumetric reading by the proportion of soil depth in the profile corresponding to it. Layers were combined according to what was felt significant differences from the volumetric water content versus depth plots. For the weighing lysimeters, layers of 0 to 0.28 m, 0.28 to 0.65 m, 0.65 to 1.04 m and 0 to 1.04 m were used. For the non-weighing lysimeters, layers of 0 to 0.49 m, 0.49 to 1.30 m, 1.30 to 2.38 m, 2.38 to 3.28 m, 0 to 2.38 m and 0 to 3.28 m were used.

Runoff

Runoff data were taken from each weighing and non-weighing lysimeter after each precipitation event. Runoff on the weighing lysimeters was measured in ml. Runoff on the non-weighing lysimeters was measured in gallons and converted to ml. Runoff was then converted to cm by dividing the volume by the surface area of the lysimeter. Mean runoff values from both weighing and non-weighing lysimeters were accumulated over time by treatment. Accumulated runoff was expressed in mm by multiplying all values by 10.

Soil Characteristics

Soil characteristics were placed on each lysimeter according to the depth at which the neutron probe soil moisture readings were taken. Readings which occurred in the same horizon were given the same soil lab analysis. This allowed for comparisons of soil characteristics between each type of lysimeter at each neutron probe reading.

Analysis

Data will be evaluated based on a randomized complete block design. Data will be analyzed on a per period basis due to variability in climatic conditions from date to date. An analysis of variance will be conducted to determine differences between soil water content, deep percolation, runoff, evapotranspiration, and soil characteristics. Duncan's multiple comparison test will be used to separate means (Steele and Torrie 1980).

Results and Discussion

Total precipitation recorded on the research area was 656 mm for the one year collection period (September 1985 through September 1986). The twenty-five year average from the Texas Experimental Ranch is 679 mm. Monthly totals (Figure 1) were lower than normal precipitation during September, October and December of 1985 and January, February, March and July of 1986. Higher than normal precipitation was received during November of 1985 and April, May, June and August of 1986.

Soil water in the top 0.28 m of the weighing lysimeters varied seasonally by species (Figure 2). At the beginning of data collection, the common curlymesquite-buffalograss (CMB) lysimeters had the least soil water content with sideoats grama (SOG) containing next highest and the bareground (BG) highest. This was 3 months after treatments were applied to the lysimeter. This trend continued until February. The Texas wintergrass lysimeters (TWG) were installed in January and soil moisture collection began in February. Soil water in the TWG lysimeters was much lower than the other three treatments. Both the CMB and SOG lysimeters were dormant and contained approximately equal soil water content. This trend continued until mid-April. At this time, both CMB and SOG were actively growing. The SOG and TWG lysimeters contained very similar soil water contents with the CMB lysimeter being greater from mid April to June. Soil water in the TWG and CMB lysimeters during June were equal but was lower in the SOG lysimeters. Soil water increased in the BG treatment until mid-August and it was greater than at the beginning of the study.

Total soil water (0.28 and 0.65 m) for the BG and CMB treatments in the weighable lysimeters shows were similar until mid-March (Fig. 3). The SOG treatment had lowest total soil water content throughout the data collection

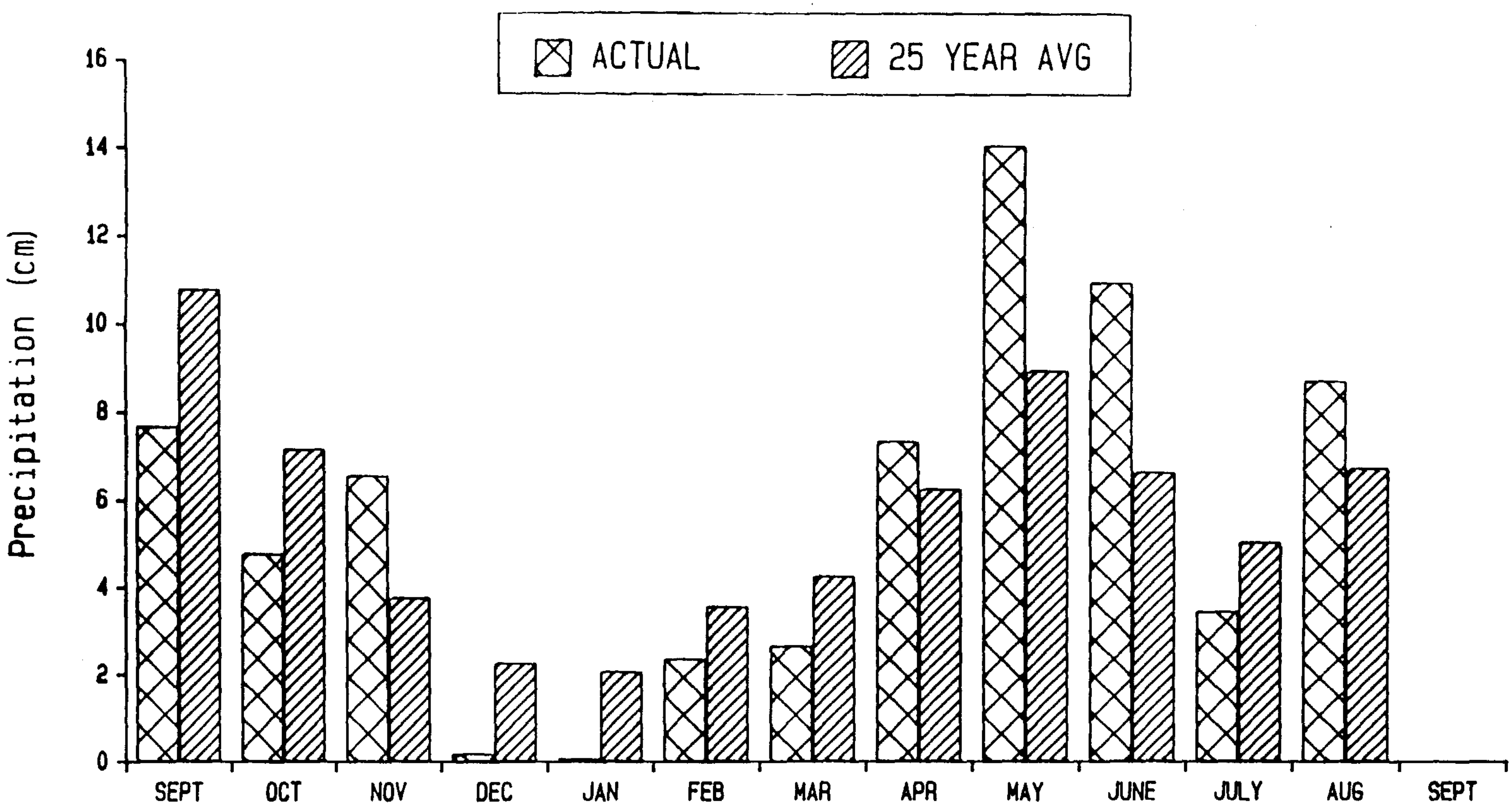

Figure 1. Monthly precipitation, Wagon Creek Spade Watershed Research Area.

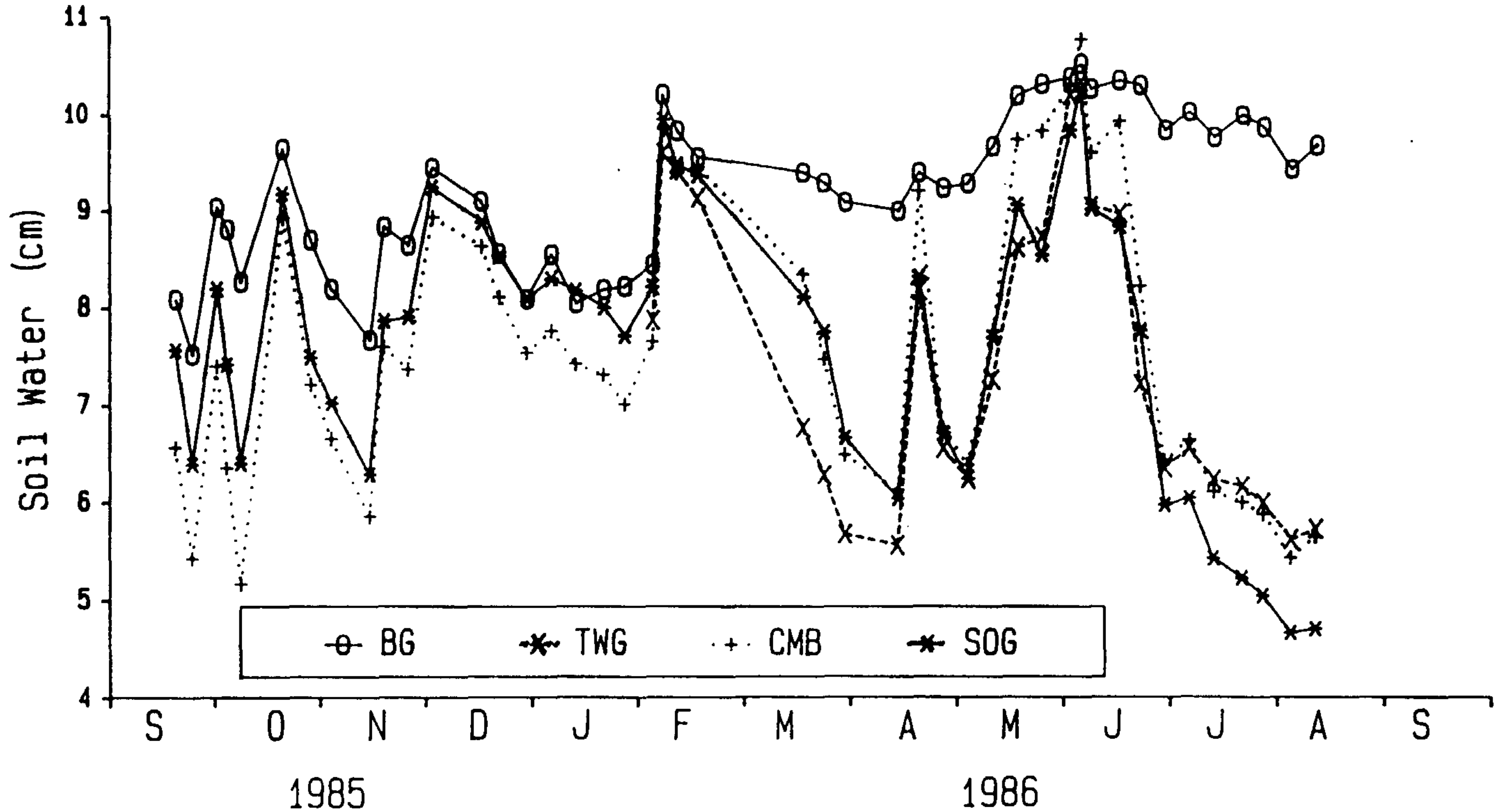

Figure 2. Total water in top 28 cm of the weighing lysimeters, Wagon Creek Spade Watershed Research Area.

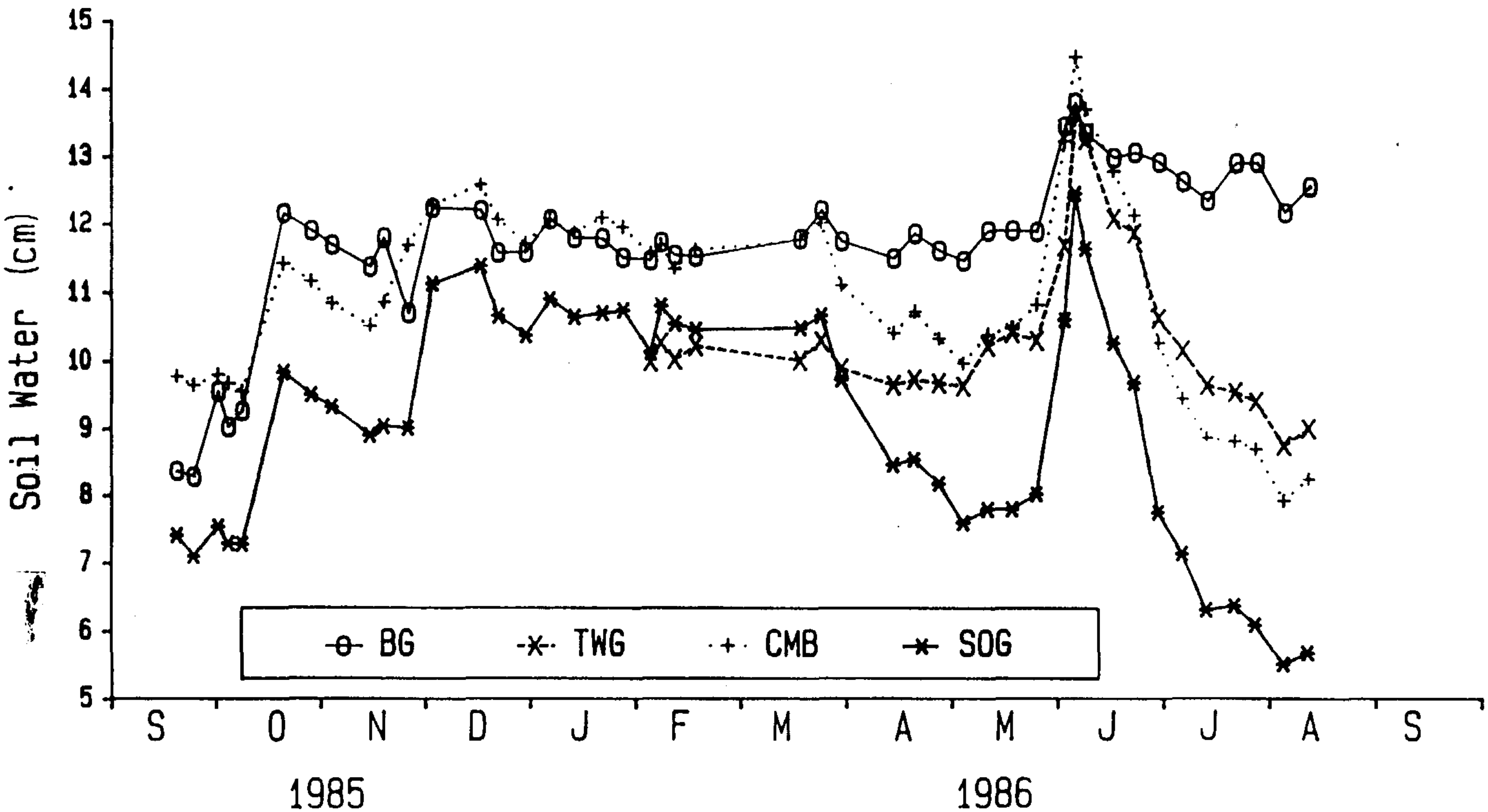

Figure 3. Total water between 20 cm and 65 cm of the weighing lysimeters, Wagon Creek Spade Watershed Research Area.

period except for the February to mid-March when the cool season grasses (TWG) were actively growing. From April to July the CMB treatments contained higher soil water content than did the TWG treatment. In July, the treatments reverse with the shortgrass containing less soil water content than the cool season treatments. Soil water (0 to 0.28 m)was greater than at the beginning of the study.

Total soil water (0.65 m to 1.04 m) for the treatment SOG had the lowest soil water throughout the year (Fig. 4). The TWG treatment soil water content was lower than the CMB treatment until May or June, but during July and August soil water was greater in the CMB than in the TWG treatment. Soil water (0.65 to 1.04 m) for the BG treatment increased over the study period.

Total soil water from 0 to 1.04 m was highest in the bareground treatment (Fig. 5). The CMB treatments had higher soil water content than the TWG and SOG treatments until July when the TWG treatment had lower total soil water from February to late March than all other treatments. In late March, the TWG moved in between the CMB and SOG treatments until July when it was replaced by the CMB treatment. The SOG contained lowest soil water across the entire collection period except for February and March when the TWG grass was actively growing and maintained lower soil water.

Total water in the top 0.49 m of the non-weighing lysimeters was highest in the bareground (BG) treatment than all other treatments (Figure 6). The herbaceous (G) and mesquite (M) treatments show similar soil water content until late June when the G treatment separates out with lower soil water content.

Total water between 0.49 and 1.30 m (Fig. 7) was highest in the BG treatment and increased in total soil water content over time. Soil water content of the G treatment was lower than the M treatment for most of the

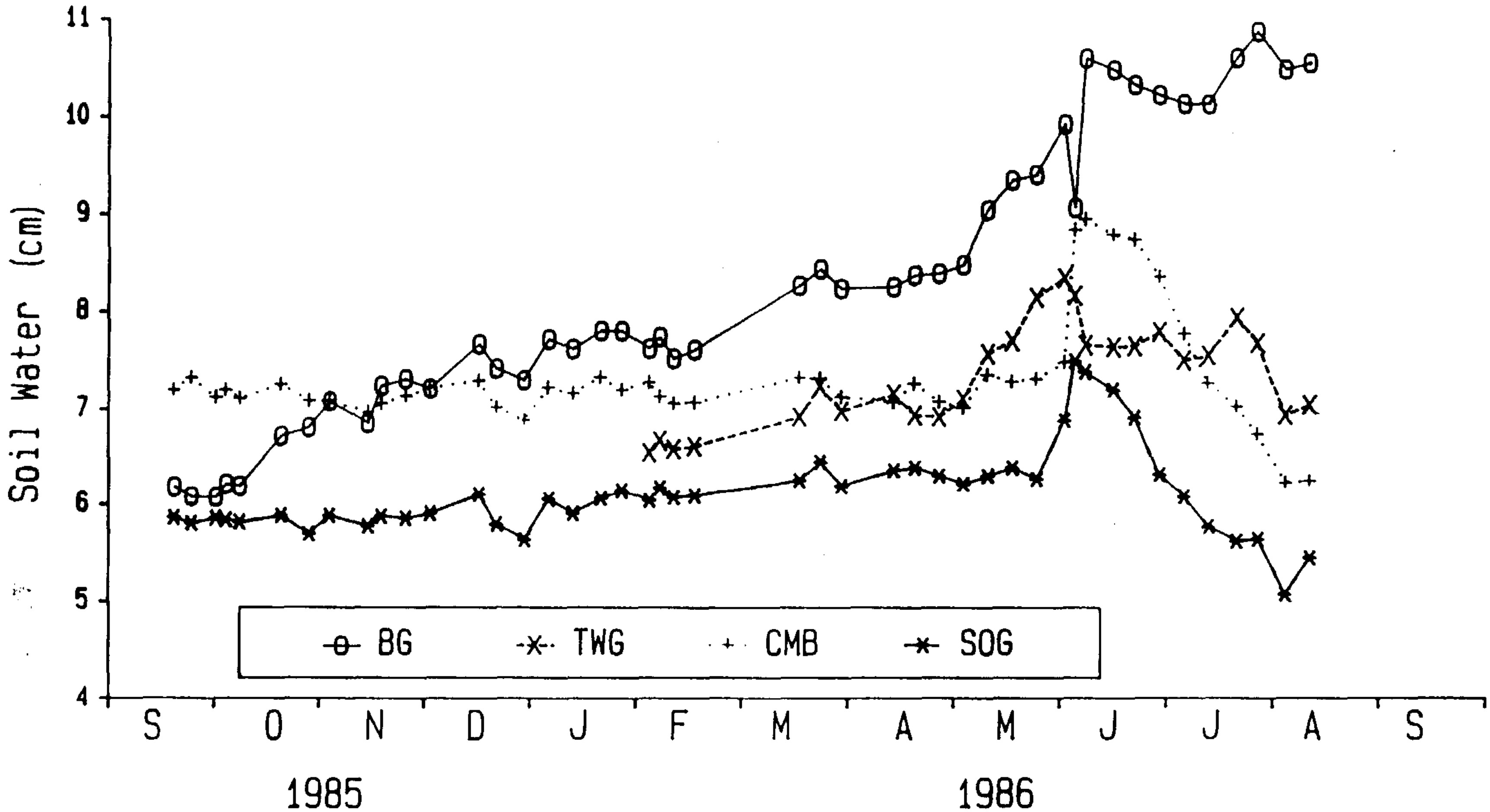

Figure 4. Total water between 65 cm and 104 cm of the weighing lysimeters, Wagon Creek Spade Watershed Research Area.

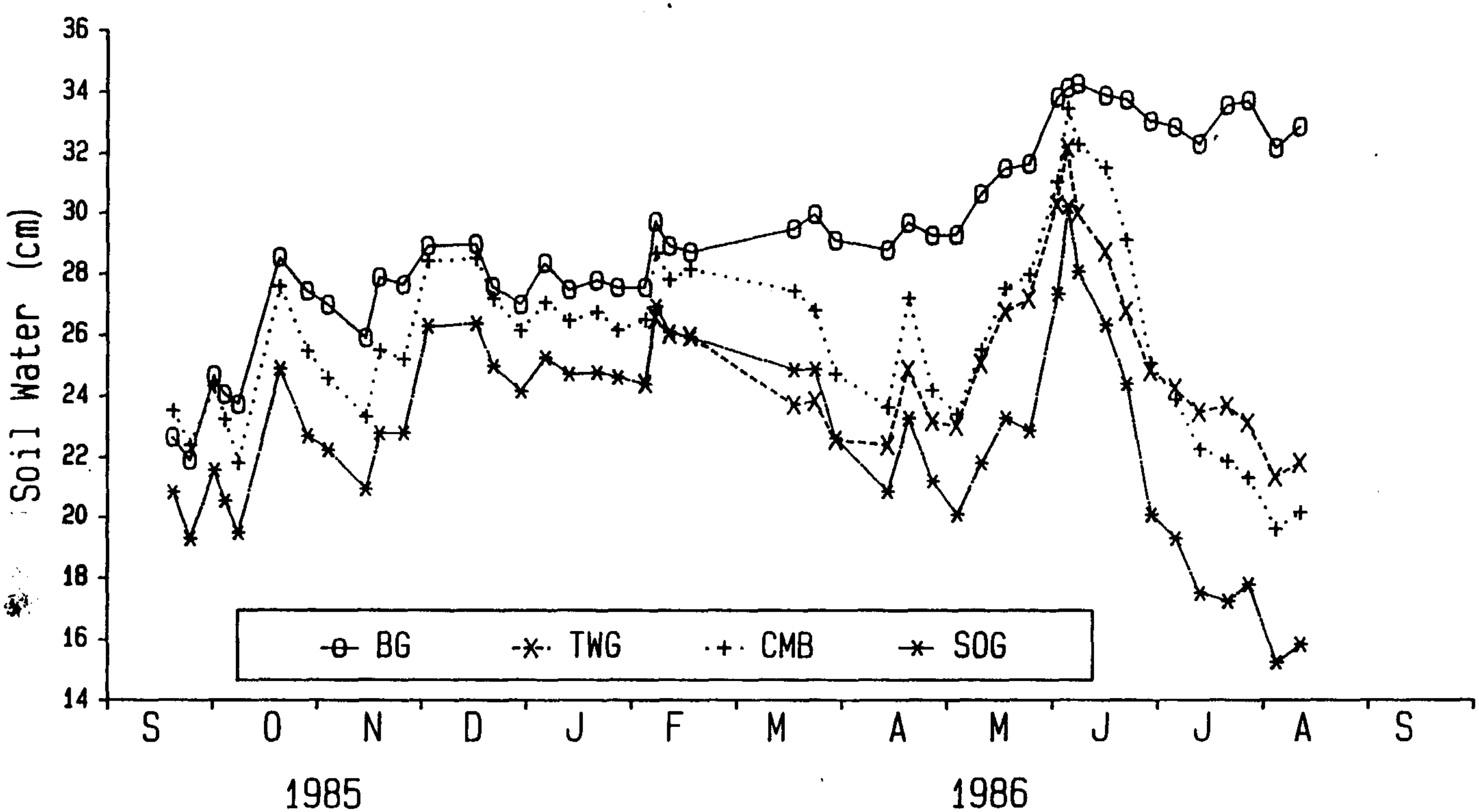

Figure 5. Total water in weighing lysimeter profiles, Wagon Creek Spade Watershed Research Area.

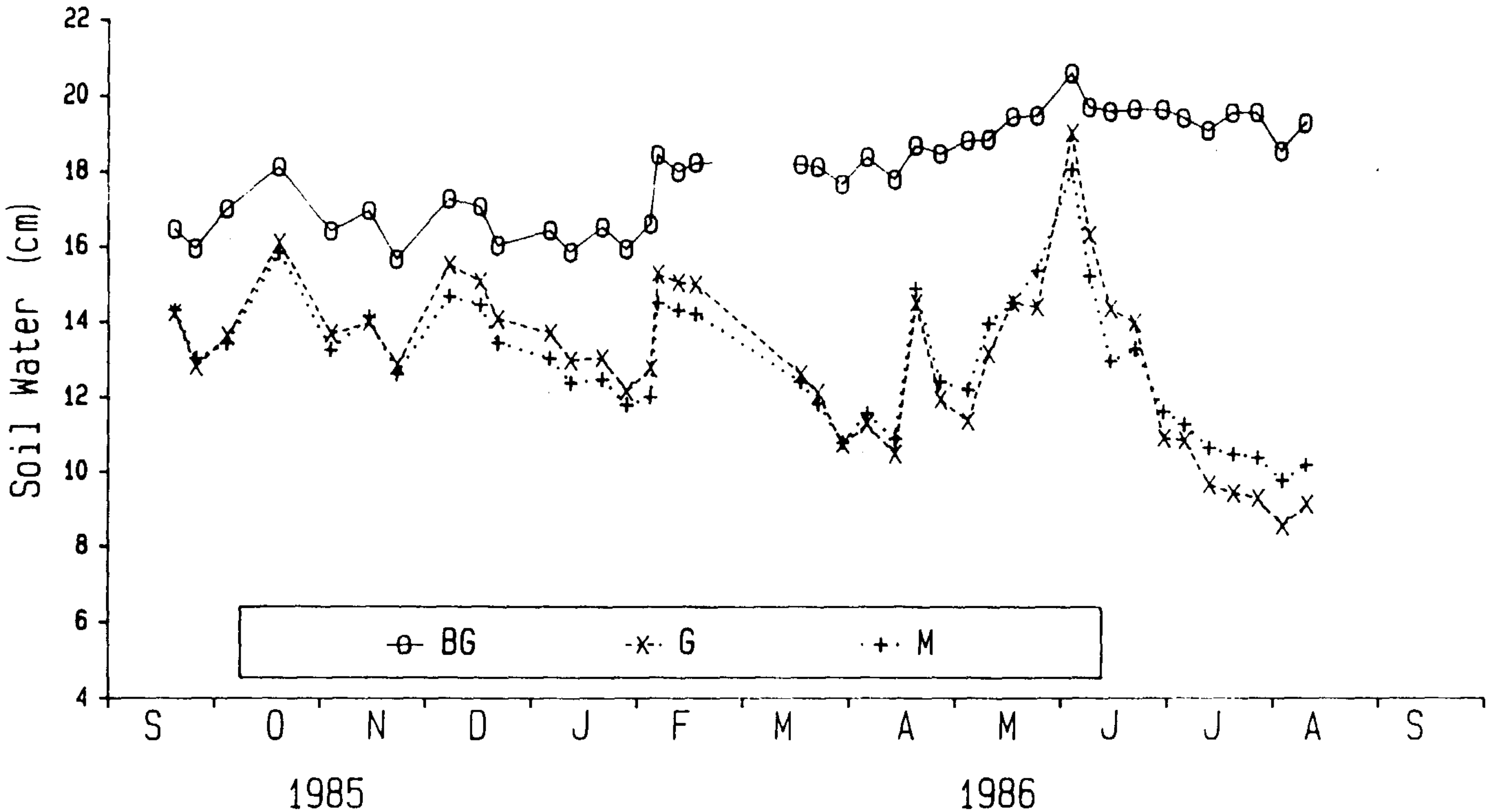

Figure 6. Total water in top 49 cm of the non-weighing lysimeters, Wagon Creek Spade Watershed Research Area.

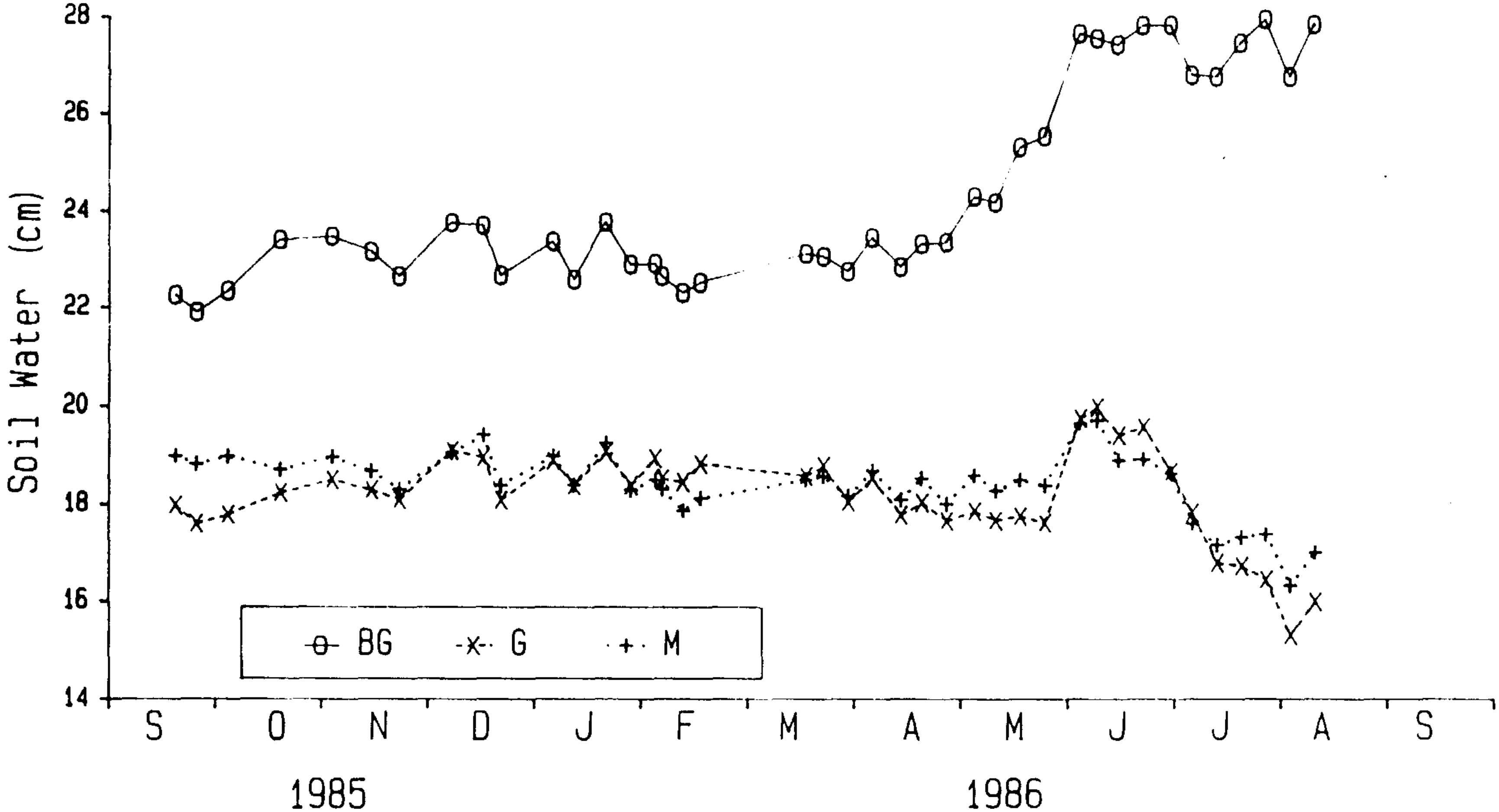

Figure 7. Total water between 49 cm and 130 cm of the non-weighing lysimeters, Wagon Creek Spade Watershed Research Area.

collection period. Between the 1.30 and 2.38 m depth a clean separation in soil water between all treatments occurred (Fig. 8). Soil water was greater in the BG treatments than in the two other treatments. The G treatments held the second highest soil water content and the M treatment had the lowest water in the soil layer.

Total water in the soil profile from the surface to 2.38 m (the bottom of lysimeter sides) was highest in the BG treatment (Fig. 9). The M treatments had lowest soil water content and the G treatments contained soil water in between the other treatments throughout the study.

Total water content between 2.38 m (the bottom of the lysimeter sides) and 3.28 m (the lowest soil moisture reading) shows the G treatments with the highest soil water content (Fig. 10). The BG and M plots separate from the BG with lower soil water. Preliminary results of drainage shows deep percolation in the BG treatment and movement of water upward in the M treatment, which would support this.

Total water in the profiles of the non-weighing lysimeters was combined from the surface to 3.28 m (lowest neutron probe reading). The BG treatments showed highest soil water content (Fig. 11). The G treatments had values in between the BG and M treatments, which had the lowest reading.

Runoff

Mean runoff by treatment was accumulated over time in both the weighing and non-weighing lysimeters. Two accumulations were made in the weighing lysimeters due to the addition of the Texas Wintergrass treatment in January. Figure 12 shows accumulated runoff over time with the BG, CMB, and SOG treatments. By November the BG treatment had separated from the other treatments. Accumulated runoff for the CMB treatment by July was greater than the SOG treatment.

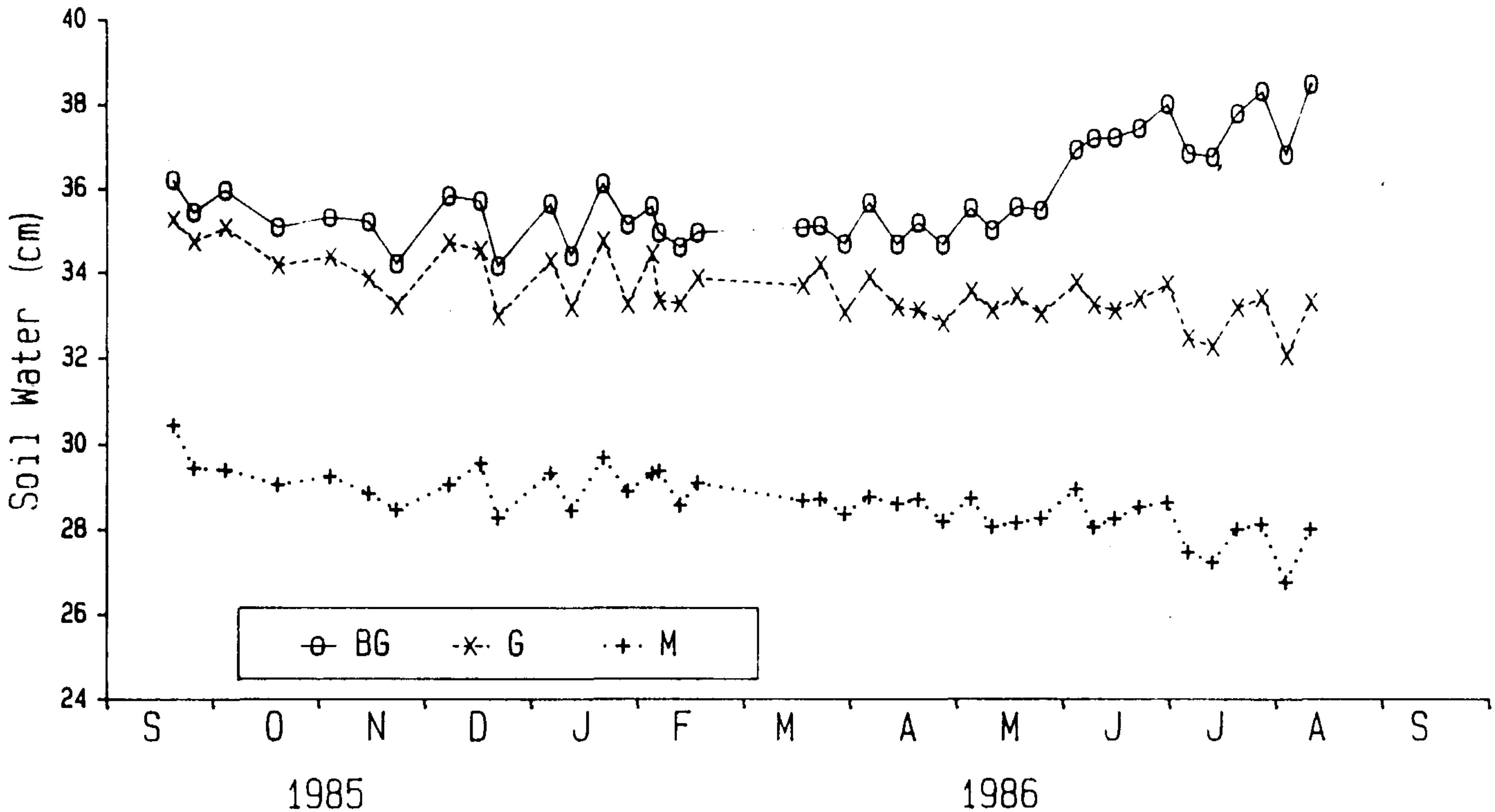

Figure 8. Total water between 130 cm and 238 cm of the non-weighing lysimeters, Wagon Creek Spade Watershed Research Area.

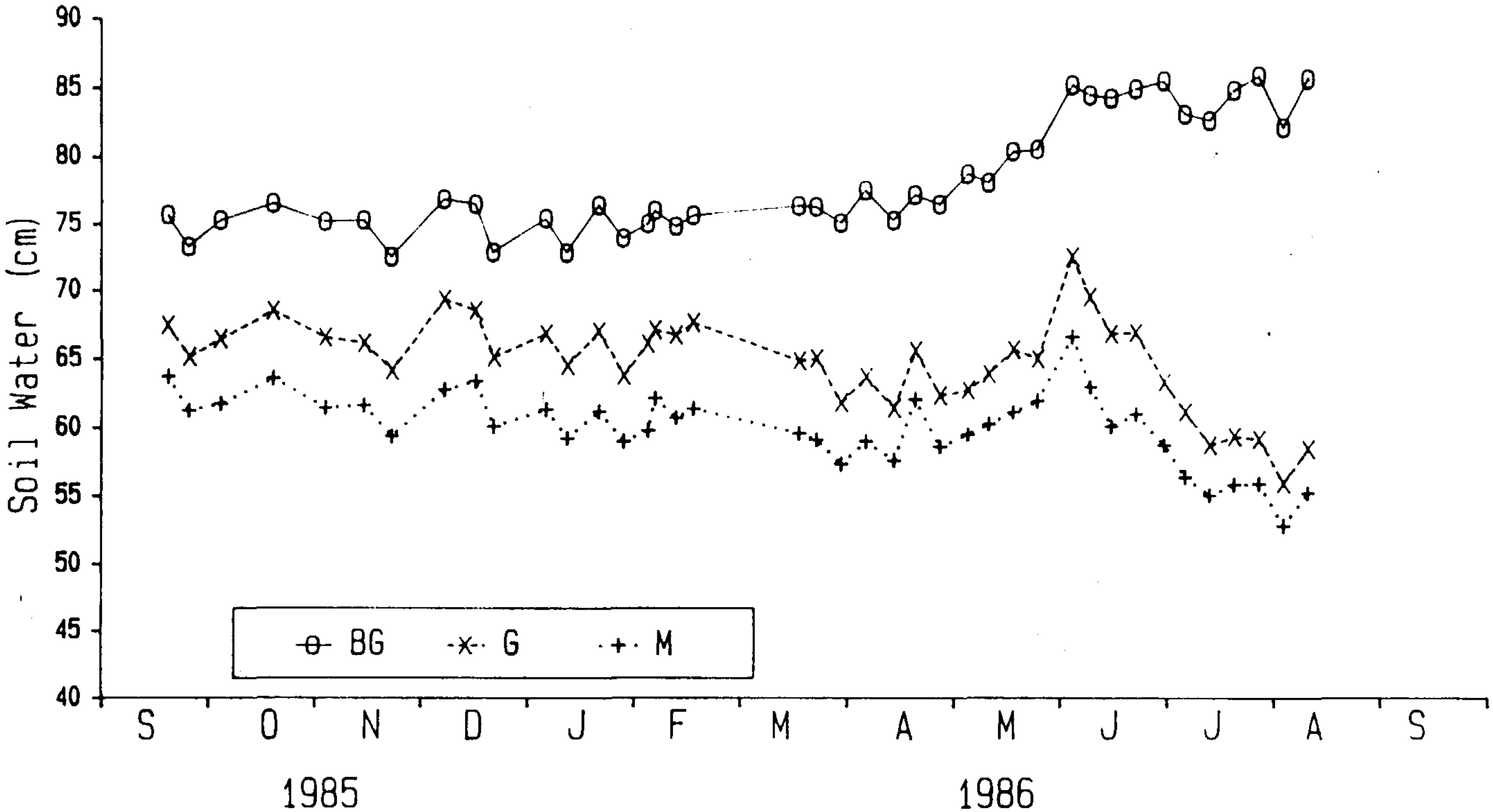

Figure 9. Total water in top 238 cm of the non-weighing lysimeters, Wagon Creek Spade Watershed Research Area.

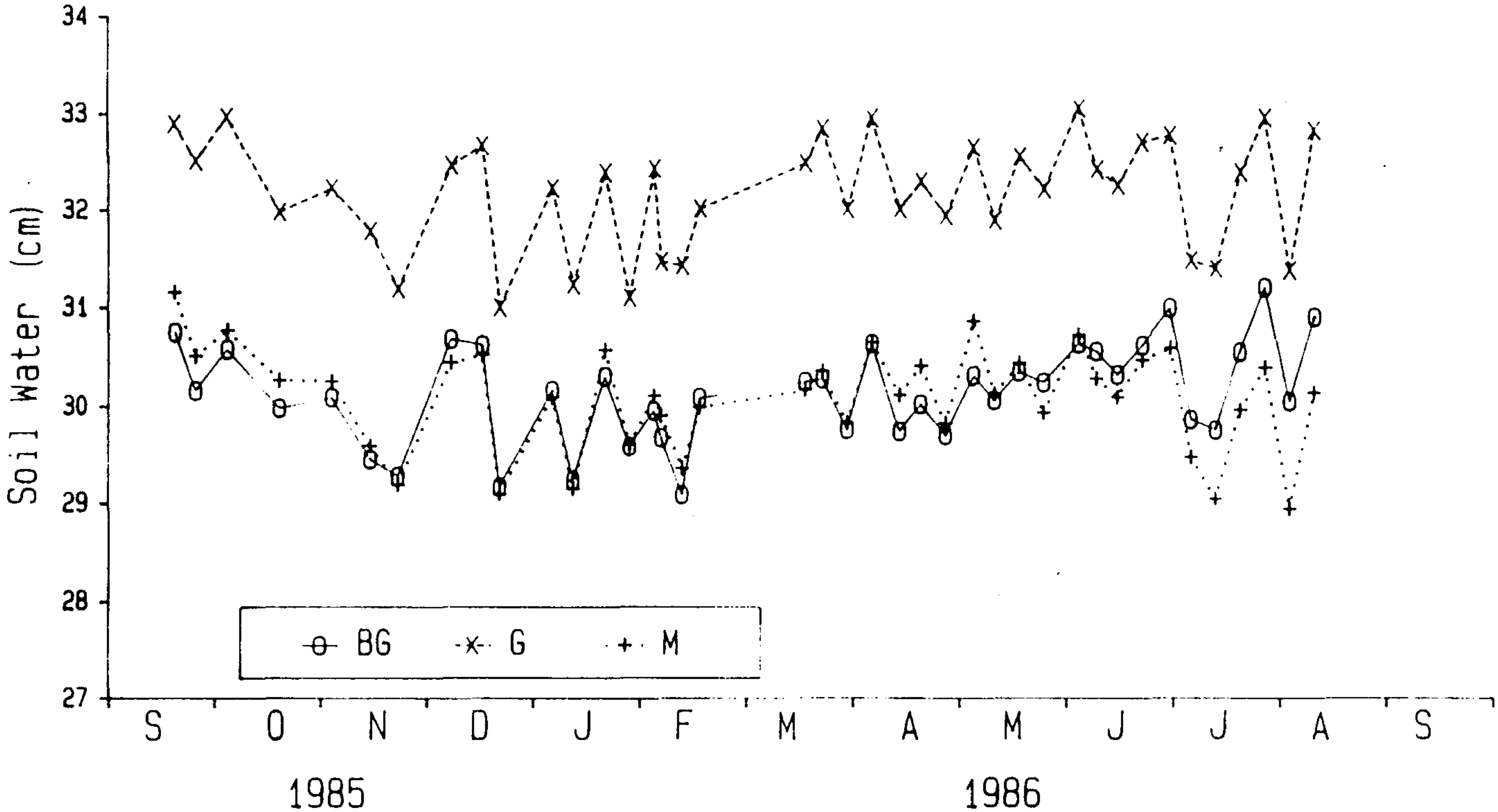

Figure 10. Total water between 238 cm and 328 cm of the non-weighing lysimeters, Wagon Creek Spade Watershed Research Area.

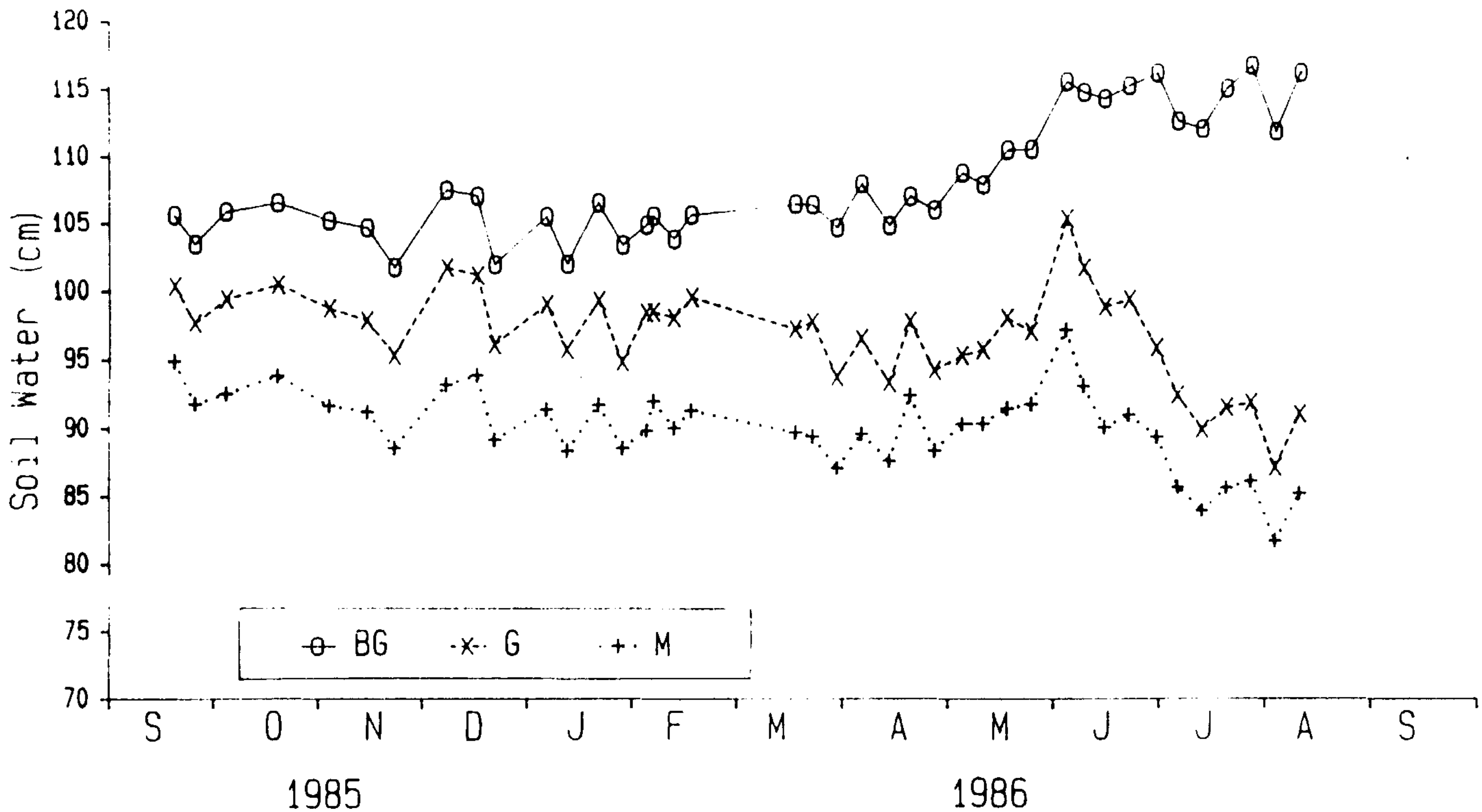

Figure 11. Total water in top 328 cm of the non-weighing lysimeters, Wagon Creek Spade Watershed Research Area.

Runoff values for the four treatments were re-accumulated starting in February when the TWG treatment was added (Fig. 13). Runoff for the BG treatment soon became greater than the other three treatments. Runoff from the CMB treatment was again the second highest with the SOG having third highest and the TWG the lowest. A good seal between the soil and the sides of the lysimeter in the TWG may explain some of the lower runoff values from this treatment.

Accumulated runoff (mm) from the non-weighing lysimeters shows BG with the highest values (Fig. 14). The M treatments had the second highest accumulated runoff and the G treatment had the least runoff. Errors in the installation process resulted in the higher runoff values from the mesquite and grass lysimeters. Herbaceous material around the edge of the lysimeters was inadvertently killed by covering with plastic. The grass lysimeters healed quickly and the mesquite lysimeters have yet to revegetate themselves naturally due to heavy mesquite root competition. Final results of this study will be presented in a Master's Thesis.

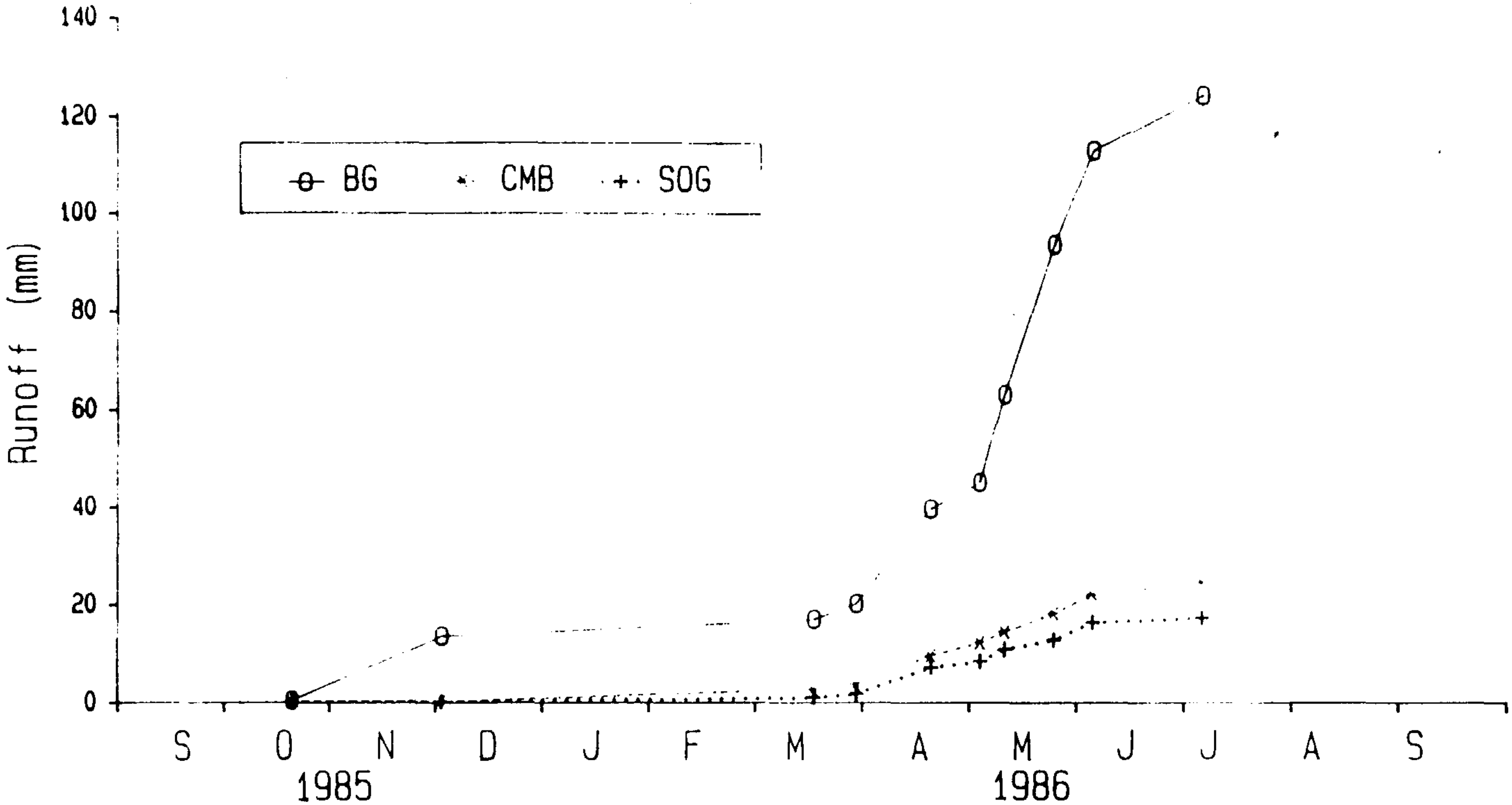

Figure 12. Total accumulated runoff (mm) from weighing lysimeters, Wagon Creek Spade Watershed Research Area.

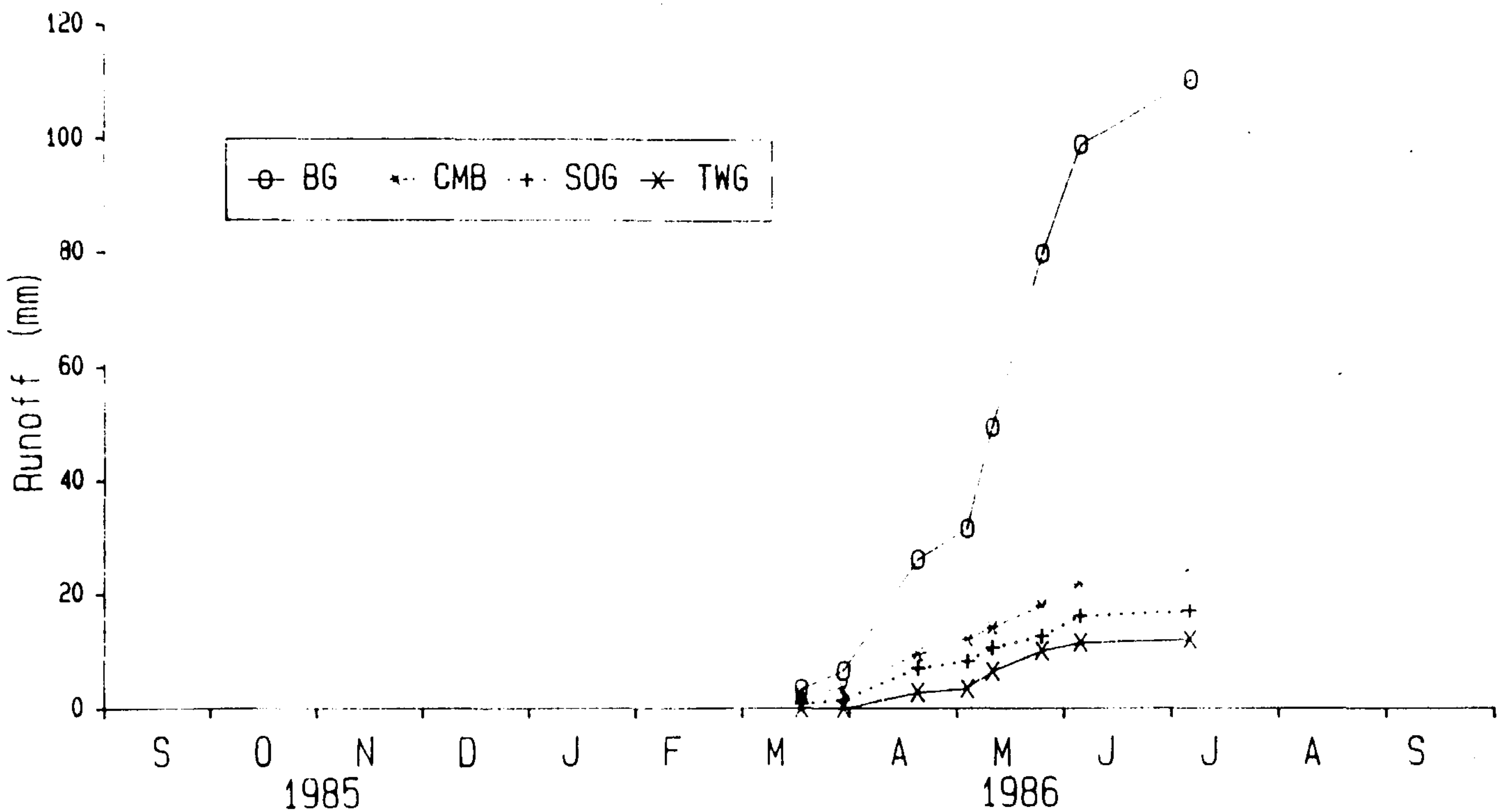

Figure 13. Total accumulated runoff (mm) from weighing lysimeters with Texas wintergrass treatment included, Wagon Creek Spade Watershed Research Area.

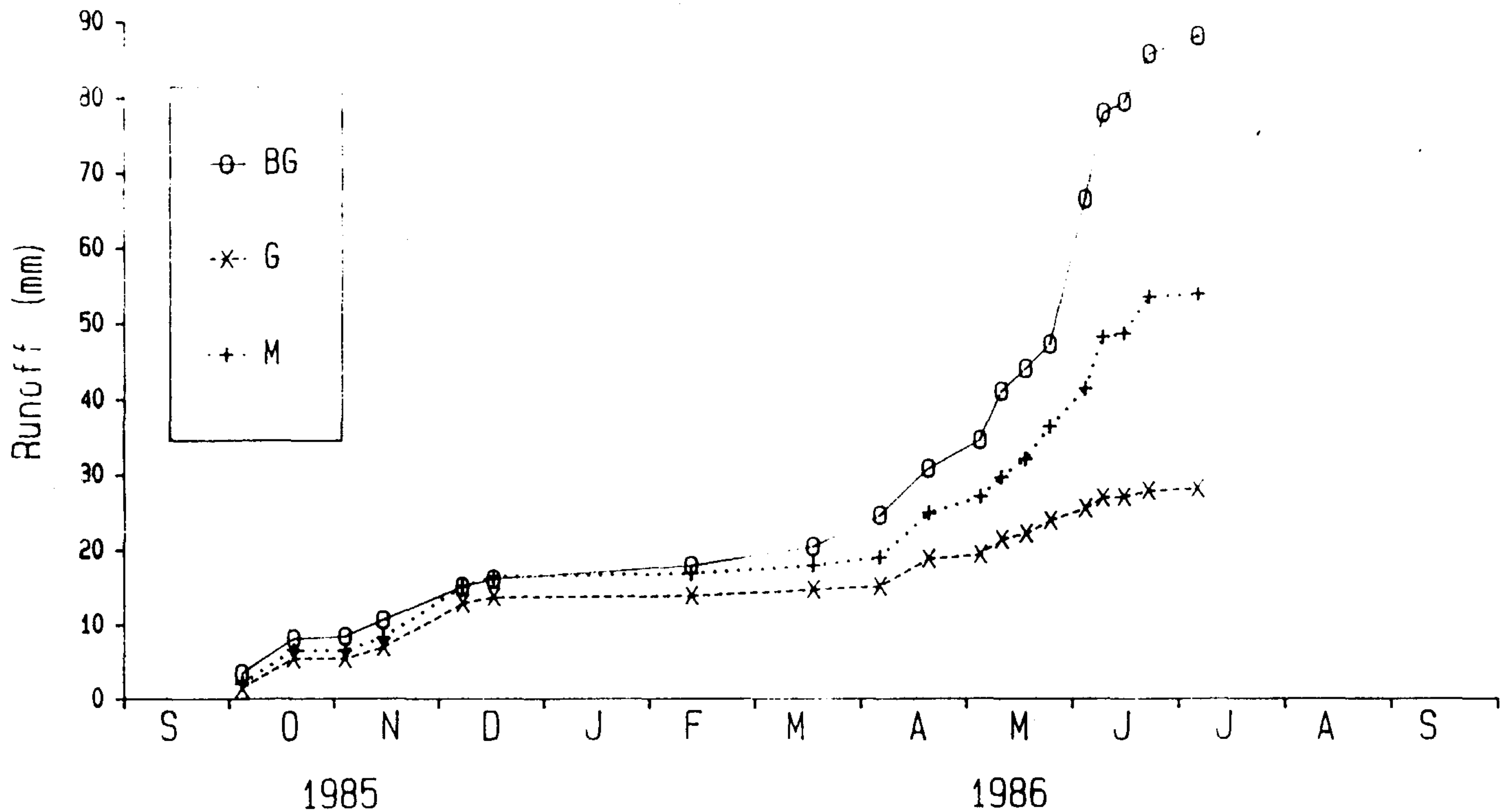

Figure 14. Total accumulated runoff (mm) from non-weighing lysimeters, Wagon Creek Spade Watershed Research Area.

Literature Cited

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soil. Agron. J. 54:464-465.

Kemper, W.D. 1965. Aggregate stability, p. 511-519. In: C.A. Black (ed.), Methods of soil analysis. Amer. Soc. Agron. Series No. 9.

Klute, A.L. 1965A. Water diffusivity, pp. 262-274. In: C.A. Black (ed.), Methods of soil analysis. Amer. Soc. Agron. Series No. 9.

Klute, A.L. 1965B. Laboratory measurement of hydraulic conductivity of saturated soils, pp. 210-221. In: C.A. Black (ed.), Methods of soil analysis. Amer. Soc. Agron. Series No. 9.

Steele, R.G.D. and J.H. Torrie. 1980. Principles and procedures of statistics. McGraw-Hill Book Co., New York.

Walkley, A. and A.I. Black. 1934. An examination of the Deqtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29-38.

Simulated Rainfall Interception by Range Grasses

R.W. Knight and T.A. Wright

Summary

Shortgrasses intercepted more rainfall on a percent of dry forage weight when compared to midgrasses. Litter had the higher interception percentage when compared to the grass foliage. The higher rainfall rates of 10.2 and 15.3 cm/hr satisified the interception capacity of all the treatments after 15 minutes of rainfall duration. The curlymesquite had higher rainfall interception percentage than buffalograss at the lowest rainfall rate of 2.5 cm/hr. Further work will include construction of response surfaces to be used to predict interception over the range of observed natural rainfall events. Interception study of mesquite trees is also in progress.

Methods

This research was conducted at the Texas Experimental Ranch north of Throckmorton. The grasses used in this study included sideoats gram (*Bouteloua curtipendula*), curlymesquite (*Hilaria belangeri*), buffalograss (*Buchloe dactyloides*) and Texas wintergrass (*Stipa leucotricha*). These species were selected because of their dominance at the Wagon Creek Spade Research Site. The litter was also collected for both the sideoats grama and Texas wintergrass samples.

Replicates of homogeneous vegetation of the desired species, 30 cm by 30 cm squares, were excavated and placed in wire mesh containers. The container held the vegetation, litter and soil in a relatively undisturbed configuration. Moisture content of the grass vegetation and litter was obtained by clipping adjacent paired samples and drying at 60°C. This data was used to estimate moisture content of the excavated samples. The excavated samples were taken to the laboratory where simulated rain was applied using a drip-type rainfall simulator. Rainfall rates of 1.3, 2.5, 5.1, 10.2 and 15.3 cm/hr were selected to simulate naturally occurring storms. Rainfall durations of 1/2, 1, 3, 5, 10, 15, 20 and 30 minutes were used in combination with each of the rainfall rates. Ten replicates of each species were used for each time and rainfall combination. There were a total of 400 samples run for each species. At the conclusion of the simulated rainfall the samples were placed in a freezer adjacent to the rainfall simulator. The freezer was used to freeze the intercepted water and retard evaporation. The samples were then clipped at ground height and weighted. The vegetation was dried and percent interception excluding the prior vegetation moisture calculated from the paired sample. The litter of the sideoats grama and Texas wintergrass samples was collected after the vegetation was removed. The litter was then weighed, dried, and reweighed to determine its interception storage capacity. No litter was collected from the curlymesquite or buffalograss samples because of the extremely small amounts involved. Data from the sideoats grama samples will not be reported here.

Results and Discussion

There were three grass types represented in this study two shortgrass species (curlymesquite, buffalograss) a bunch-type midgrass (Texas wintergrass) and a rhizomeous midgrass (sideoats grama). The shortgrasses exhibited similar interception rates at rainfall intensities of 5.1 cm/hr or greater (Figure 1). Texas wintergrass generally had lower percent rainfall interception than the other species at the higher rainfall rates. Curlymesquite and Texas wintergrass had a slightly higher interception rate than did buffalograss at the lower rainfall rates. This could be due to the pilose leaves of this specie compared to the relatively glabrous blades of the

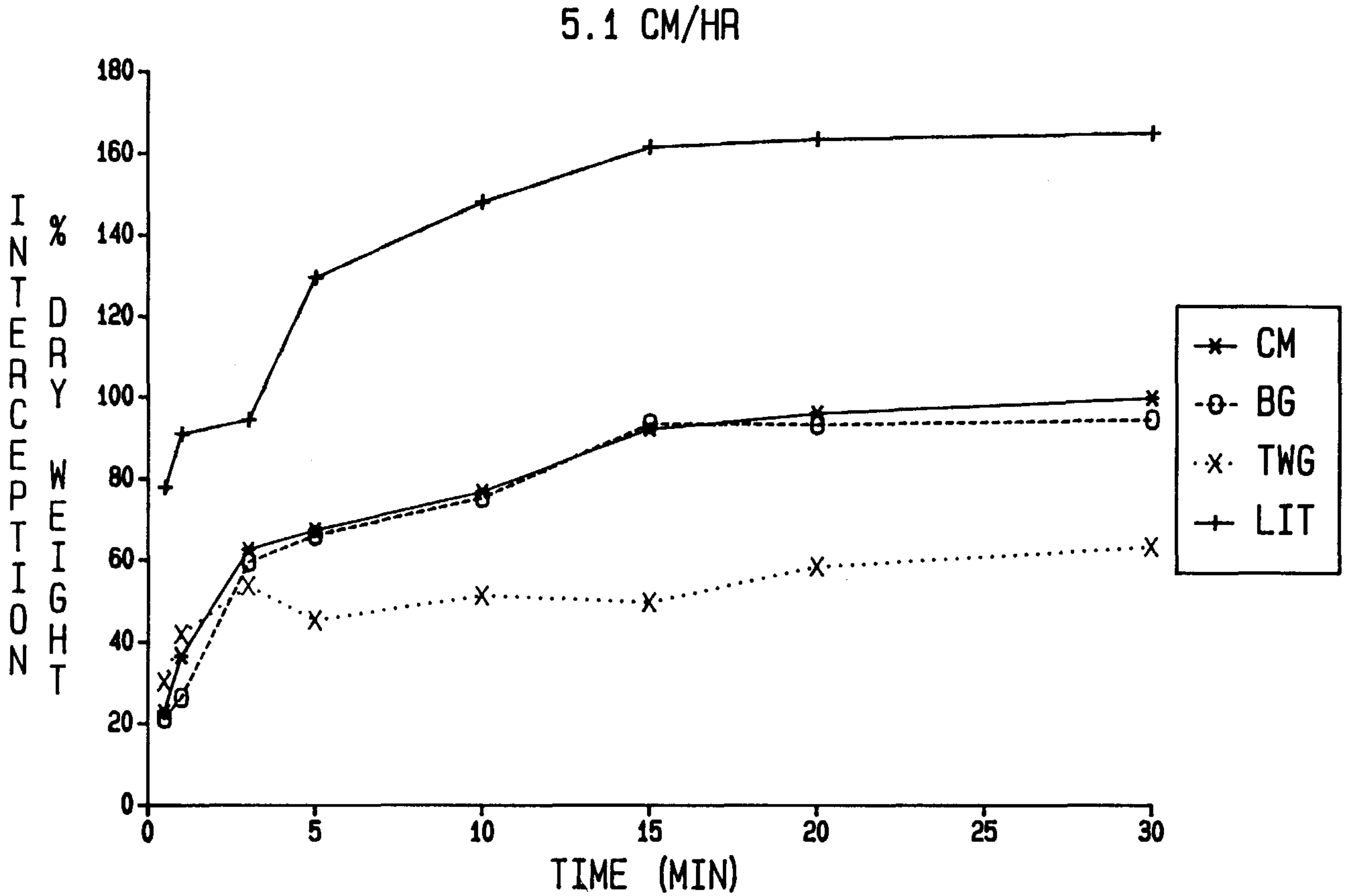

Figure 1. Interception percentages for curly mesq=tte (cm), buffalograss (BG), Texas wintergrass (TWG) and litter (LIT) with a rainfall intensity of 5.1 cm/hr.

buffalograss. The litter had about double the interception percentage of the foliar part of the Texas wintergrass at all rainfall rates.

The interception percentage of rainfall generally increased as the rainfall rates increased until the higher rates were reached. The interception percent increased rapidly with increasing time up to about 15 to 20 minutes at which it usually remained constant.

Curlymesquite had an interception percentage of over 100% of dry matter for the rainfall rates of 5.1 cm/hr and above at 30 minutes duration (Figure 2). The lower rates of rainfall had interception percentages of 60-70%. Rainfall interception percentage was relatively constant for the 10.2 and 15.3 cm/hr rates after 10 minutes. The interception of the lower rainfall rates did not level off until about 20 minutes.

The buffalograss exhibited interception percentages that were about identical to the curlymesquite at the rates of 5.1 cm/hr or above (Figure 3). In contrast to the curlymesquite, the interception percentages had started to level off for most rainfall rates at 15 minutes of duration on the buffalograss. The 1.3 cm/hr rate even had a slight declined in interception percentage after 15 minutes of rainfall.

The interception rates of the Texas wintergrass tended to be more variable than the other species because of the presence standing dead material (Figure 4). Generally the interception percentages of Texas wintergrass were lower than the shortgrass species. The longer, flexible leaves of the Texas wintergrass tended to bend and allow water to runoff dispite being pilose.

The high interception rates exhibited the importance of litter cover for minimizing raindrop impact (Figure 5). Litter could reduce soil moisture because of the high interception percentages. The reduction in soil moisture would probably be offset by gains from reduction of soil water evaporation from the shading effect of the litter. Litter was able to intercept almost 200% of its weight at high rainfall rates of long duration. All rainfall rates exceeded 100% interception percentage after a duration of 10 minutes.

Future analysis of the data will include the use of a response surface for estimating rainfall interception on a yearly basis related to forage production. The results of this study will apply specifically to the Texas Exp. Research and Wagon Creek Spade Watershed Research Site, but could be extended to other sites through further research. Work is also being conducted on the interception of rainfall by mesquite trees.

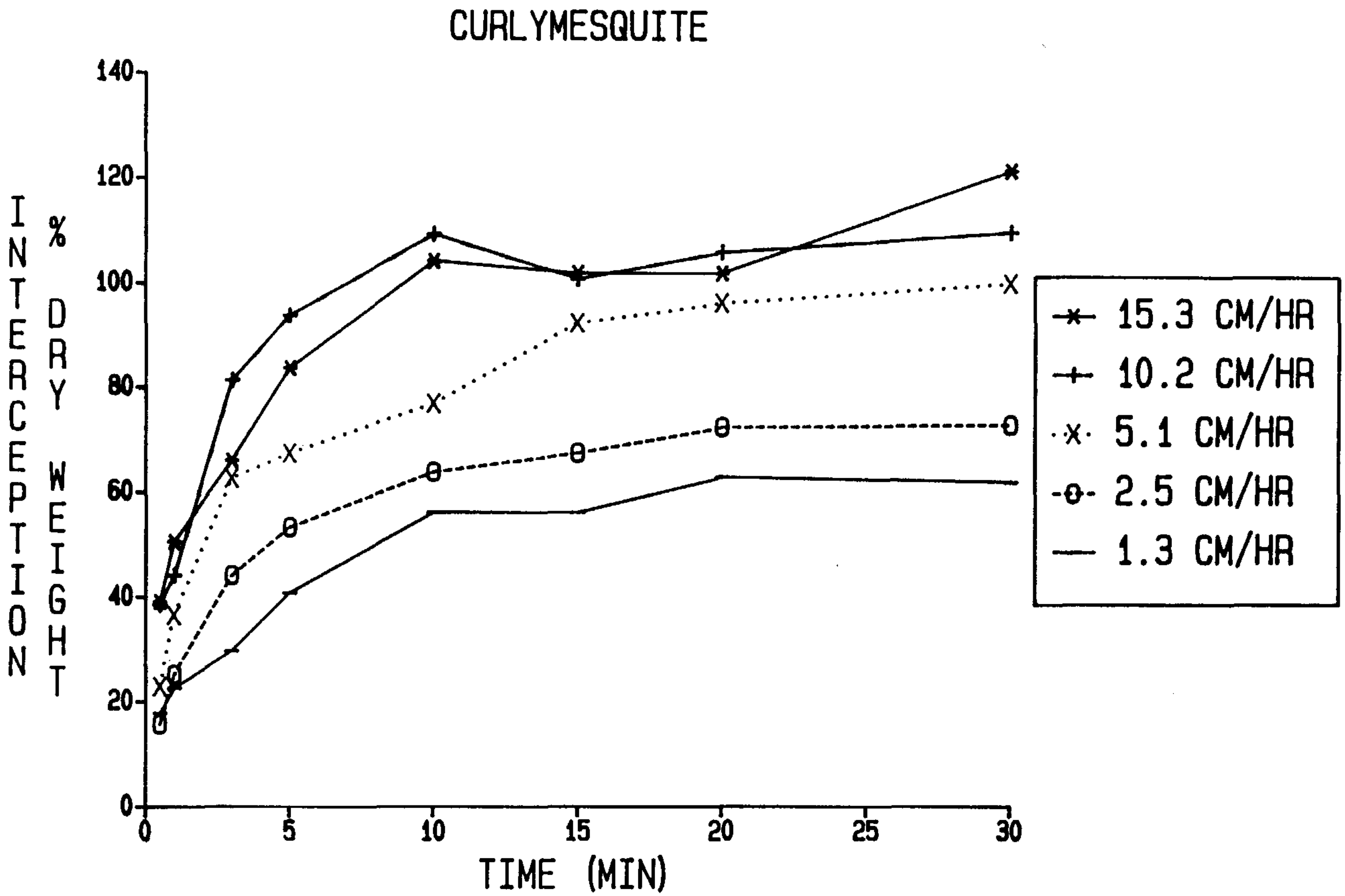

Figure 2. Interception percentages for several rainfall rates for curlymesquite.

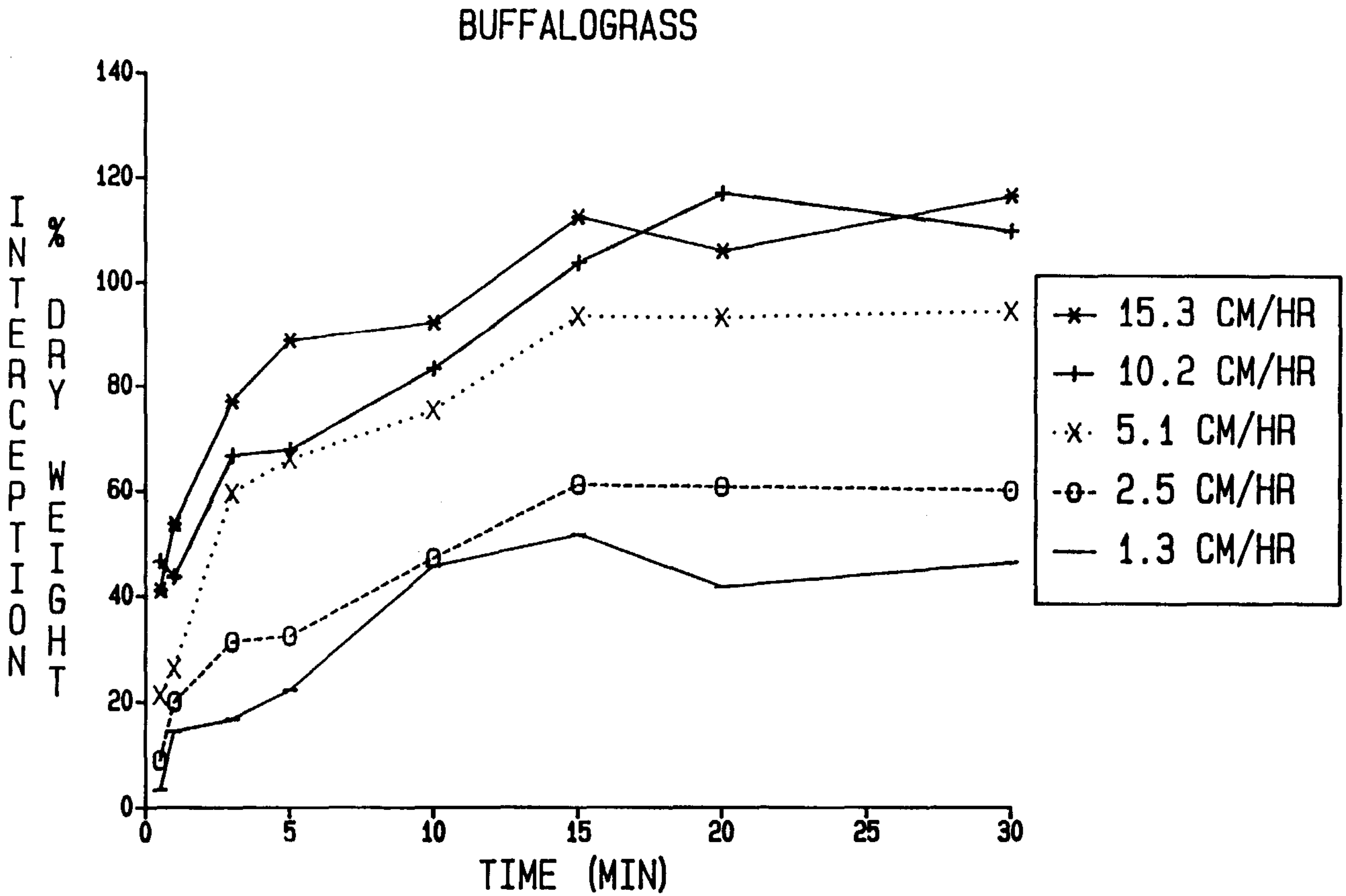

Figure 3. Interception percentages for several rainfall rates for buffalograss.

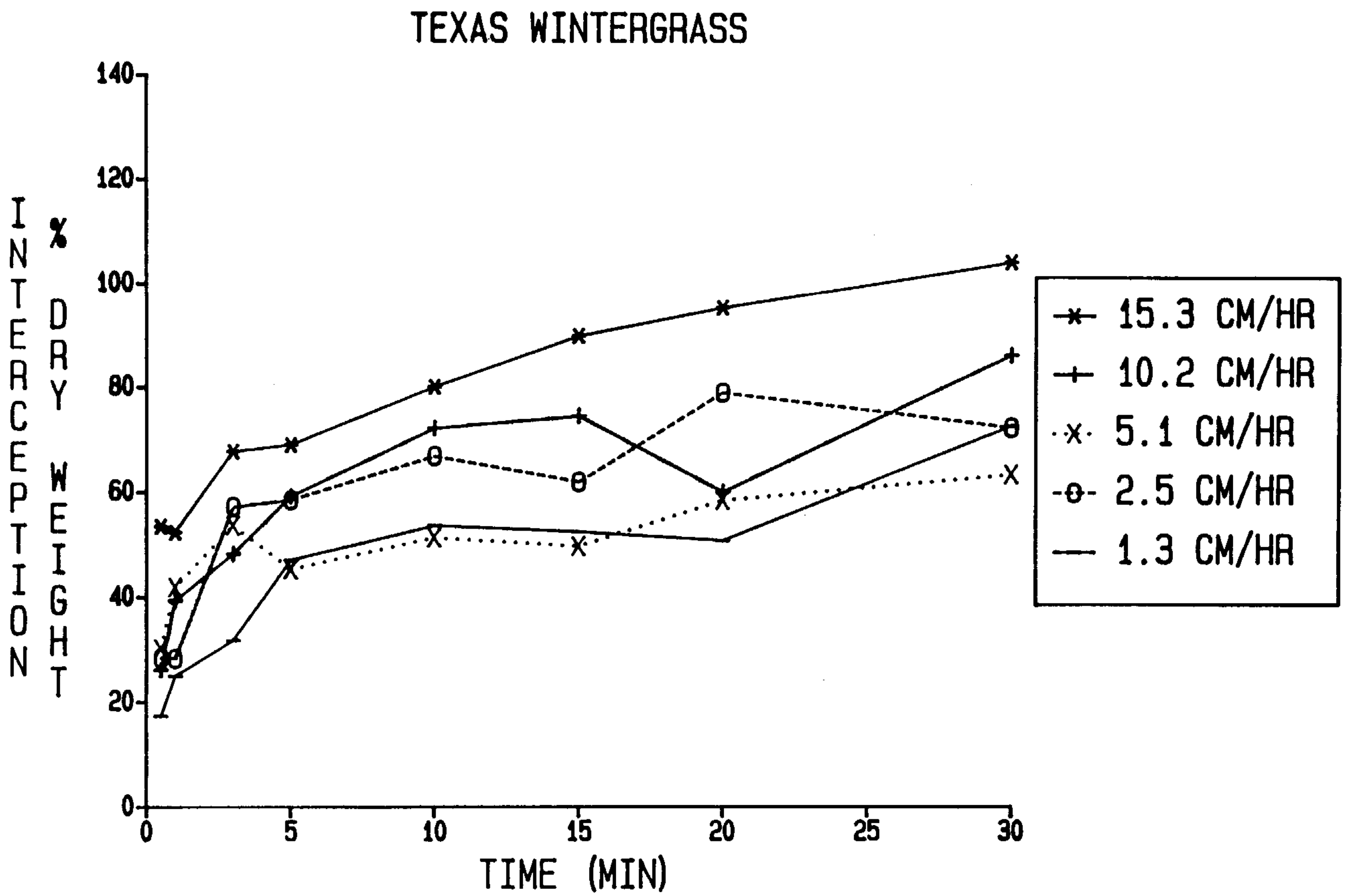

Figure 4. Interception percentages for several rainfall rates for Texas wintergrass.

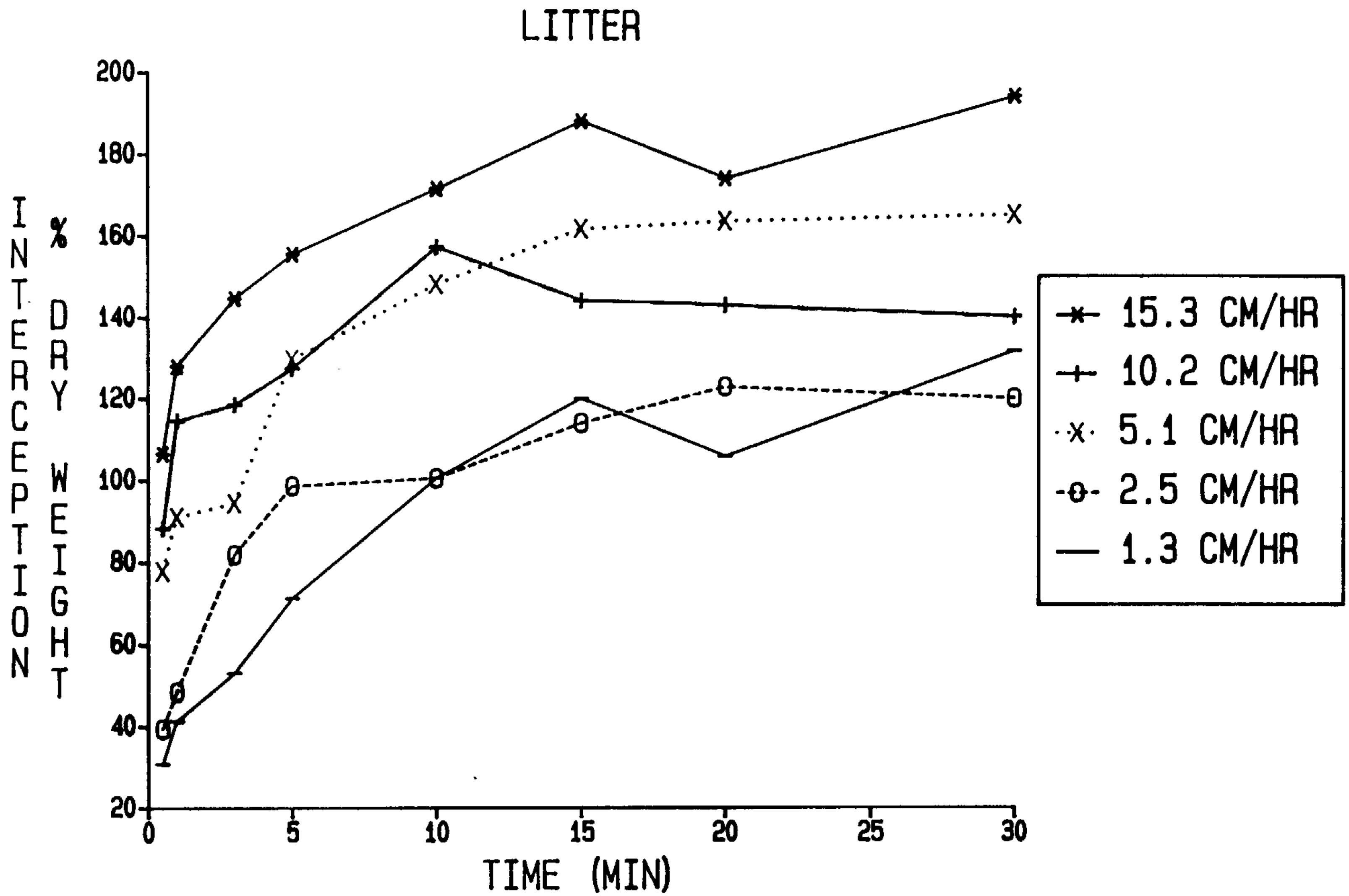

Figure 5. Interception percentages for several rainfall rates for litter.

Water Use Efficiency of *Stipa leucotricha*, *Bouteloua curtipendula*, and *Hilaria berlangeri* in a Rolling Plains Grassland Community

R. A. Hicks, C. A. Call, and R. J. Ansley

Summary

Water use efficiency (WUE) was measured at the physiological level (individual leaves) for Texas wintergrass (*Stipa leucotricha*), sideoats grama (*Bouteloua curtipendula*), and common curly mesquite (*Hilaria berlangeri*) in instrumented weighing lysimeters from late May to mid-September 1986 at the Wagon Creek Spade Ranch site near Throckmorton. Diurnal patterns of CO_2 uptake and water vapor flux were measured with a portable gas exchange system. Water use efficiency was calculated as net CO_2 uptake per amount of water transpired per unit leaf area. Differences in WUE between the three grass species over the growing season were related to differences in photosynthetic rates, transpiration rates, and season of growth. Efficiency of water use declined from May through mid-summer and increased as growing conditions became more favorable during September. *Stipa leucotricha*, a cool season bunchgrass, was most efficient in May and September; *B. curtipendula*, a warm season bunchgrass, was the most efficient species over the entire study period; and *H. berlangeri*, a warm season sodgrass, was least efficient of the three species due to a consistently higher transpiration rate.

Methods

Water use efficiency (WUE) was measured at the physiological level for Texas wintergrass [(*Stipa leucotricha*), a cool-season, bunch-type midgrass], sideoats grama [(*Bouteloua curtipendula*), a warm-season, bunch-type midgrass], and common curly mesquite [(*Hilaria berlangeri*), a warm-season, sod-forming shortgrass] in instrumented weighing lysimeters at the Wagon Creek Spade Ranch near Throckmorton. Vegetation and soils at the study site, and construction and instrumentation of the weighing lysimeters have been described in other sections (see Franklin et al. of this report).

Gas Exchange Measurements

Simultaneous measurements of CO_2 and water vapor flux of individual leaf blades were made _in situ_ with a portable gas exchange system (Li-Cor Model LI-6000) on several dates from late May to mid-September 1986. Calculation of transpiration is based upon initial values of stomatal resistance and vapor density gradient. Calculation of apparent photosynthetic rate is based upon the rate of change of CO_2 concentration in the leaf cuvette. Calculation of WUE is based upon net CO_2 uptake per amount of water transpired per unit leaf area. Two to three expanded leaves on one vegetative tiller were used for gas exchange measurements on _S. leucotricha_ and _B. curtipendula_. Several problems were encountered with the placement of enough small leaves of low growing _H. berlangeri_ in the cuvette to achieve an adequate draw-down of CO_2. Thus, an entire clump of tillers (8 to 10 expanded leaves) at an unrooted node along the stolon was placed in the cuvette for gas-exchange measurements. A standardized leaf orientation, parallel to the soil surface, was maintained during each measurement for all three species. Diurnal gas-exchange measurements were initiated at 1 hour post-sunrise and continued at 2-hour intervals until sundown on each sampling date.

CO_2 concentrations within the cuvette were maintained between 275-375 ppm over the entire sampling season. Cuvette relative humidity and temperature, leaf temperature in the cuvette, and photosynthetic photon flux density (PPFD) outside the cuvette were monitored at the time of each measurement. Leaf material was harvested at the end of each sampling period, and leaf areas were determined with a Li-Cor Model LI-3000 leaf area meter.

Analysis

The lysimeters were arranged in a completely randomized design. Each species was replicated in three separate lysimeters, and two separate tillers (or two separate clumps of tillers on stolons of *H. berlangeri*) were selected for measurement in each lysimeter. Transpiration, photosynthesis, and WUE values will be subjected to analysis of variance to determine differences between species on each sampling date. Duncan's Multiple Range Test will be used to separate the mean values for each parameter.

Results and Discussion

Data have been recorded for May 22, June 21, July 19, August 13, and September 14, 1986; however, only pertinent data from May, July and September sampling dates will be presented in order to minimize redundancy.

Abiotic Variables

The 1986 growing season at the study site was characterized by below-ormal monthly precipitation through March and then above-normal monthly precipitation from April through September, except for July (see Franklin et al. in this report). The above-normal precipitation in May and June extended the growing period of *S. leucotricha* from late May/early June to late June/early July.

There were few differences in PPFD and leaf temperature measurements for the three species on each sampling date (Figures 1-9). PPFD peaked at mid-day on the cloudless sampling dates in May and July and varied somewhat during mid-day on the partly cloudy sampling date in September. Leaf temperatures in the cuvette reached 40°C by 5 hours post-sunrise on May 22 (Figures 1-3), 42°C by 5 hours post-sunrise on July 19 (Figures 4-6), and 34°C by 5 hours post-sunrise on September 14 (Figures 7-9).

Gas Exchange

Daily gas exchange patterns varied between C_3 (S. leucotricha) and C_4 (B. curtipendula and H. berlangeri) grasses as temperatures increased over the growing season. On May 22, the rate of photosynthesis for S. leucotricha gradually increased to a peak at 3 hours post-sunrise and gradually declined below early morning rates by 9 hours post-sunrise (Figure 1). The rate of transpiration also peaked at 3 hours post-sunrise and remained fairly constant until 9 hours post-sunrise (Figure 1). Photosynthetic rates were higher for B. curtipendula (Figure 2) and H. berlangeri (Figure 3) than S. leucotricha at 3 hours post-sunrise, but declined in a similar manner by 9 hours post-sunrise. Transpiration rates for th two C_4 species increased gradually until 7 hours post-sunrise and then decreased rapidly by 9 hours post-sunrise (Figures 2 and 3). The peak transpiration rate for H. berlangeri was twice that of S. leucotricha or B. curtipendula.

Limiting water and higher temperatures resulted in lower photosynthesis and transpiration rates for the three grass species on July 19. Photosynthetic rates remained low for S. leucotricha with slight peaks under more favorable ambient conditions at 3 and 11 hours post-sunrise (Figure 4). Photosynthetic rates for B. curtipendula (Figure 5) and H. berlangeri (Figure 6) increased rapidly from 1 to 3 hours post-sunrise, then decreased rapidly until 9 hours post-sunrise, and then increased slightly under more favorable conditions during the late afternoon hours. Transpiration rates gradually increased for the three species until 9 hours post-sunrise and then gradually declined during the late afternoon hours (Figures 4-6). Transpirational losses were higher for H. berlangeri than S. leucotricha or B. curtipendula.

Photosynthetic rates increased for the three grass species on September 14 in response to frequent precipitation events and cooler temperatures. The peak photosynthetic rate of newly exerted S. leucotricha leaves at this time (Figure 7) was six times the rate measured for senescing leaves on the July sampling date (Figure 4). When comparing the two C_4 species, B. curtipendula attained a higher peak photosynthetic rate during the more favorable morning hours (Figure 8) while H. berlangeri maintained a higher photosynthetic rate during the mid-day hours. Patterns of transpirational loss were quite similar for the three grasses, with B. curtipendula having a slightly lower rate of transpiration than S. leucotricha or H. berlangeri over the course of the day (Figures 7-9).

Water Use Efficiency

Differences in WUE between the three grass species were related to differences in photosynthetic rates, transpiration rates, and season of growth. On May 22, B. curtipendula was most efficient in water use and H. berlangeri was least efficient (Fig. 10A). Transpiration rates for H. berlangeri were twice those of B. curtipendula at each sampling interval throughout the day (Figures 2 and 3). By late May, S. leucotricha had reached its reproductive stage and leaves are usually senescing in preparation for the summer dormant period. Favorable rainfall during late May and early June extended the period of growth, but higher temperatures may have reduced photosynthetic rates below optimum rates which would have occurred during late March through April. Thus, WUE on May 22 was intermediate between that of B. curtipendula and H. berlangeri (Figure 10A).

All three species showed signs of leaf senescence on July 19 due to elevated temperatures and limited available water in the upper soil profile. Water use efficiencies were lowest at this mid-summer sampling date (Figure 10B), and did not increase until regrowth occurred under more favorable conditions in early September. Water use efficiencies were greater for the warm-season species than for S. leucotricha during the mid-morning hours, but decreased below S. leucotricha during the remainder of the day as transpiration rates increased.

Water use efficiencies were greater for all three species on the September sampling date (Figure 10C). As previously mentioned, plants were actively regrowing in response to a series of precipitation events and cooler temperatures. Regrowth of S. leucotricha is usually delayed until October when conditions are more favorable for cool-season species. Warm-season grasses had WUE's of 1.5 or greater during mid-day hours. This was the only sampling date on which H. berlangeri had equivalent or slightly higher WUE than B. curtipendula.

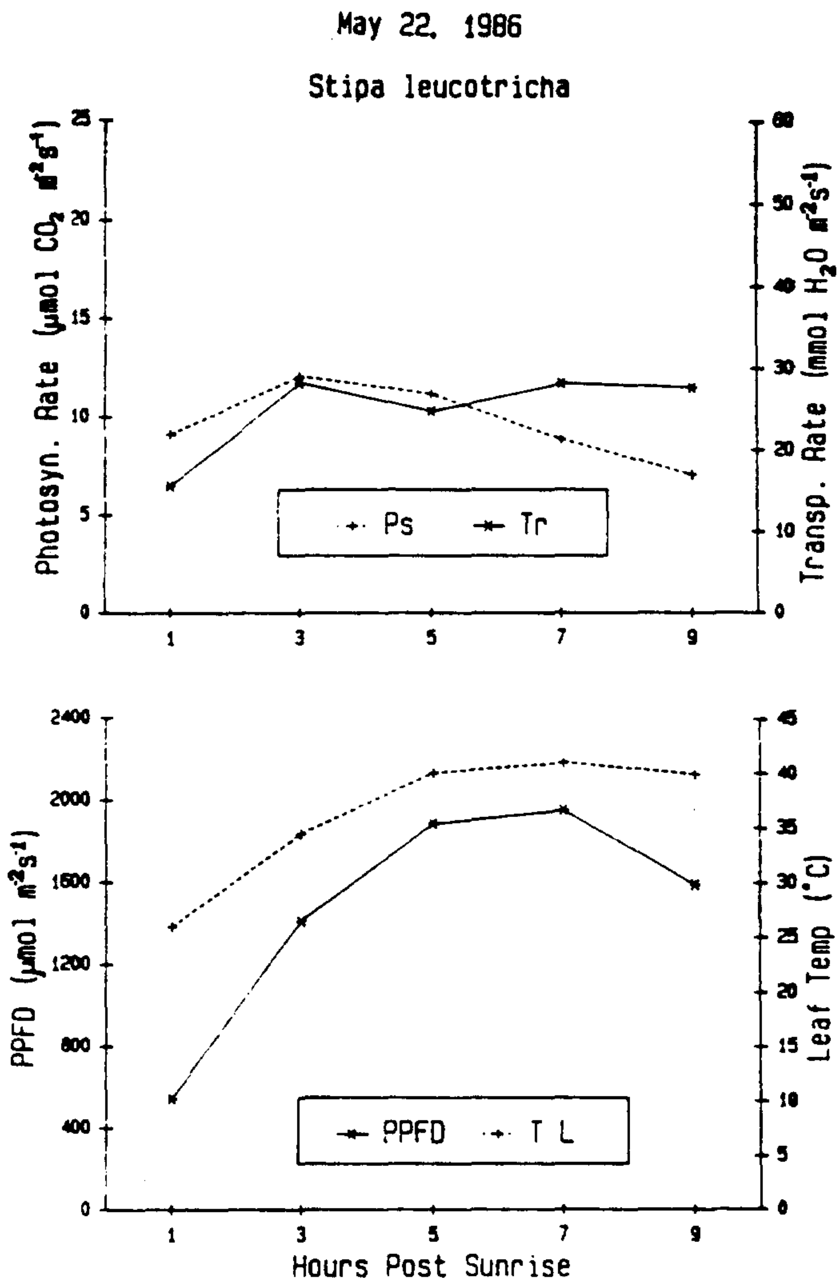

Fig. 1. Daily patterns of net photosynthesis rate (Ps) and transpiration rate (Tr) of S. leucotricha on May 22, 1986; and daily patterns of photosynthetic photon flux density (PPFD) and leaf temperature (LT) associated with gas exchange measurements.

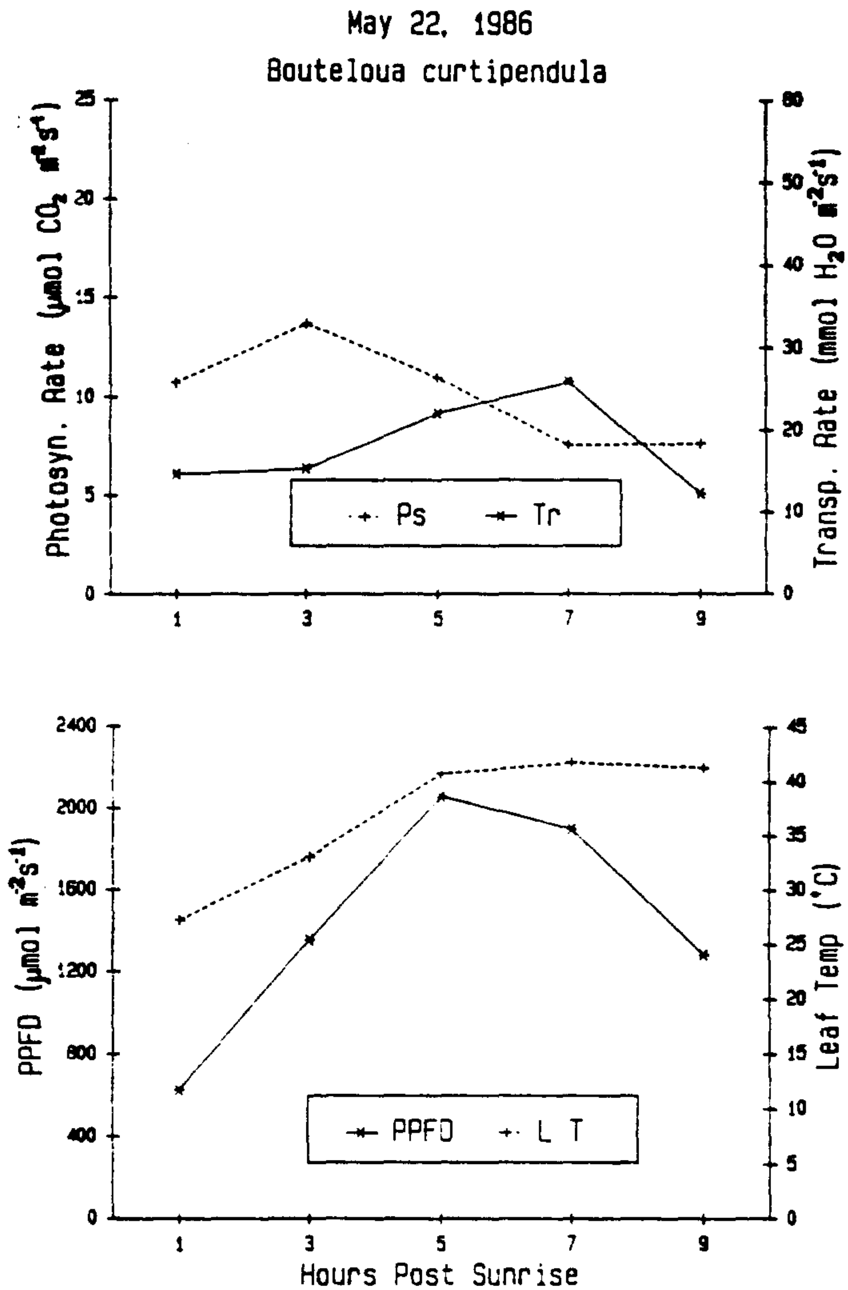

Fig. 2. Daily patterns of net photosynthesis rate (Ps) and transpiration rate (Tr) of B. curtipendula on May 22, 1986; and daily patterns of photosynthetic photon flux density (PPFD) and leaf temperature (LT) associated with gas exchange measurements.

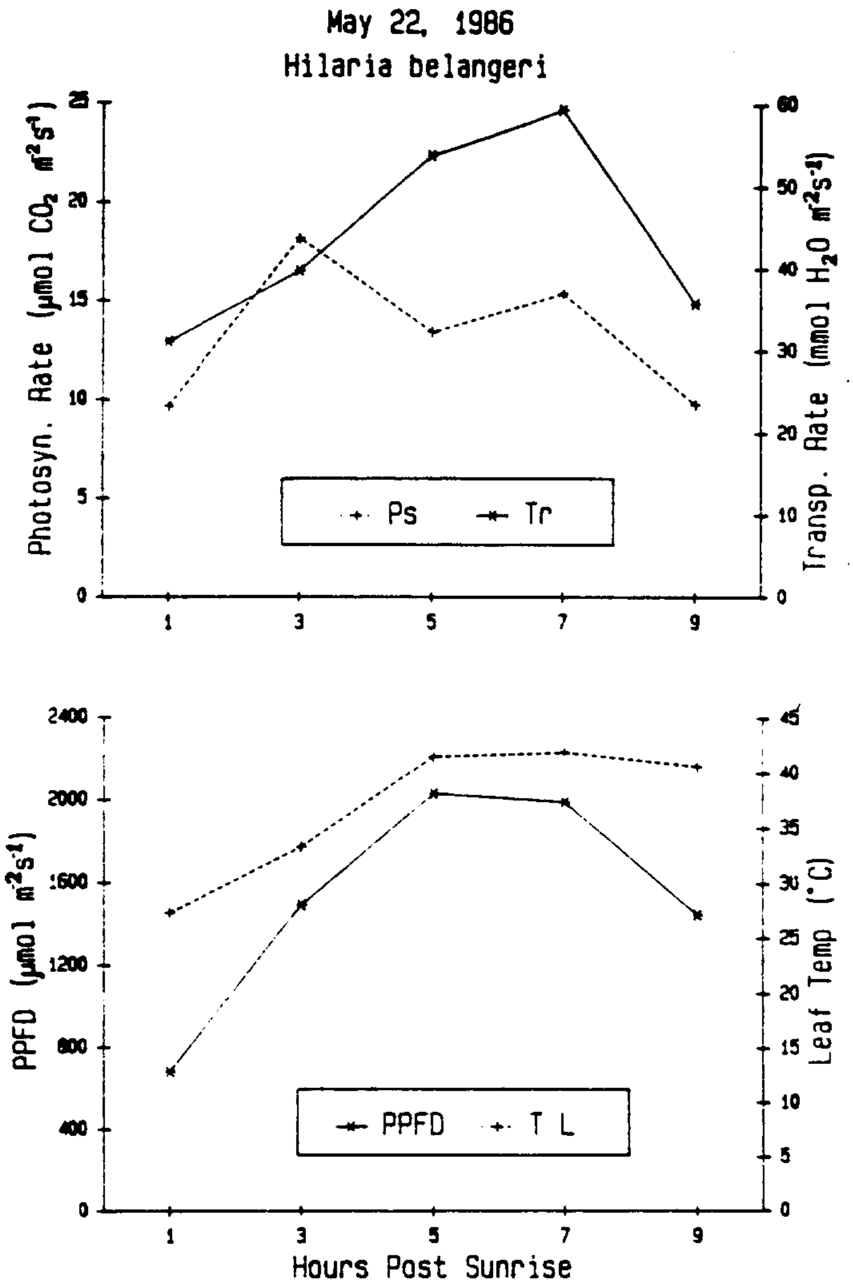

Fig. 3. Daily patterns of net photosynthesis rate (Ps) and transpiration rate (Tr) of H. berlangeri on May 22, 1986; and daily patterns of photosynthetic photon flux density (PPFD) and leaf temperature (LT) associated with gas exchange measurements.

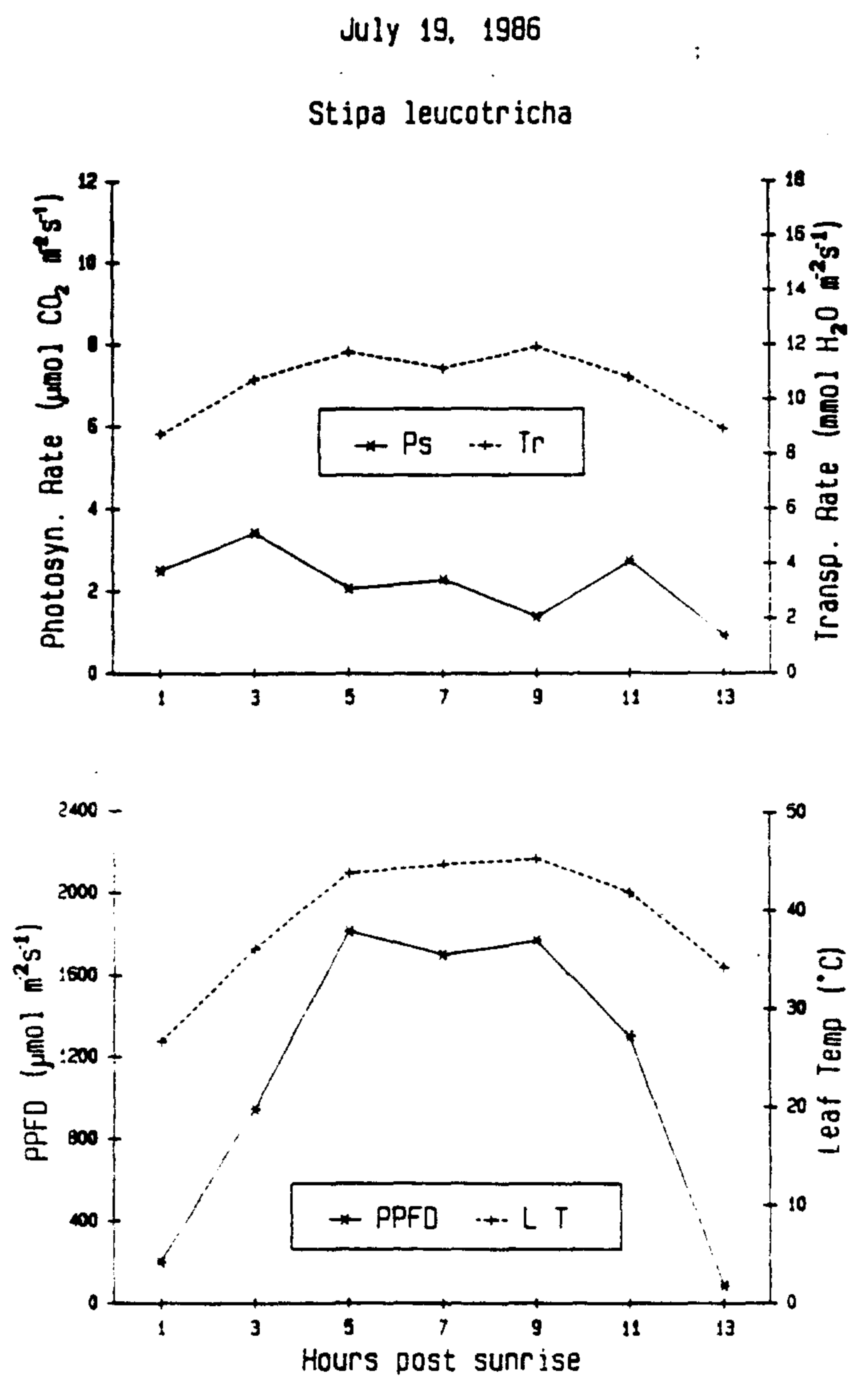

Fig. 4. Daily patterns of net photosynthesis rate (Ps) and transpiration rate (Tr) of S. leucotricha on July 19, 1986; and daily patterns of photosynthetic photon flux density (PPFD) and leaf temperature (LT) associated with gas exchange measurements.

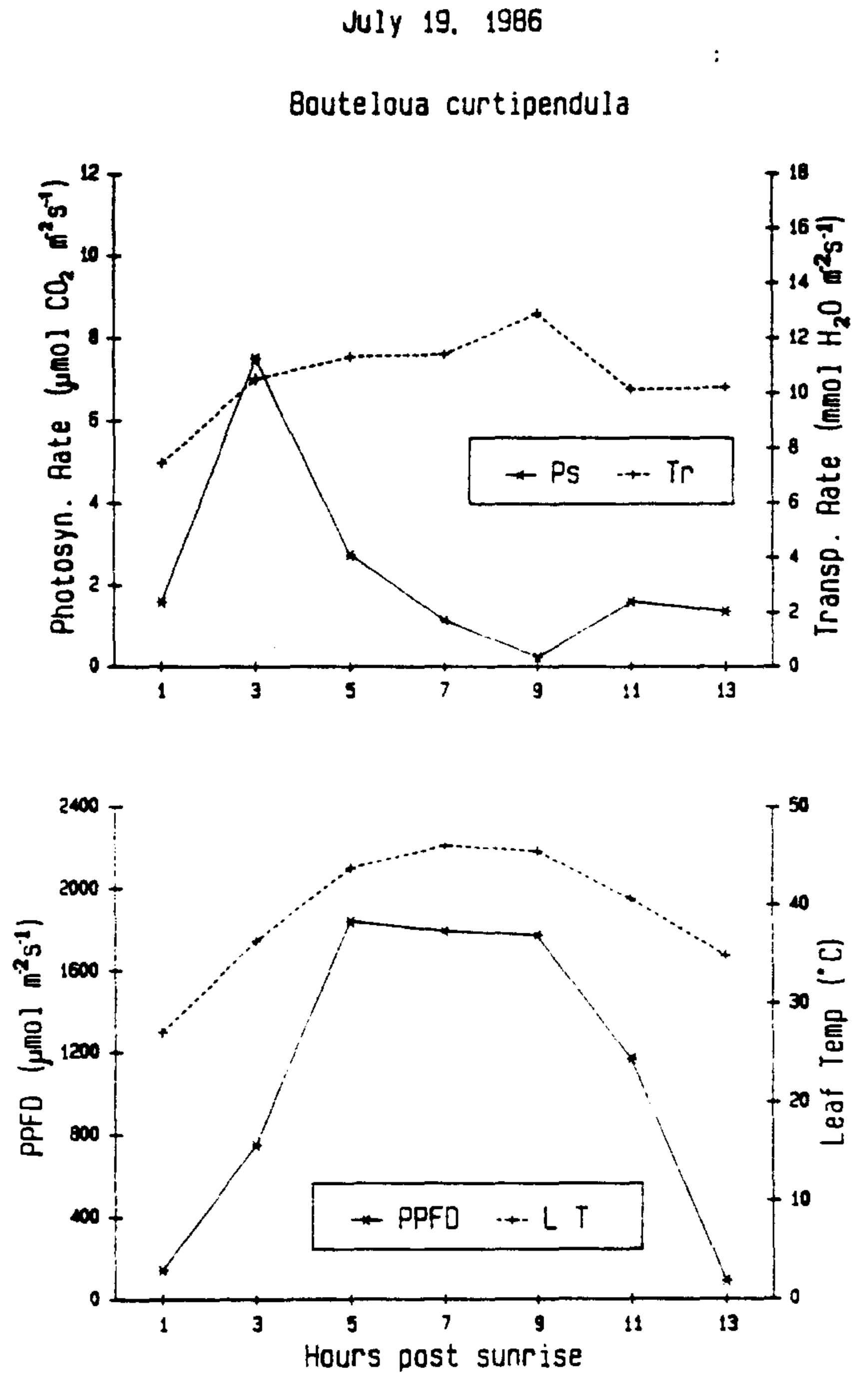

Fig. 5. Daily patterns of net photosynthesis rate (Ps) and transpiration rate (Tr) of B. curtipendula on July 19, 1986; and daily patterns of photosynthetic photon flux density (PPFD) and leaf temperature (LT) associated with gas exchange measurements.

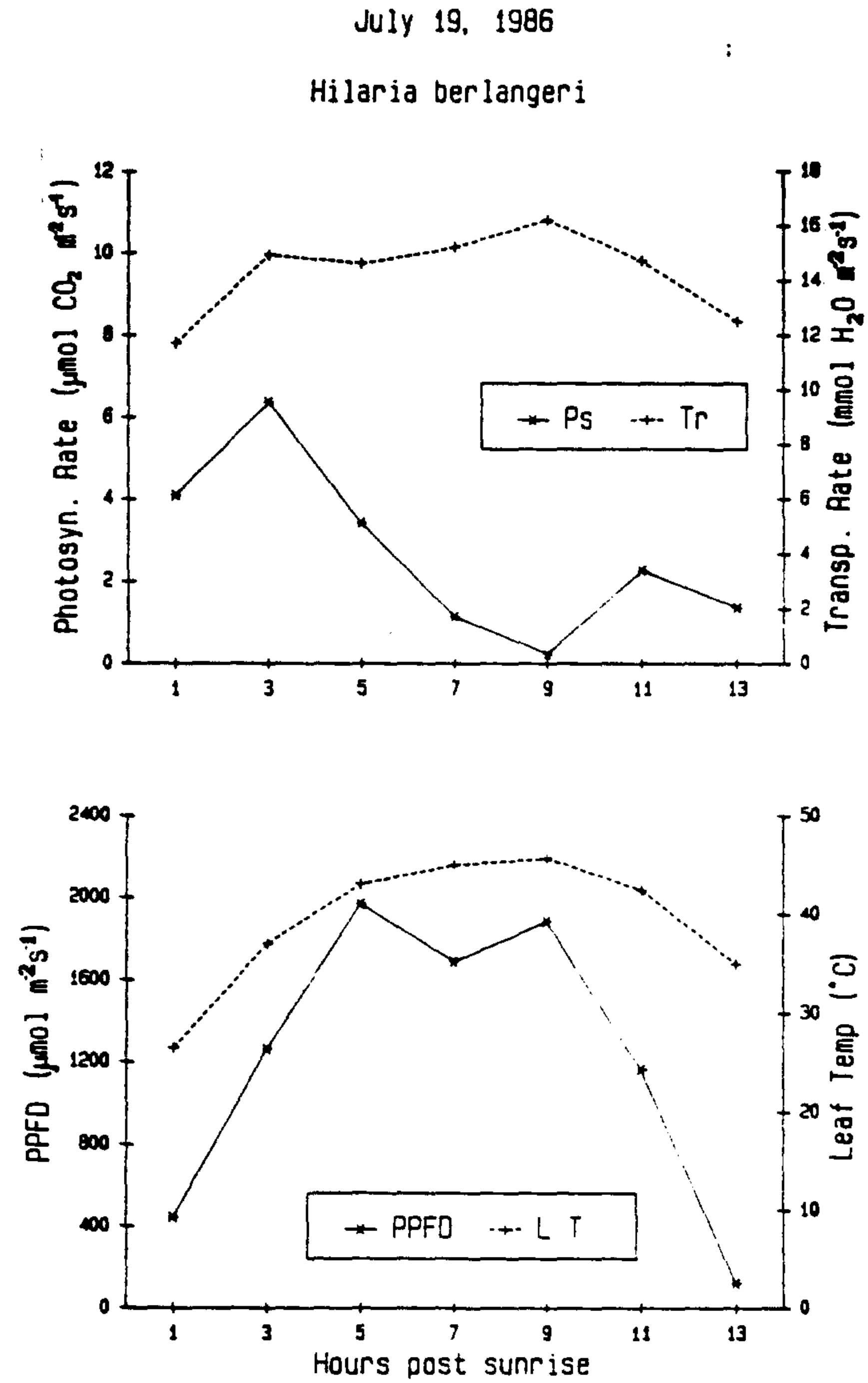

Fig. 6. Daily patterns of net photosynthesis rate (Ps) and transpiration rate (Tr) of H. berlangeri on July 19, 1986; and daily patterns of photosynthetic photon flux density (PPFD) and leaf temperature (LT) associated with gas exchange measurements.

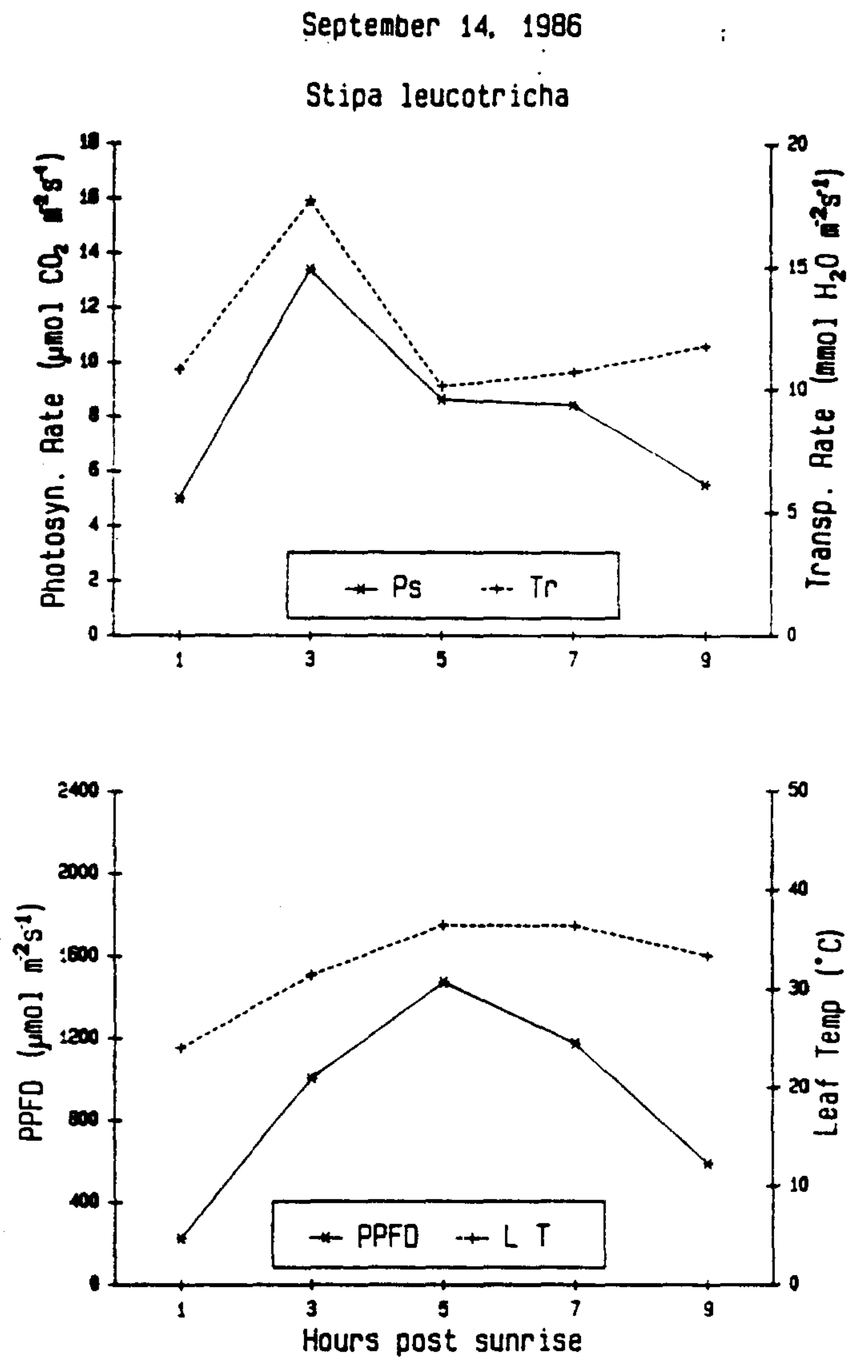

Fig. 7. Daily patterns of net photosynthesis rate (Ps) and transpiration rate (Tr) of S. leucotricha on September 14, 1986; and daily patterns of photosynthetic photon flux density (PPFD) and leaf temperature (LT) associated with gas exchange measurements.

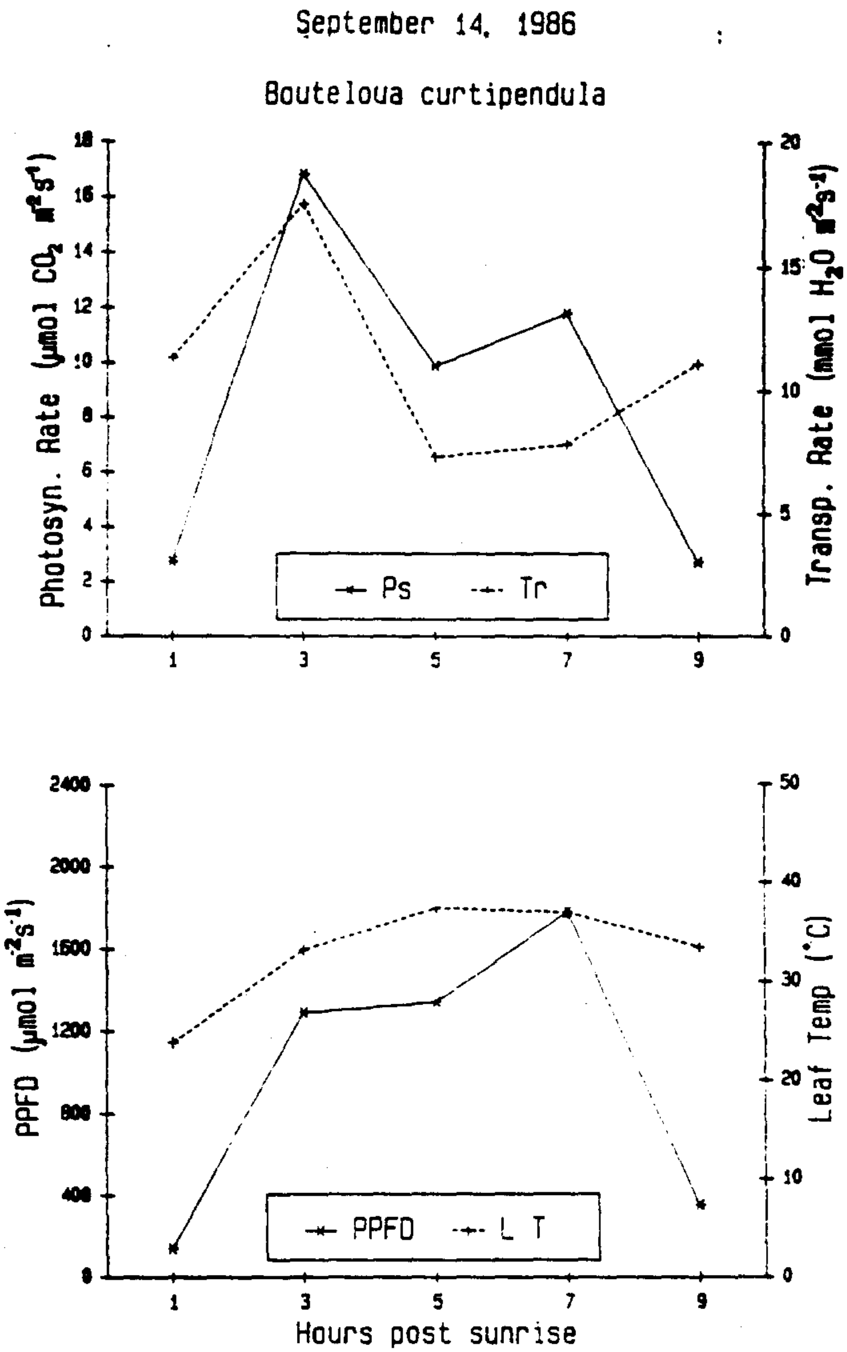

Fig. 8. Daily patterns of net photosynthesis rate (Ps) and transpiration rate (Tr) of B. curtipendula on September 14, 1986; and daily patterns of photosynthetic photon flux density (PPFD) and leaf temperature (LT) associated with gas exchange measurements.

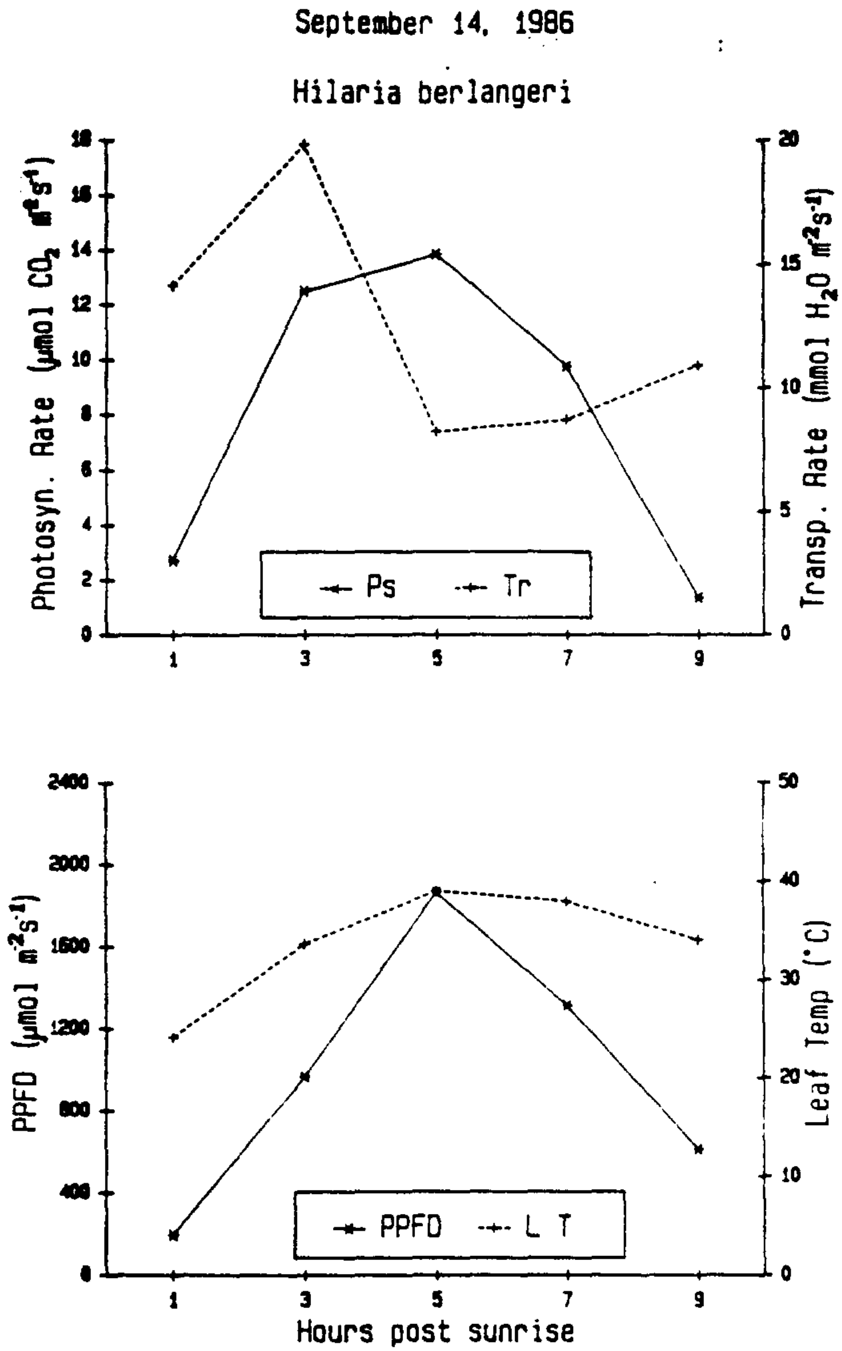

Fig. 9. Daily patterns of net photosynthesis rate (Ps) and transpiration rate (Tr) of *H. berlangeri* on September 14, 1986; and daily patterns of photosynthetic photon flux density (PPFD) and leaf temperature (LT) associated with gas exchange measurements.

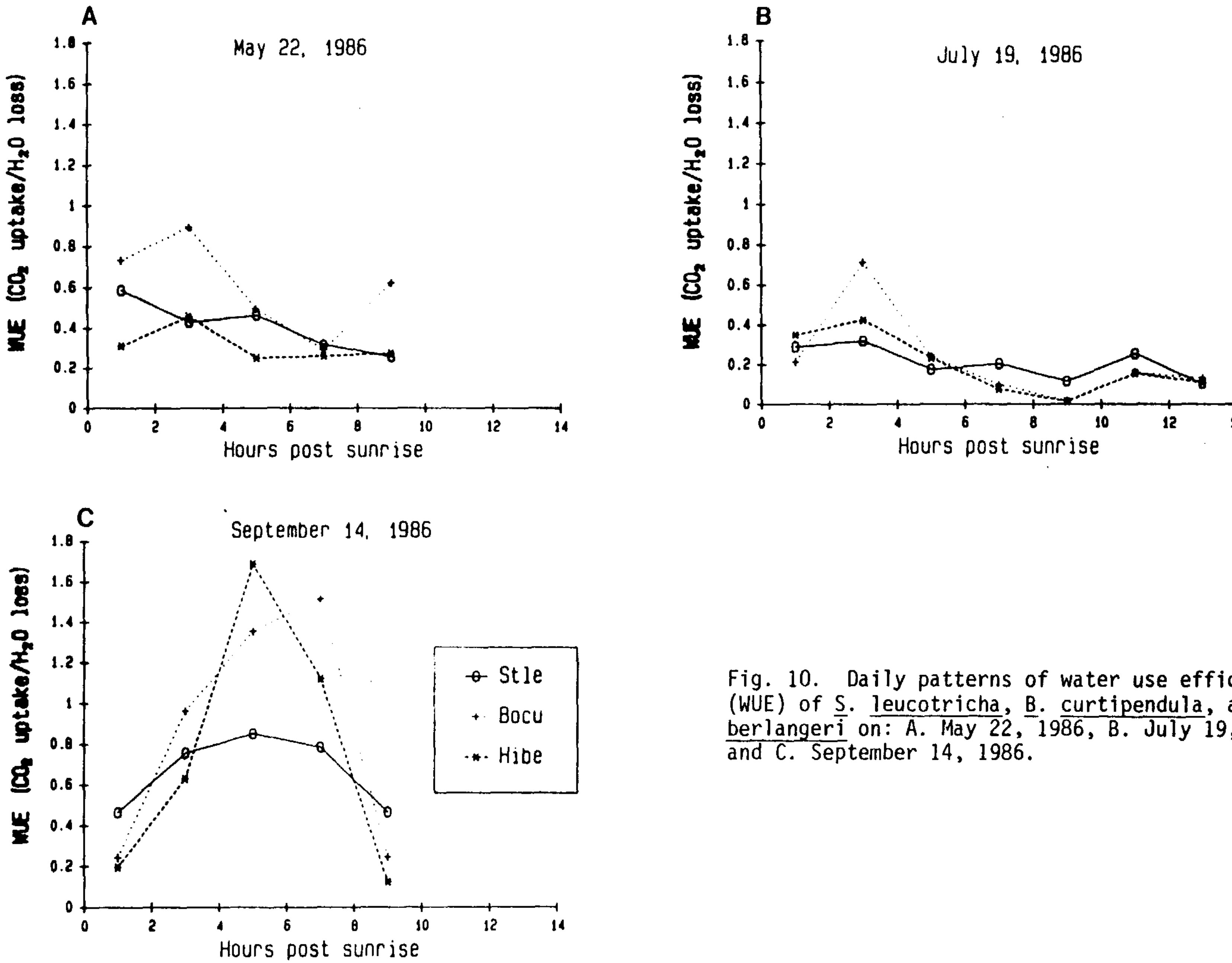

Fig. 10. Daily patterns of water use efficiency (WUE) of S. leucotricha, B. curtipendula, and H. berlangeri on: A. May 22, 1986, B. July 19, 1986, and C. September 14, 1986.

Seasonal Photosynthesis, Transpiration and Water Use Efficiency of Honey Mesquite

R. J. Ansley, C. A. Call and R. A. Hicks

Summary

Mesquite trees occurring within non-weighing lysimeters at the Wagon Creek Spade Research Area near Throckmorton were sampled during the spring and summer of 1986 to determine diurnal and seasonal patterns of photosynthesis (PS), transpiration (TR), and water use efficiency (WUE). PS of leaves on the east tree side was greatest early in the day then declined sharply as the day progressed. PS on the west side was initially very low when compared to the east side but increased gradually during the day. Diurnal PS patterns were surprisingly similar across all sample dates from April to September indicating that the leaves maintained a constant daily level of metabolic activity throughout the season.

Tree side did not influence TR rates nearly as much as it did PS rates. TR increased to maximum levels on both tree sides in June then declined in July and August. Late summer rains were responsible for an increase in TR during September almost to levels measured in June. These results indicate that honey mesquite leaves remained active throughout the growing season and were able to respond to precipitation late in the season, even after a period of drought during July and August. Moreover, since total daily TR varied considerably during the season while total daily PS did not, daily WUE (when defined as the amount of CO_2 taken upper water expended through transpiration) was quite variable during the season. Daily WUE was low when water was available and high when conditions were more arid.

Methods

Carbon exchange rates, leaf stomatal conductance, leaf temperature, photosynthesis and transpiration were measured on leaves of honey mesquite using two LICOR LI-6000 Portable Photosynthesis Systems. One of the LI-6000 units was purchased with watershed research money allocated to Dr. C. A. Call and was based in college Station. The other unit was already owned by the Brush Control Project at the TEAS Vernon Station.

Diurnal measurements were made on the east and west sides of each of three lysimeter contained trees at two hour intervals during the day beginning at one hour past sunrise (HPS), and approximately once a month from April to September, 1986. Two leaves were sampled per side per tree during each sample period. Sample date determination was based on mesquite phenological stages. Sampling was generally conducted on clear, sunny days but some days were partly cloudy during the morning and/or evening. We were unable to choose the sample date based on climatic conditions due to the logistic problems associated with scheduling two LI-6000 units from different locales to operate simultaneously on such a remote site.

Predawn and diurnal leaf water potentials were measured using the Scholander-type method and soil moisture was measured to 2 meter depths once a week.

Results and Discussion

Photosynthesis

Photosynthesis was measured on six dates in 1986 (Figure 1). PS was greatest on the east tree side at 1 or 3 HPS on each date. PS on the east side declined rapidly during the day following the early morning peak. PS on the west side was much lower than that on the east side early in the day but gradually increased so that by 7 to 9 HPS it was greater than PS on the east

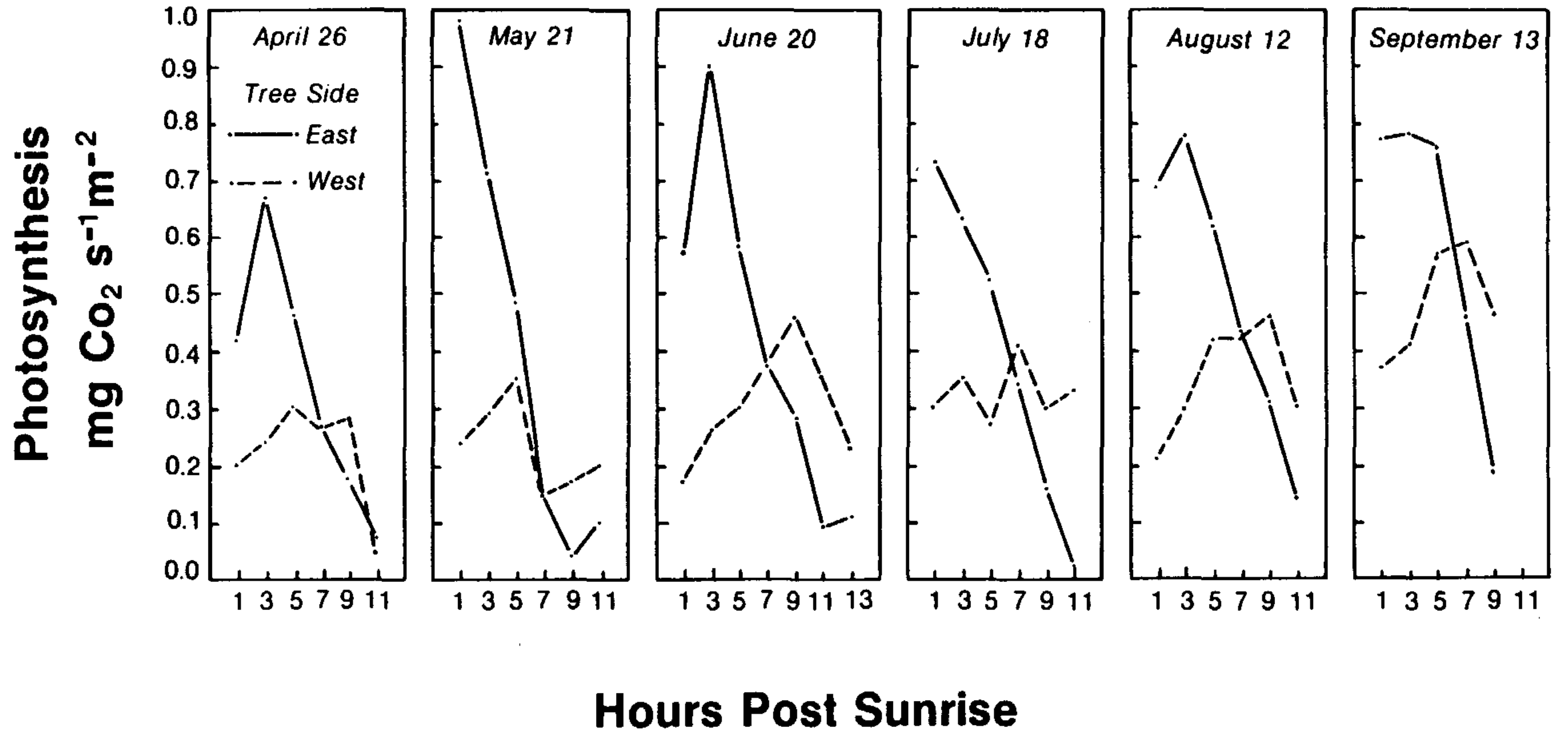

Figure 1. Photosynthesis on east and west side of honey mesquite trees in non-weighable lysimeters, Wagon Creek Spade Research Area, Throckmorton County, 1986.

side. PS rates on the west tree side never became as great during the day as early morning PS on the east side. Evidently the most ideal condition for mesquite to conduct PS was when photosynthetically active radiation (PAR) was high but the vapor pressure deficit (VPD) was not extreme as was the case on the east tree side early in the morning.

These results suggest that mesquite trees "tracked" the sun and concentrated PS on the most sun-exposed portion of the tree canopy. Moreover, the results indicate that mesquite canopies provided enough shade to cause variation in PS rates within the canopy. The effects of canopy shading on PS is further explored in Study II which follows this section.

Diurnal patterns of PS were surprisingly similar across all sample dates from April to September indication that the leaves maintained a constant daily level of metabolic activity throughout the season. The only seasonal trend detected was that total PS over the entire day increased slightly on the west side of the tree as the season progressed (Figure 1). The summer of 1986 was unusually wet with frequent showers and this could explain why PS was more constant during the season than was expected.

Transpiration

Tree side did not influence TR rates nearly as much as it did PS rates. Diurnal patterns of TR were similar on both sides of the tree except during late afternoons when TR was usually greater on the west side than the east side (Figure 2). TR increased to seasonally maximum levels on both tree sides in June then declined in July and August. Late summer rains were responsible for an increase in TR during September almost to levels measured in June. These results indicate strongly that honey mesquite leaves remained active throughout the growing season and were able to respond to precipitation late in the season, even after a period of drought in July and August.

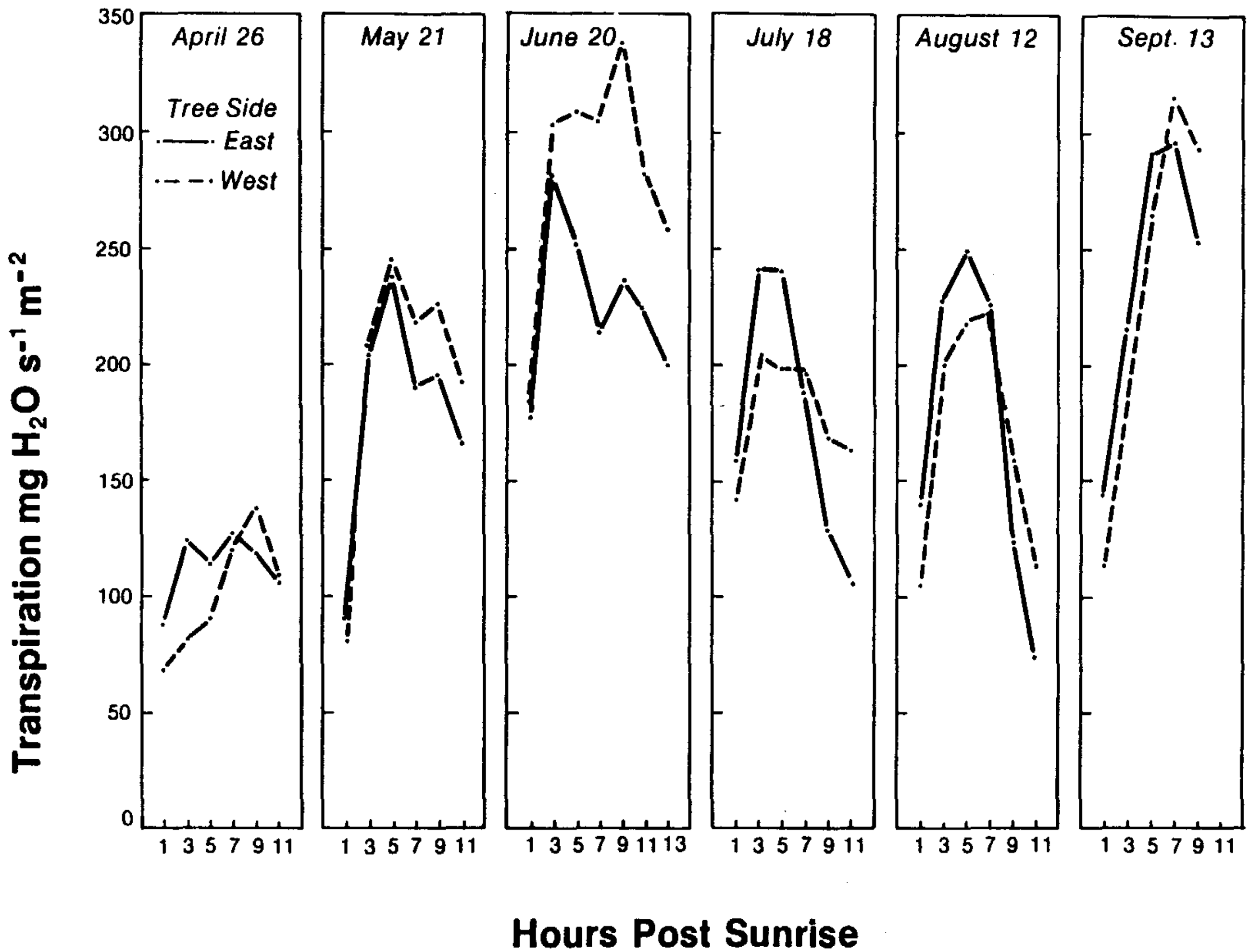

Figure 2. Transpiration on east and west side of honey mesquite trees in non-weighable lysimeters, Wagon Creek Spade Research Area, Throckmorton County, 1986.

Water Use Efficiency

Total daily TR varied considerably during the season which total daily PS did not (Figures 1 and 2). This suggests that total daily WUE (when defined as amount of CO_2 taken up per amount of water expended through transpiration) was quite variable during the season. Daily WUE was low (less efficient) when water was abundantly available such as in June, and high (more efficient) when conditions were more arid such as in July and August.

Since PS was generally greater on the east side than the west during each day while TR exhibited an opposite pattern, it is suggested that WUE was much greater on the east tree side than the west during the day.

Diurnal Variation in Photosynthesis Within Honey Mesquite Canopies

R. J. Ansley, C. A. Call and R. A. Hicks

Summary

The objective of this study was to characterize diurnal dynamics of photosynthesis (PS) within canopies of individual mesquite trees and to determine the influence of canopy shading and light extinction on photosynthetic responses. Canopies of two trees were intensively monitored at 2, 5, 8 and 11 hours post-sunrise (HPS) in May and July, 1986. Data were collected from four diurnally changing light strata (STR) which were identified within each canopy. Light strata ranged from most sunlit (STR 1) to most shaded (STR 4) areas. Throughout each day PS was greatest in STR 1 and least in STR 4. These differences were greatest at 2 HPS and were reduced during mid-day because PS declined sharply in STR 1 between 2 and 5 HPS, but declined only slightly in STR 4. Similar measurements were made on leaf conductance and transpiration but data has not yet been assimilated.

Methods

Two LICOR LI-6000 Portable Photosynthesis Systems were used to intensively sample the canopies of two trees at the Watershed Research Site near Throckmorton. Canopies were monitored at 2, 5, 8 and 11 hours post-sunrise (HPS) in May when conditions were more mesic and again in July when conditions were more xeric. Data were collected from four diurnally changing light strata (STR) which were identified within each canopy prior to each sampling period. Light strata ranged from most sunlit (STR 1) to most shaded (STR 4). Four leaves were sampled per stratum per tree. During mid-day when the sun was high in the sky, a ladder was used to measure leaves near the top to the canopy. Sampling was conducted on clear, sunny days.

Photosynthetically active radiation (PAR) was measured with a quantum sensor. Two readings were taken during the sampling of each leaf: one with the sensor oriented vertically with respect to the horizon, and a second with the sensor facing through the canopy towards the sun.

Results and Discussion

Within STR 1 and 2, the most sunlit strata, PS was maximum at 2 HPS, declined during mid-day, and in some cases such as tree 1 in July, increased slightly at 11 HPS (Figure 1). Throughout each day PS was greatest in STR 1 and least in STR 4. At 2 HPS, PS rates were three to four times greater in STR 1 than STR 4. These differences were reduced during mid-day because PS declined more sharply in STR 1 than STR 4 between 2 and 5 HPS, probably because conditions were more stressful in STR 1.

Photosynthetic responses in STR 1 and 4 closely corresponded to the PAR data which indicated maximum PAR in STR 1 and minimum PAR in STR 4 (Figure 2). PAR increased in both STR 1 and STR 4 during mid-day but this did not promote an increase in PS in STR 1 on either date. It may explain why PS increased slightly in STR 4 during midday in May although this trend was not repeated in July, probably because of drier conditions.

Both PS and PAR responses were not clearly defined in the two middle strata and it is suggested that only three strata be used when this study is continued next year.

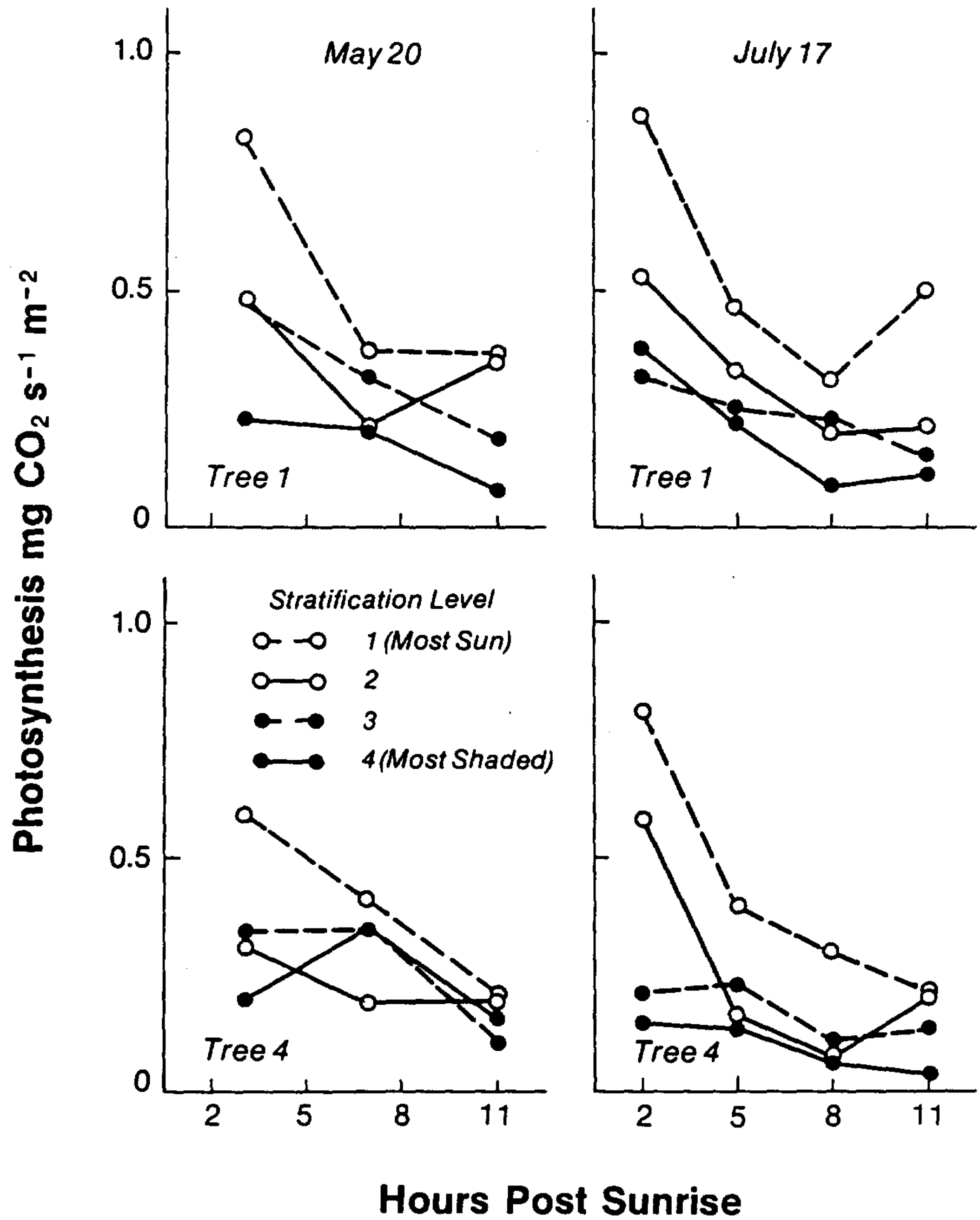

Figure 1. Photosynthesis in four levels of light strata within canopies of two honey mesquite trees on two dates, Wagon Creek Spade Research Area, Throckmorton County, 1986.

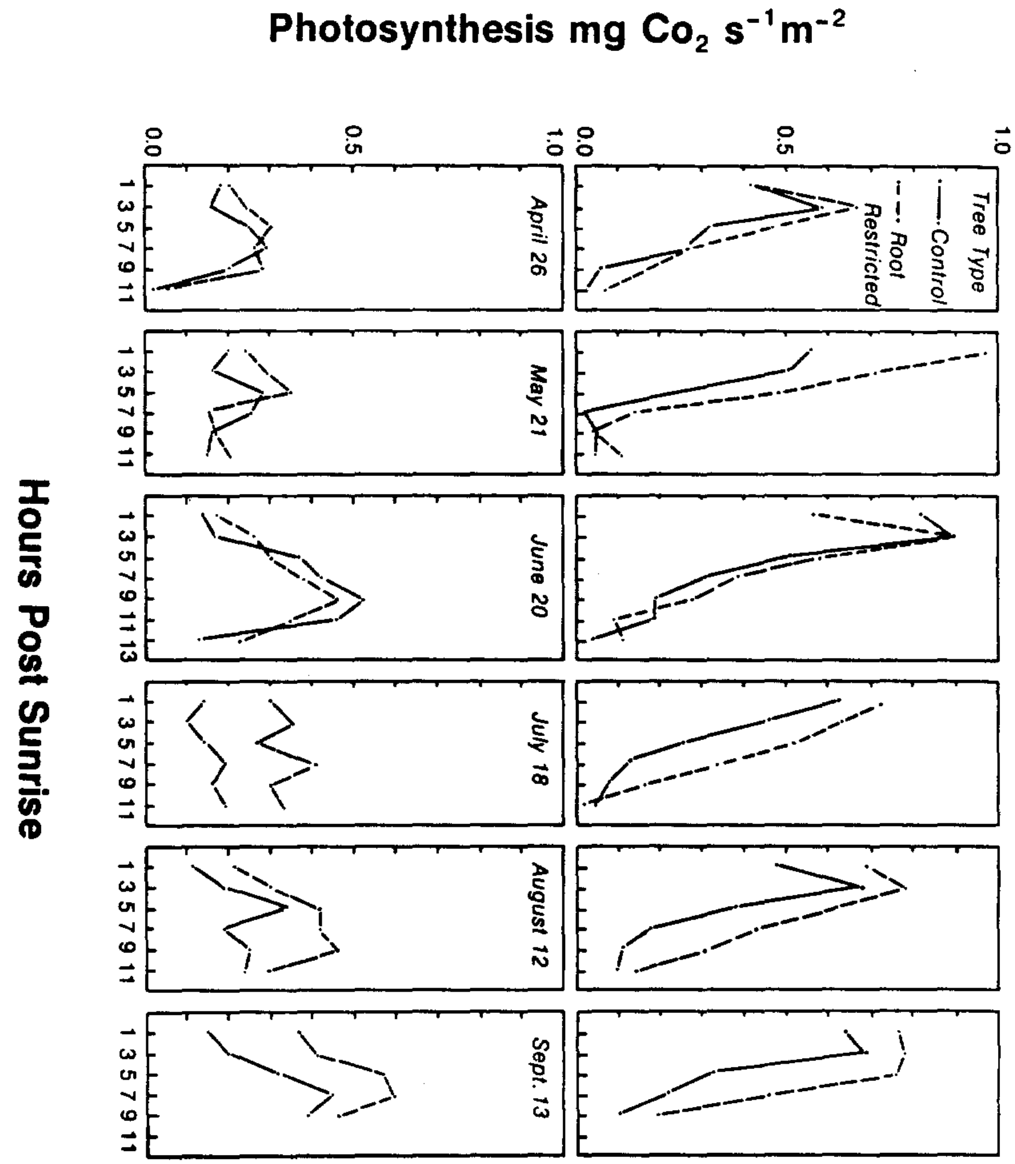

Figure 1. Photosynthesis of the east side (top row) and west side (bottom row) of honey mesquite trees in the non-weighing lysimeters that have lateral roots restricted (dashed lines) and unrestricted control trees (solid lines) for six sample periods during 1986, Wagon Creek Spade Research Area, Throckmorton County.

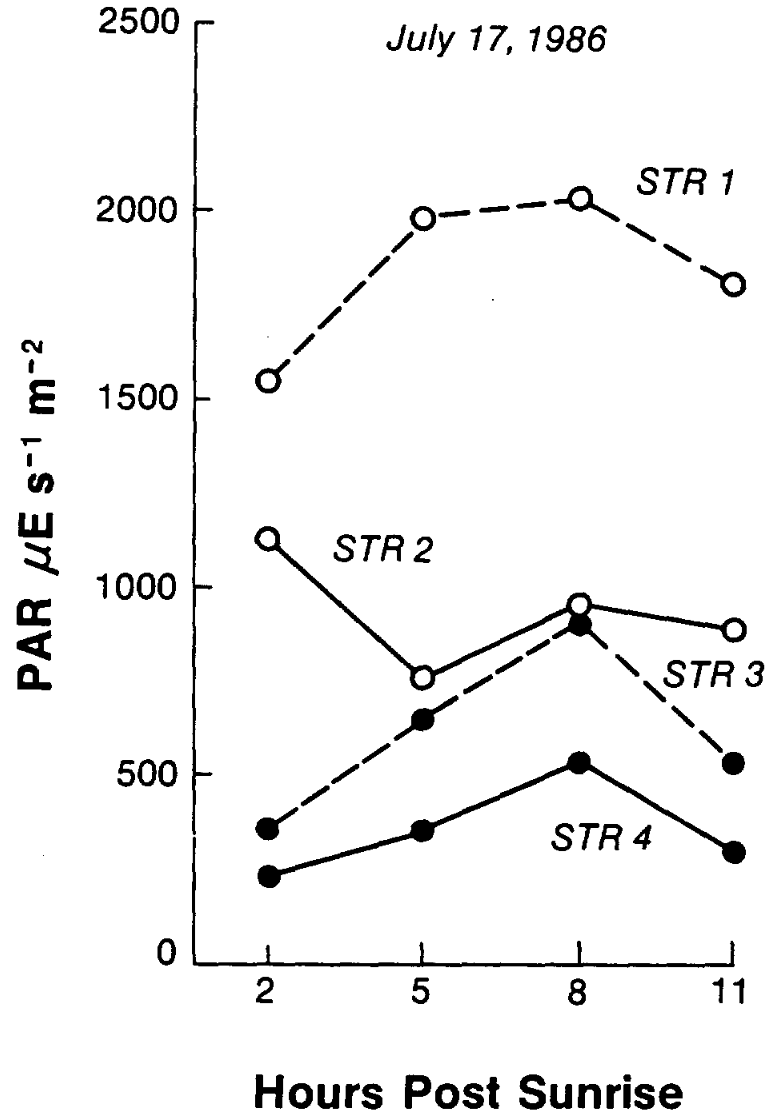

Figure 2. PAR at four light stratification levels (STR 1 to 4) within the canopies of two honey mesquite trees. PAR was recorded with the quantum sensor facing the sun through the canopy, Wagon Creek Spade Research Area, Throckmorton County, 1986.

Influence of Lateral Root Restriction On Honey Mesquite Photosynthesis and Water Relations

R. J. Ansley, C. A. Call and R. A. Hicks

Summary

The objective of this study was to determine what effect the imposition of root barriers around mesquite trees in the non-weighing lysimeters had on tree activity when compared to similar size control trees which did not have the root barrier. Both photosynthesis (PS) and transpiration (TR) were similar for the root-restricted and control trees from April to June. From July to September, however, PS, and to an even greater degree, TR were greater on both the east and west sides of the root-restricted lysimeter trees than on the control trees. Since the root-restricted trees experienced a substantial leaf drop between the June and July sample date and the control trees did not, it was suggested that the root-restricted trees were under stress and reduced the total leaf load in the tree canopy and maintained higher than average metabolic activity (i.e., PS, TR) on those leaves that remained.

Methods

PS and TR measurements were made on three root-restricted lysimeter trees and on three paired "control" trees which were similar in canopy volume to the lysimeter trees but did not have lateral root restriction. Diurnal and seasonal sampling techniques for PS, TR and other parameters were identical to those described in Study I.

Results and Discussion

Since honey mesquite grows in an arid environment and usually has an extensive system of lateral and tap roots, we felt it was important to determine what effect the imposition of root barriers around the non-weighing lysimeter trees in the watershed study has on tree activity and soil moisture when compared to similar trees which did not have the barrier and were growing under natural conditions.

Photosynthesis (PS) was not different between the root-restricted and control trees on either the east or west side of the trees from April to June (Figure 1). However, from July to September leaves on both sides of the restricted trees had greater PS rates than leaves on the control trees. Virtually the same trends were found when comparing transpiration (TR) of restricted and control trees except that late summer differences between the two were much greater than that found with PS (Figure 2). In July and August TR was almost twice as great in the restricted trees than the control trees.

These results would suggest that the restricted trees were in better physiological condition than the control trees in late summer were it not for the observation that between the June 20 and July 18 sample data all three of the restricted trees dropped a substantial amount (at least half by ocular estimation although this was not quantified) of their leaves while the control trees did not. We suggest that the restricted trees were under moisture stress by the June 20 sample date. This is supported by the TR results on the east side of the trees in Figure 2 which show that TR is grater in the control trees on June 20. After this date the restricted trees implemented a strategy to cope with stress induced by the loss of lateral roots and reduced the total leaf load in the canopy while maintaining higher than average activity (i.e., PS, TR) on those leaves that remained. This strategy was implemented rather than retaining <u>all</u> the leaves and reduction PS/TR per leaf.

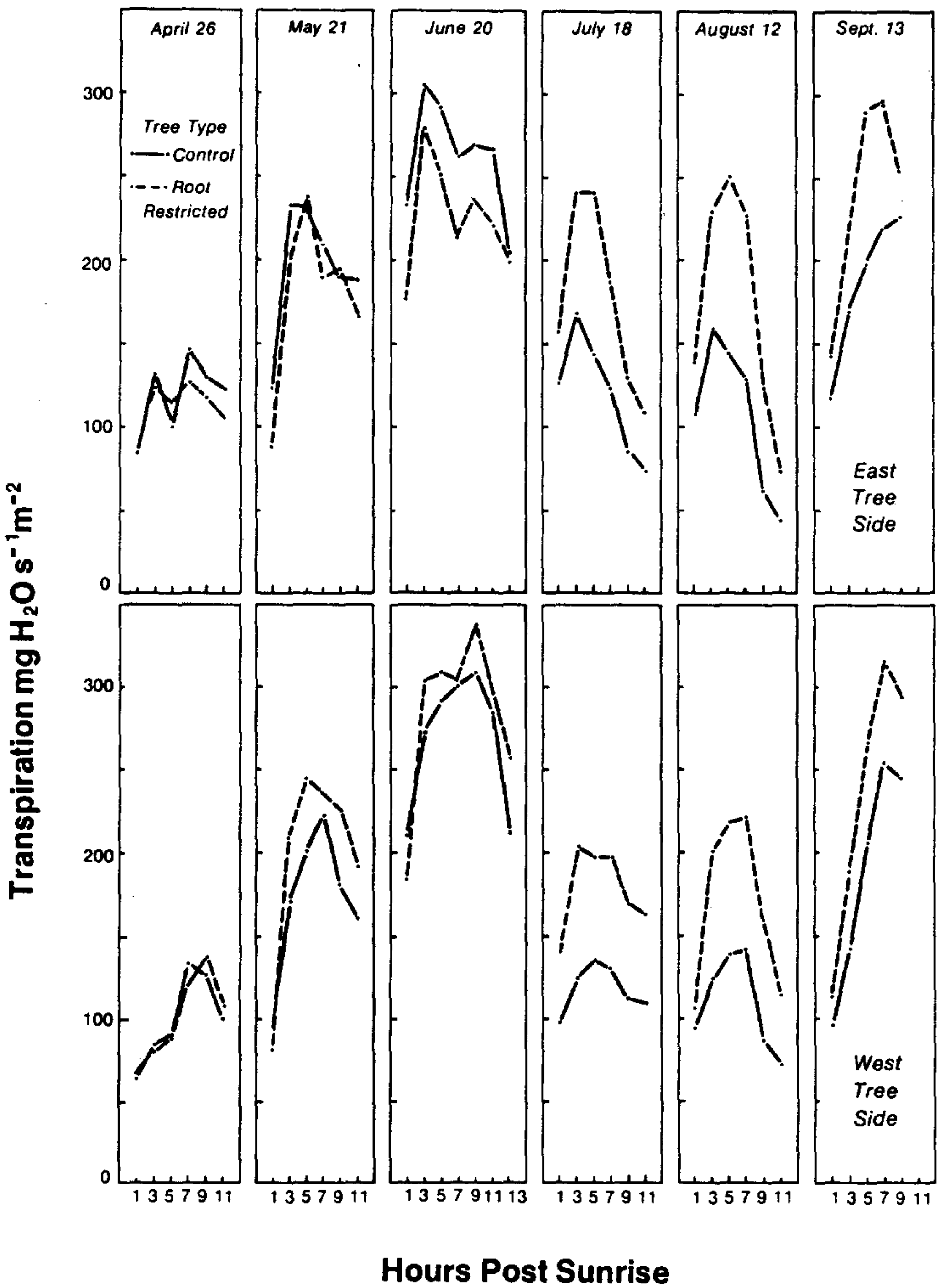

Figure 2. Transpiration of the east side (top row) and west side (bottom row) of honey mesquite trees inside non-weighing lysimeters (dashed lines) and outside (solid lines) the lysimeters, Wagon Creek Spade Research Area, Throckmorton County, 1986.

Morphological Characteristics of a Honey Mesquite Root System

R. K. Heitschmidt, S. L. Dowhower, T. A. Wright, and D. L. Price

Summary

The root system of a mature, single-stemmed honey mesquite (*Prosopis glandulosa* var. *glandulosa*) tree was partially excavated to examine the morphological characteristics of its rooting system. Rooting characteristics tend to support a hypothesis that mesquite does directly compete with herbaceous vegetation for soil water in the upper 1 m of the soil profile. However, rooting characteristics also tend to support a hypothesis that mesquite can extract water form soil depths below those normally exploited by the herbaceous species. At present, only descriptive results are available.

Methods

The primary method of excavation was manual labor. Although a tractor-mounted backhoe was used to partially remove soil from one side of the tree, most was removed by hand.

Leaf area and weight were estimated in August by removing all leaves by hand. Total leaf area was estimated by subsampling leaves to quantify leaf area (leaf are meter)-weight relationships using linear regression procedures.

Results and Discussion

Partial excavation of this single tree (Figure 1) revealed an extensive perennial root system in both the horizontal (Figure 2) and vertical planes (Figure 3). Major lateral roots near the base of the tree had an extensive system of sublaterals that extended both upward toward the soil surface and downward into the soil parent material. A single lateral root that extended outward to a distance of about 12 m was excavated. The diameter of the lateral near the base of the tree was about 9 cm. Diameter at 12 m was about 1 cm.

Although a major tap root was excavated, its size was less than anticipated. Initial diameter at the soil-trunk interface was approximately 34 cm. By a depth of about 40 cm this had declined to about 8 cm. At 1 m below the soil surface, the tap root gave way to 2 roots each about 4 cm in diameter. When the excavation was halted at a depth of 140 cm, these 2 roots were about 3 cm in diameter.

Excavation began in early June when the tree canopy was fully leaved. During August after most of the year's excavation had been completed, a rather severe drought was encountered, however, the tree continued to function with a full canopy of leaves throughout the summer thereby indicating its ability to extract soil moisture. In fact, once the leaves were removed for quantitative determinations, a full canopy of new leaves was produced. It is apparent the tree is continuing to derive moisture from the soil medium. (Note: No abnormal loss of leaves has been observed as of this date, 26 September 1986).

Preliminary analyses of the leaf area data show a strong correlation between leaf area and leaf weight. Subsequent analyses are attempting to establish relationships between leaf areas and various stem diameters. The objective of these analyses are to provide insight for developing nondestructive sampling methods for quantifying honey mesquite leaf area over time. This is a major task that must be undertaken during the 1987 growing season.

Tap Root System

Lateral Root w/ Sublateral
Tap Root

Excavated Tree

Figure 1. Photographs of the partial excavated honey mesquite tree's root system, showing the tap root (top left), lateral root with sublateral tap root (top right) and excavated tree (bottom), Wagon Creek Spade Research Area, Throckmorton County, 1986.

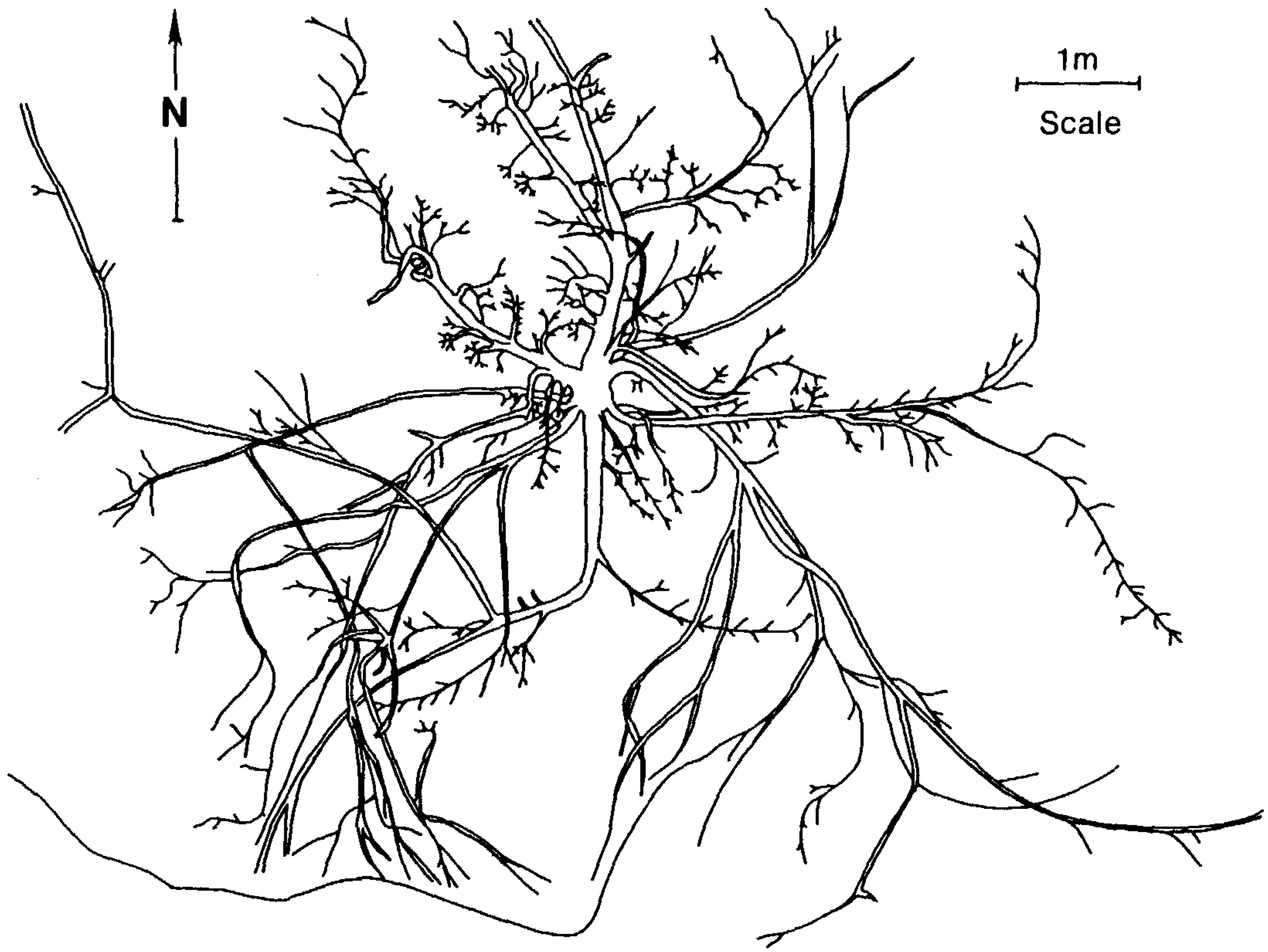

Figure 2. Schematic drawing of an 8 m x 10 m cross-section of a honey mesquite tree root system in the tap 20 cm of the soil profile, Wagon Creek Spade Research Area, Throckmorton County, 1986.

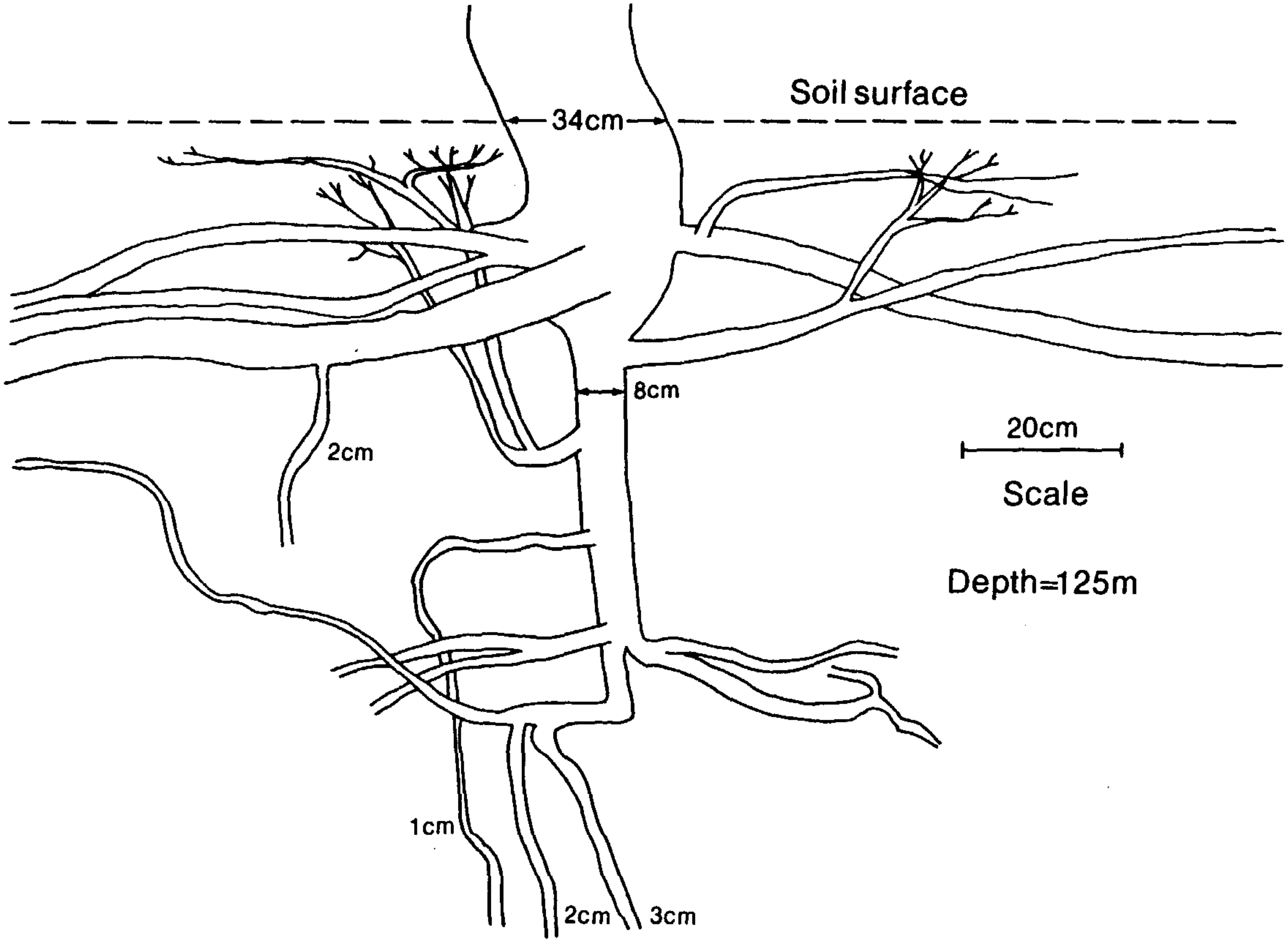

Figure 3. Schematic drawing of a 2 m x 1.2 m cross-section of a honey mesquite tree root system to a depth of 1.25 m, Wagon Creek Spade Research Area, Throckmorton County, 1986.

Some Effects of Honey Mesquite on Herbage Standing Crops

R. K. Heitschmidt, S. L. Dowhower, T. A. Wright, and S. K. Canon

Summary

Use of a nondestructive point frequency method of sampling herbaceous standing crops in 9 weighing and 6 non-weighing lysimeters has proven successful. Preliminary analyses show herbaceous standing crop in the grass non-weighing lysimeters is greater than in the grass and mesquite lysimeters. This difference may in part be the result of the interaction effect of competition for water and nutrients between honey mesquite trees and herbaceous forage species. Preliminary results form the 9 weighing lysimeters suggest sideoats grama sods are more productive than Texas wintergrass and shortgrass sods.

Methods

Research consists of two studies. The first study is designed to evaluate the effect of honey mesquite (*Prosopis glandulosa* var. *glandulosa*) on herbage production and ultimately water use efficiency. Nine non-weighing lysimeters were installed in 1985 around honey mesquite trees. Following installation 3 replications of 3 treatments were established. Treatments are: 1) bareground (BG) where both the honey mesquite tree and all associated herbage were killed and removed; 2) grass (G) where only the honey mesquite tree was removed; and 3) grass plus mesquite (G+M) where neither the grass nor honey mesquite were removed. The second study is designed to evaluate the water use efficiency of the dominant herbaceous species growing on this honey mesquite dominated rangeland. Twelve weighing lysimeters were installed in this study to establish 4 sodded treatments of 3 replications each. Treatments are: 1) bareground (BG) where all vegetation was removed; 2) sideoats grama (*Bouteloua curtipendula*) sod (Bocu); 3) shortgrass sod (Shgr) dominated by common curlymesquite (Hilaria berlangeri) and buffalograss (Buchloe dactyloides); and 4) Texas wintergrass (Stipa leucotricha) sod (Stle).

Research objectives necessitate the use of non-destructive sampling methods to monitor herbaceous standing crops in both the weighing and non-weighing lysimeters. Frequency hits frame 10-point frame is utilized in the effort. Hits/pin are recorded by species by live leaf, dead leaf, and stem periodically along permanent transect lines. Following sampling, areas outside the lysimeters are selected to establish the relationships between frequency of hits and standing crop. Ten, 0.25 m^2-quadrats are objectively selected for study on each sample date. Three frequency frames are read/quadrat prior to clipping standing crop by species. Following clipping, 3 subsamples of each dominant species are hand separated into live leaf, dead leaf, and stem for establishing surface area to weight relationships using standard linear regression techniques. All herbage is then dried at 60° C to a constant weight for expression on a dry weight basis.

Results and Discussion

Research was initiated in March of 1986. Frequency data for herbage standing crop has been collected about every 4 weeks. Although no data summaries have been initiated to quantify the contribution of live leaves, dead leaves, and stems to standing crop, analyses by species and sample dates indicate a satisfactory relationship does exist between frequency/pin and weight of individual species. Figure 1 depicts the relationships established by species by date. Figure 2 is a summary of the relationships established by linear regression for each sample date averaged across species while Figure 3 depicts the relationships for each species averaged across dates. All models depicted in Figures 2 and 3 were significant at $P<0.01$ although no points of

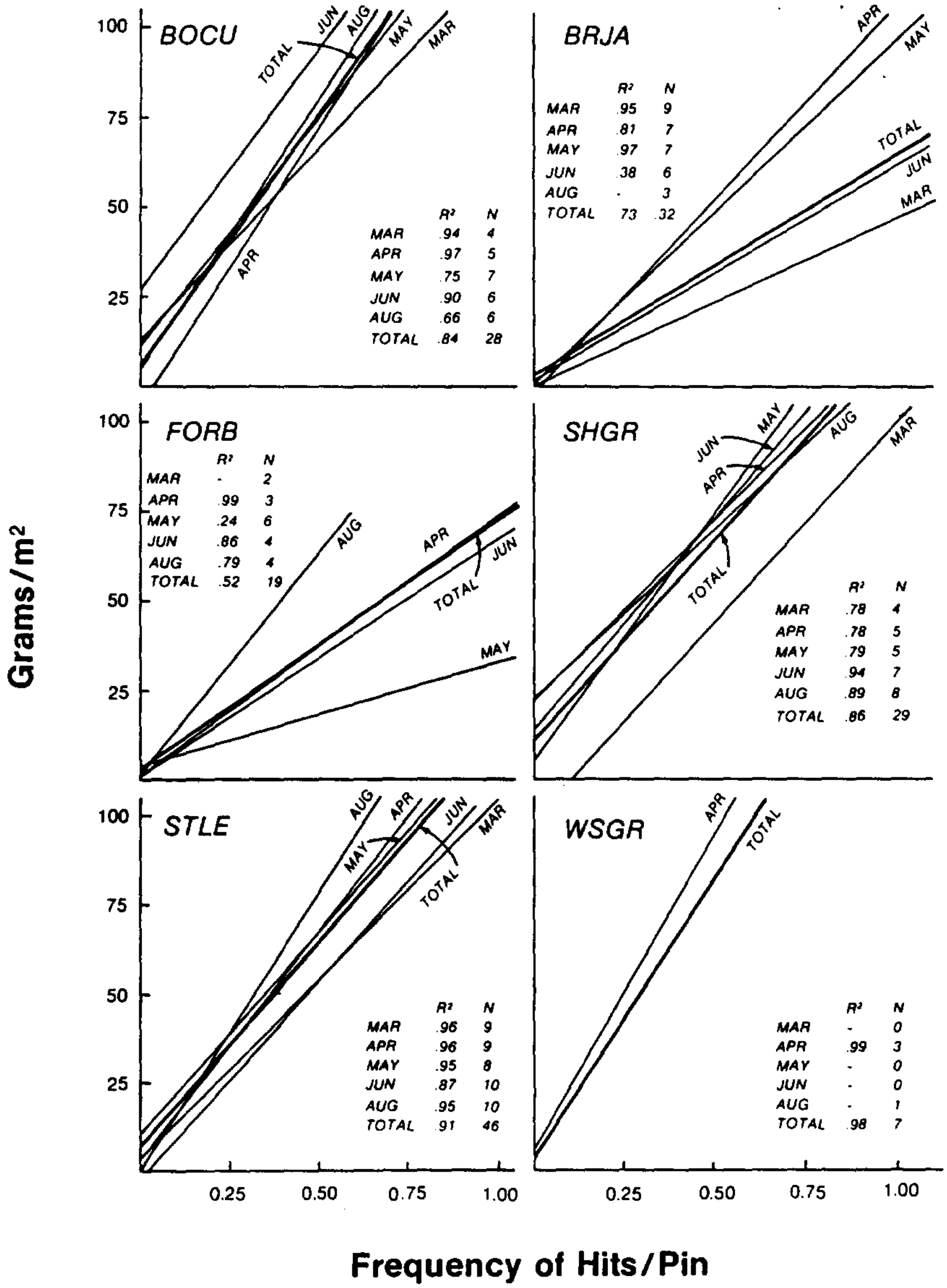

Figure 1. The relationship (R^2) of frequency and weight of individual species, sideoats grama (Bocu), Japanese chess (Bromus japonicus) (Brja), Shortgrass (Shgr), Texas wintergrass (Stle), other warm season grasses (Wsgr), and forbs (Forb) by sample date, Wagon Creek Spade Research Area, Throckmorton County, 1986.

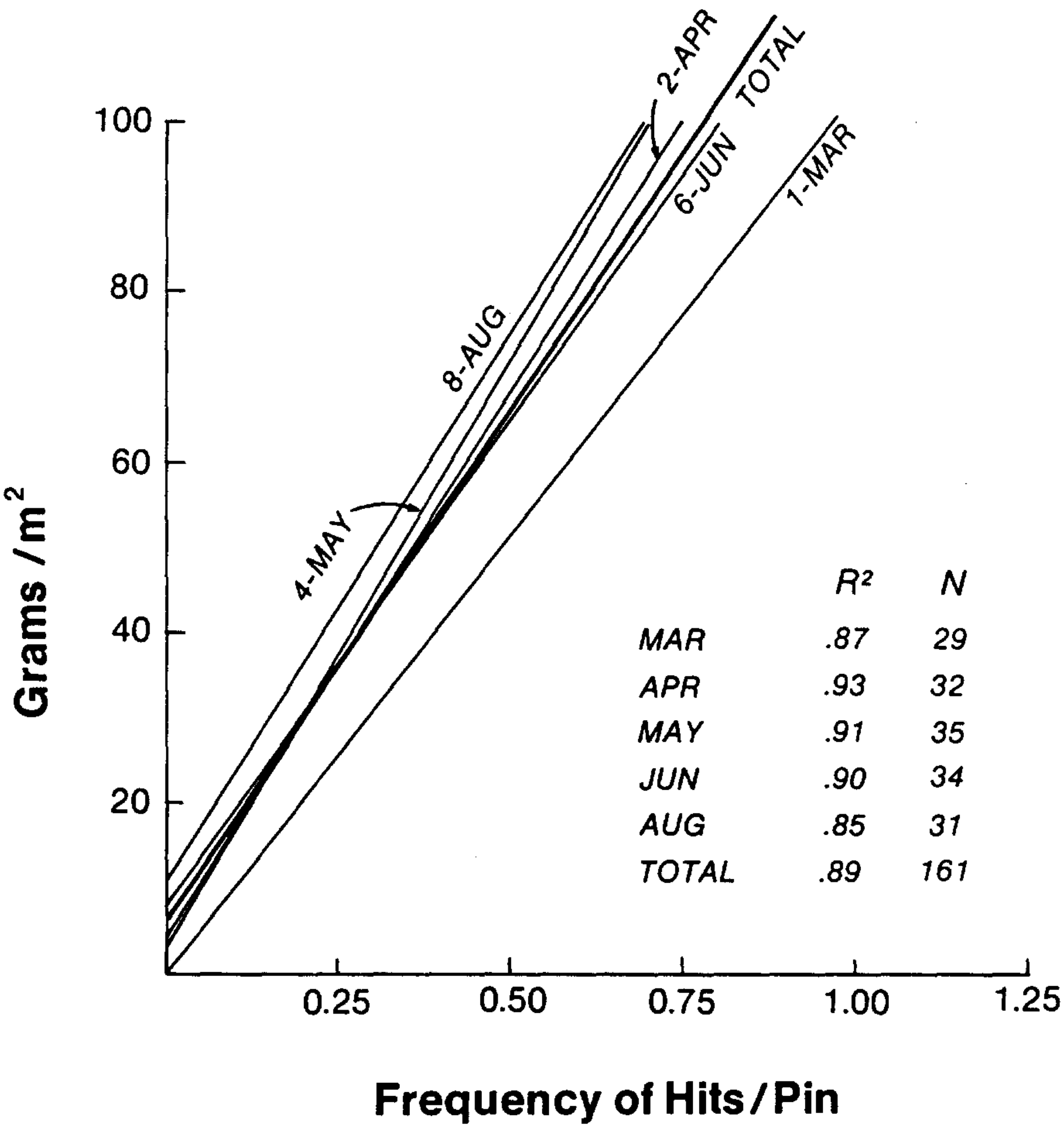

Figure 2. The relationship (R^2) of frequency and weight of all species by sample date, Wagon Creek Spade Research Area, Throckmorton County, 1986.

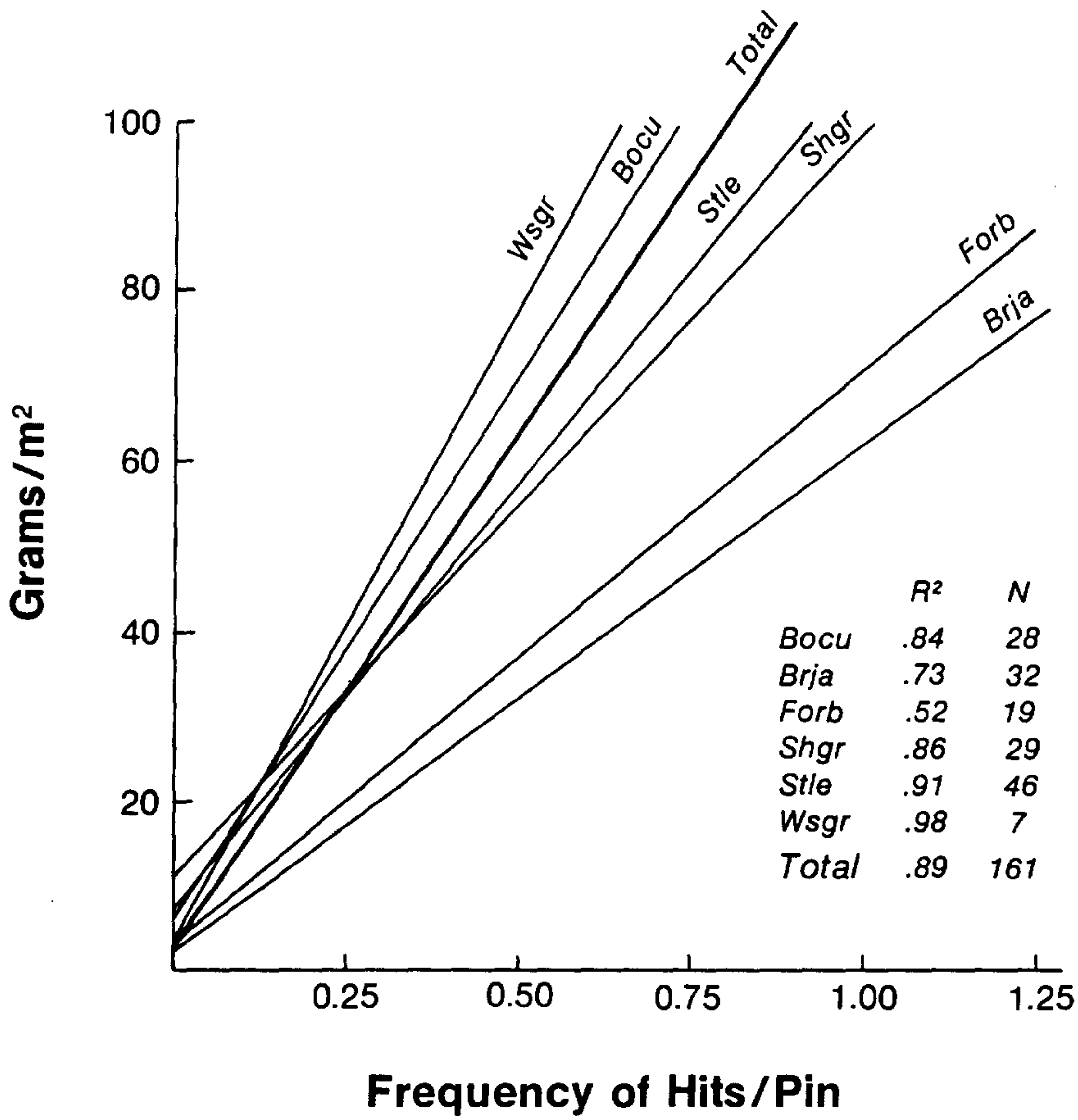

Figure 3. The relationship (R^2) of frequency and weight for all sample dates by species, sideoats grama (Bocu), Japanese Chess (_Bromus japonicus_) (Brja), shortgrass (Shgr), Texas wintergrass (Stle). other warm season grasses (Wsgr), and forbs (Forb), Wagon Creek Spade Research Area, Throckmorton County, 1986.

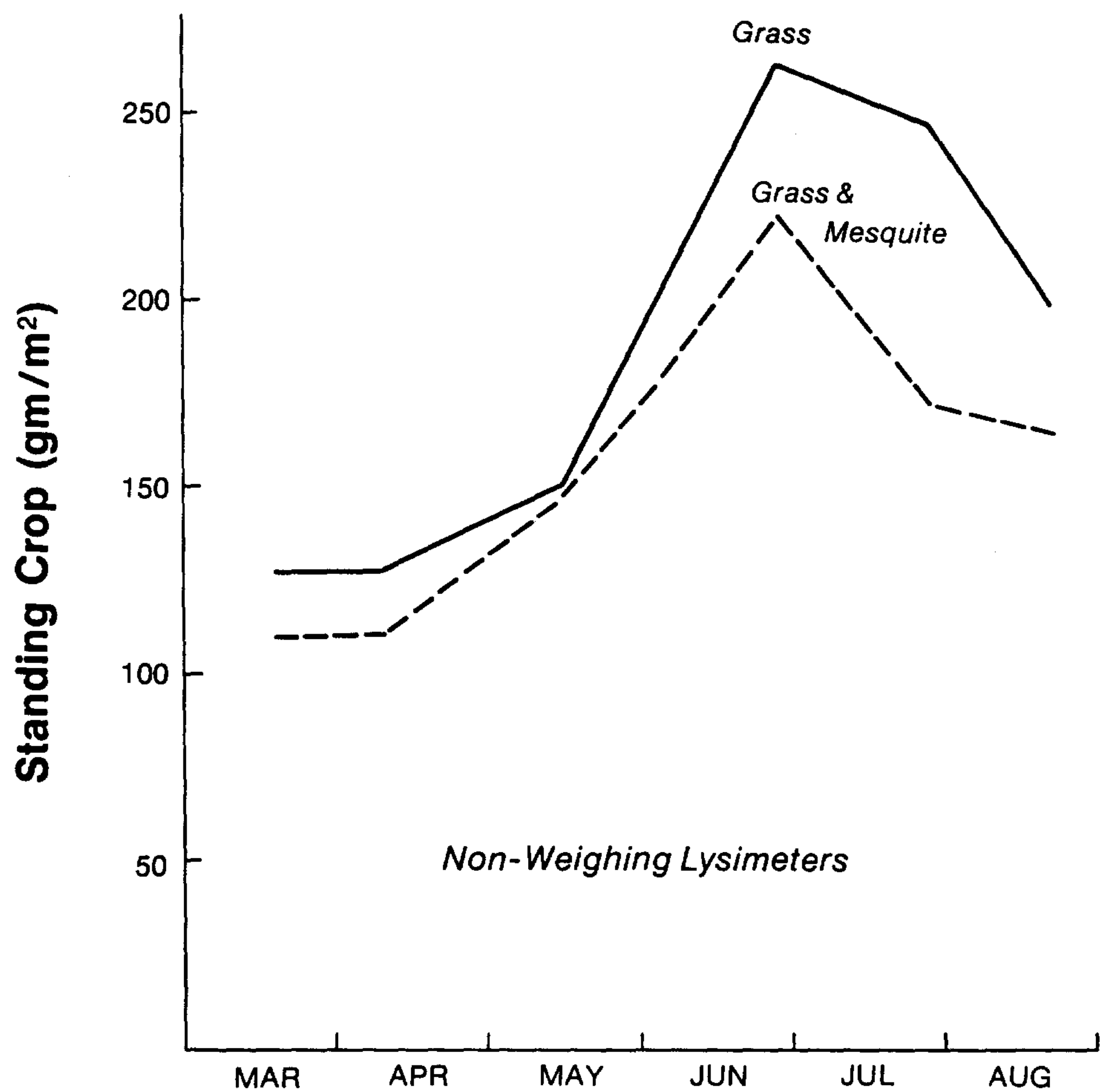

Figure 4. Herbaceous standing crop in the grass and grass plus honey mesquite non-weighing lysimeters by sample date, Wagon Creek Spade Research Area, Throckmorton County, 1986.

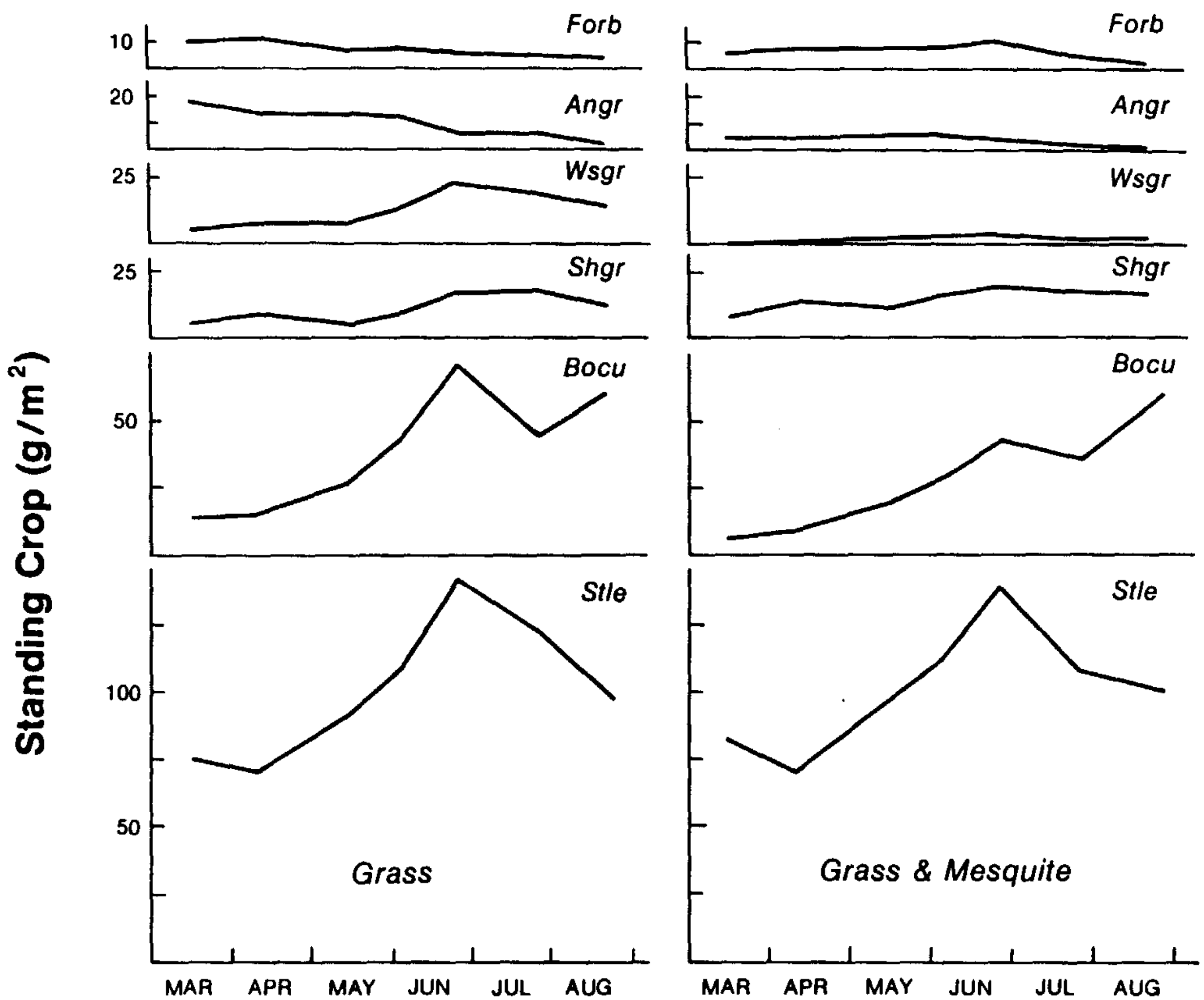

Figure 5. Standing crop of the grass and grass plus honey mesquite lysimeters by species, Texas wintergrass (Stle), sideoats grama (Bocu), shortgrass (Shgr), other warm season grasses (Wsgr), annual grasses (Angr), and forbs (Forb), and sample date, Wagon Creek Spade Research Area, Throckmorton County, 1986.

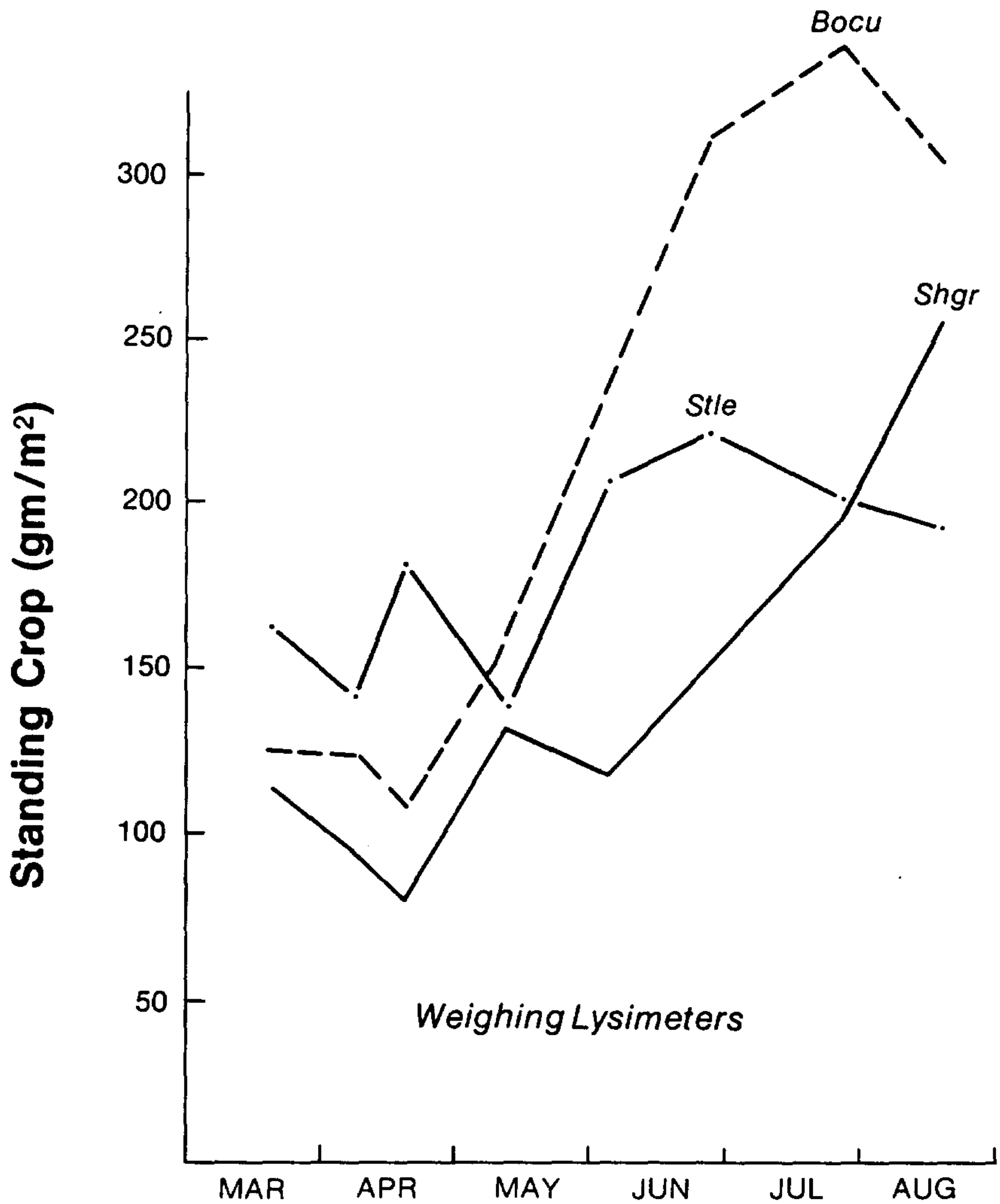

Figure 6. Standing crop of the weighing lysimeters by sample date and species, shortgrass (Shgr), Texas wintergrass (Stle), and sideoats grama (Bocu), Wagon Creek Spade Research Area, Throckmorton County, 1986.

interception differed significantly from zero. Based on these analyses, the decision was made to use the models depicted in Figure 3 to estimate standing crops for the 8 sample dates.

Data for the 6 vegetated non-weighing and 9 vegetated weighing lysimeters are presented in Figures 4, 5, and 6. Total standing crop in the G+M treatment was generally less than in the G treatment particularly after May (Figure 4). There are basically two reasons for these differences. First, the herbaceous vegetation inside the borders of the lysimeters was destroyed during installation. However, by June 1986 these barren areas inside the G lysimeters had revegetated naturally while those inside the G+M lysimeters had not. This difference may reflect, in part, a treatment effect. The second cause for the difference between treatments after May was induced by researchers trampling the vegetation while sampling the mesquite tree inside the G+M lysimeters. The growth dynamics were similar in both treatments with peak standing crop occurring in June. Similarities were the result of similarities in species composition (Figure 5).

Growth dynamics in the weighing lysimeters varied considerably among treatments (Figure 6) because of differences in species composition. Peak standing crop in the Stle treatment occurred in late June. Peak standing crop in the Bocu treatment occurred in late July. Peak standing crop in the Shgr treatment occurred in mid-August. The general decline in standing crop from March to April in these treatments is presumably because standing crops were over-estimated during the early part of the growing season. This was because we used the regression models for species (Figure 3) for the entire year and the slope of the regressions for March were generally less for all species (Figures 1 and 2) than the slope of the regression model used. This would be expected because there were no stems early in the year. More detailed analyses at year's end will attempt to correct for this deficiency.

Root Biomass and Distribution of Roots for Three Major Grasses at the Texas Experimental Ranch

D. L. Price and R. K. Heitschmidt

Summary

Root biomass in approximately the upper meter of the soil profile was estimated at 5,868 kg/ha for sideoats grama, 4,553 kg/ha for Texas wintergrass and 5,476 kg/ha for common curly mesquite. Approximately 80 percent of the root biomass of each species was found within the upper 50 centimeters of soil and over 50 percent was distributed in the crown area and upper 10 centimeters of soil. Only 1 to 2 percent of the sampled root biomass, of the three species, was found between 91 and 100 centimeters in the soil profile. These data indicate that little, if any, soil water is used by these grasses below 1 meter in the soil profile.

Methods

An experimental area approximately 100 by 100 meters on the Wagon Creek Spade Research Area was chosen and divided into three replications. Within each replication three sites were chosen; one supporting primarily *Bouteloua curtipendula* (sideoats grama), one supporting *Stipa leucotricha* (Texas wintergrass) and one supporting *Hilaria berlangeri* (common curly mesquite). Trenches measuring 2 by 1.5 by 1 meters were dug at each site with a backhoe. A 1 by 1 meter square was delineated, leveled and smoothed on one side of each trench. Aboveground biomass was clipped within a 100 centimeter by 10 centimeter quadrat at the soil surface adjacent to the leveled side of each trench. Biomass was ovendried and weighed. The leveled side of each trench was marked with a grid pattern deliniating one hundred 10 by 10 centimeter squares and the soil surface adjacent was marked deliniating ten 10 by 10 centimeter squares. Therefore, an outline was created for a soil monolith (Bohm 1979) of

0.1 cubic meters to be excavated by blocks of 10 by 10 by 10 centimeters. The top 2 to 3 centimeters of each monolith were excavated separately to separate plant crowns from their root systems. After blocks of soil were removed from the monoliths they were stored in plastic bags and frozen. Frozen soils were then thawed in water and washed removing soil from roots (Bohm 1979). Roots were ovendried and weighed and then ashed in a muffle furnace for four hours at 500°C. Weight of the ash was subtracted from dry matter weight yielding organic matter weight. This was done to correct for any soil contamination remaining on the roots. Parameters estimated for each species were root biomass, vertical distribution of roots by weight and standing crop biomass associated with the roots.

A detailed soil description was made at each trench by the Area Soils Scientist. Also, soil parameters, bulk density, organic matter and texture were measured for each profile.

Analysis

Data were evaluated based on a randomized complete block design with cluster sampling. Analyses thus far are not completed, however, simple means and associated standard deviations are reported.

Results and Discussion

Mean aboveground biomass for the sideoats grama sites was 2,840 kg/ha, of that, 91.2% was sideoats and 8.8% was other grasses and forbs. Associated mean root biomass for those sites was 5,868 kg/ha meter or 67.4 percent of total plant biomass. Mean aboveground biomass for the Texas wintergrass sites was 2,920 kg/ha, 94.5 percent of the composition was wintergrass and 5.5% other grasses and forbs. Associated mean root biomass was 4,553 kg/ha meter or 61% of the plant biomass. For the curly mesquite sites mean aboveground biomass was 2,645 kg/ha with 87.8% curly mesquite and 12.2% other grasses and forbs. Associated root biomass was 5,476 kg/ha meter or 67.5 percent of total plant biomass (Table 1). These data indicate that root biomass of Texas wintergrass comprises about 7% less of total plant biomass than root systems of either sideoats grama or curly mesquite. Distribution of root biomass by strata is given in Table 2. The crown portion of the root systems comprised 47% for sideoats, 37% for wintergrass and 28% for curly mesquite. This may be explained by the rhizomotous growth form of sideoats and the stoloniferous form of curly mesquite. However, for all three species about 80% of the root biomass sampled was within the upper 50 centimeters of the soil profile. These data tend to support work done on the same species at the Experimental Ranch in weighing lysimeters. Joe Franklin (personal communication) indicates that there is little or no draw down of soil water below 1 meter in the soil profile.

The soils work mentioned in the Methods section have not been completed at this time.

Table 1. Mean above- and belowground biomass in grams associated with a 0.1 cubic meter soil monoliths for three major grasses at the Wagon Creek Spade Research Area, Throckmorton County, 1986.

	Sideoats grama Monolith		Texas wintergrass Monolith		Curly mesquite Monolith	
	Sideoats	Other grasses and forbs	Wintergrass	Other grasses and forbs	Curly Mesquite	Other grasses and forbs
Aboveground Biomass	25.90	2.5	27.60	1.6	23.05	3.4
Belowground Biomass	58.68		45.53		54.76	
Percent of Total Plant Biomass Roots Comprise	67.40		61.00		67.5	

Table 2. Root biomass (kg/ha organic matter) and distribution of roots for three major grasses at the Wagon Creek Spade Research Area, Throckmorton County, 1986.

	Sideoats Grama			Texas Wintergrass			Curly Mesquite		
Strata	$\overline{X}$	S.D.	%	$\overline{X}$	S.D.	%	$\overline{X}$	S.D.	%
Crown	2,732	380	47	1,670	580	37	1,512	650	28
1-10 cm	1,021	359	17	1,269	930	28	1,224	820	22
11-20 cm	429	161	7	415	180	9	658	360	12
21-30 cm	388	175	7	292	16	6	452	210	8
31-40 cm	247	195	4	197	67	5	312	120	6
41-50 cm	305	246	5	175	65	4	345	190	6
51-60 cm	198	75	4	161	51	4	214	67	4
61-70 cm	182	75	3	138	64	3	278	170	5
71-80 cm	148	62	2	115	31	2	193	90	4
81-90 cm	123	76	2	71	28	1	163	130	3
91-100 cm	95	68	2	50	13	1	125	70	2
TOTALS	5,868			4,553			5,476		

Literature Cited

Bohm, W. 1979. Methods of studying root systems. Springer-Verlag Berlin Heidelberg New York. 188 p.

LA COPITA RESEARCH AREA

The research area is located in Jim Wells County approximately 20 km southwest of Alice, Texas, on the Texas Agricultural Experiment Station La Copita Research Area. Mean elevation of the 1,093 ha research area is 76 m above sea level. Mean annual temperature is 22.4 C and the growing season is 289 days (Minzenmayer 1979). Normal precipitation is 704 mm, of which 493 mm (70%) usually falls from April through September. The heaviest recorded 1-day rainfall during the past 35 years was 338 mm (Minzenmayer 1979). Convection-type storms of high intensity occur about 30 days a year mainly during summer (Orton 1969, and Minzenmayer 1979).

The research site is located on a Delfina fine sandy loam (1-3%)-Miguel fine sandy loam (1-3%) soil complex, and is classified as a sandy loam range site. The soil closely resembles a Miguel fine sandy loam soil. The Miguel soil series is classified as a fine, mixed, hyperthermic, Udic Paleustalf.

Presently, landscapes are characterized by thorn woodlands or grasslands interspersed with shrub clusters. Archer and Scifres (1986) proposed that the grasslands are pioneered by honey mesquite (*Prosopis glandulosa* var *glandulosa*) where it modifies soils and microclimate, and facilitates the ingress and establishment of additional woody species. The result is a landscape of discrete shrub clusters in a grassland matrix.

Within the 5 ha exclosure 40% of the area is occupied by shrub clusters. Archer and Scifres (1986) defined eight size classes of shrub clusters organized around a central honey mesquite. Common subdominant species within the shrub clusters are brasil (*Condalia hookeri*), spiny hackberry (*Celtis pallida*), lime pricklyash (*Zanthoxylum fagara*), Agarito (*Berberis trifolioata*), Texas persimmon (*Diospyros texana*), lotebush (*Ziziphus obtusifolia*), wolfberry (*Lycium berlandeiri*), Texas colubrina (*Colubrina *texensia*) and cacti (*Opuntia* spp.). Many of the more productive grasses such as thin paspalum (*Paspalum setaceum*), root bristlegrass (*Setaria geniculata*), Texas grama (*Bouteloua rigidiseta*), and windmillgrass (*Chloris verticillata*) have been replaced by red lovegrass (*Eragrostis trifida*), red grama (*Bouteloua trifida*), threeawn (*Aristida* spp.) and common grassbur (*Cenchrus incertus*)

Determination of Leaf Area to Leaf Biomass Relationships for Selected Shrubs in South Texas

M. A. Weltz, W. H. Blackburn and C. J. Scifres

Summary

For deciduous plants such as honey mesquite and Texas colubrina, no equation predicted leaf biomass over a growing season. Mesquite usually attains full canopy about 30 days after leaf initiation. After that point the canopy gradually loses its leaflets and leaves through the interactions of insects, drought, and abrasion from wind (Meyer et al. 1971). Instead of a single equation, a series of equations based upon the time of the year will be needed to predict leaf biomass. Ludwig et al. (1975), using the upper half of a prolate spheroid on matt-forming mesquite shrubs, predicted a leaf weight/volume ratio of 73 g/m^3. This is approximately one half of our predicted leaf weight. Honey mesquite plants evaluated in this study were single stemmed and ranged in size from 0.5 to 6 m in height. Ludwig et al. (1975) cautioned that for plants like mesquite, the physiogonomy of which ranges from shrub to matt-forming in the Chihuahuan desert and treelike in the Sonoran desert, a readily predictable equation should not be expected for all growth forms.

The log-log equation developed for mesquite in May 1985 using canopy volume was tested against the April 1986 sample. A homogeneity of slope test indicated no significant difference ($P \leq 0.05$). The functional form of the equation is:

$$\log(\text{leaf biomass}) = -2.163 + 0.716 * \log(\text{crown volume}) \quad (r^2 = 0.94)$$

A single equation using canopy volume to predict leaf biomass of mesquite at maximum canopy development may be possible at a given location. The equations predicting leaf biomass over the remaining portion of the growing season are

harder to define as a result of the interaction of weather and insects. Mesquite leaf biomass had a disappearance rate function that approached a Chi-square distribution.

For evergreen plants such as lime pricklyash the same functional relationship predicted leaf biomass at any point of the growing season. The functional form of the equation is:

$$\log(\text{leaf biomass}) = -\ 1.867 + 0.651 * \log(\text{crown volume}) \quad (r^2 = 0.84)$$

Canopy volume can be used to predict leaf biomass for mesquite or lime pricklyash with either a quadratic or a log-log function. No equation predicted leaf biomass over the entire growing season for either Texas persimmon or Texas colubrina. To improve the relationship for plants with non-uniform growth forms, like Texas persimmon, the plant should be divided into small sections and the volume of each part calculated separately and the values for the individual sections summed.

Methods

Shrubs which commonly occur in the mesquite-dominated shrub clusters and selected for evaluation were honey mesquite, lime pricklyash, Texas persimmon and Texas colubrina. Mesquite, Texas persimmon and Texas colubrina are drought deciduous while lime pricklyash is an evergreen. In May of 1985, a total of 20 mesquite, 20 lime pricklyash, 10 Texas colubrina and 10 Texas persimmon were sampled. Ten plants of each species were also sampled in August and November of 1985 and in January and April of 1986. Mesquite and Texas colubrina were defoliated in January and thus were not sampled. The sample dates perceived to correspond to phenological stage: (1) maximum leaf area, (2) mid growing season, (3) autumn, just prior to the final leaf drop, (4) after leaf drop for the deciduous shrubs, and (5) maximum leaf area.

Individuals of each species were selected such that the range of sizes on the study area was represented. For each shrub, the following attributes were measured: (1) longest diameter of the canopy, (2) diameter of the canopy at a right angle to the first measurement, (3) maximum height of the shrub, (4) canopy depth (distance between the upper and lowermost extension of foliage), (5) stem diameter at 10 cm, and (6) number of stems. The shrub architecture was visually appraised and compared to one of 14 geometric shapes. The equation of the geometric shape that appeared to represent the canopy architecture was used to estimate canopy volume (cm^3). Canopy volume was defined as the canopy area, the area from the base of the canopy to ground line was excluded from canopy volume. Canopy area for Texas persimmon located near the center of a shrub cluster was determined by estimating the canopy volume of major branch units of the shrub and then summing for total crown volume.

Leaf biomass was estimated by using a modified reference unit method. A open-ended cube (25 cm on a side) was used to determine a volume ratio. The volume ratio was defined as:

$$\text{Volume ratio} = \text{leaf biomass (g)} / 15625\ \text{cm}^3 \qquad (1.1)$$

The volume ratio for each shrub was determined by sampling at 1 m intervals diagonally through the canopy along the longest axis. The mean of the volume ratio samples was used to estimate leaf biomass (g).

$$\text{Leaf biomass} = \text{volume ratio} * \text{canopy volume} \qquad (1.2)$$

$$\text{canopy volume} = \text{canopy volume calculated from geometric shape } (\text{cm}^3)$$

Leaves inside the cube were removed by hand, placed in plastic bags to retard drying and thus changing their surface area (cm^2) to weight (g) relationship, and the bags were placed on ice.

Leaf area was determined with a 'Li-Cor 3000' leaf area meter attached to a li-3000 conveyer belt. The samples were then oven dried at 60 C for 3 days and weighed. After the volume ratio samples were collected, the shrubs were cut at ground line and all the remaining leaves removed by hand, dried and weighed.

Several predictive equations to estimate leaf biomass were evaluated based on maximum coefficient of determination (r^2). The equations evaluated were linear ($Y = a + b_1X$), quadratic ($Y = a + b_1X + b_2X^2$), log-log ($\log Y = a + \log b_1X$), semilog ($\log Y = a + b_1X$), and multiple regression ($Y = a + b_1Z_1 + b_2Z_2$) functions, where Y = total leaf biomass, X = calculated canopy volume, and Z = an independent variable.

Linear regression techniques were used to analysis the leaf area data for each sample period. A homogeneity of slope test was used to test for differences between the slopes of the regression equations between sample periods within species (Steel and Torrie 1980). Regression were computed using Statistical Analysis Systems (SAS 1982).

Results and Discussion

Leaf biomass

The crown volume of mesquites was most frequently estimated by either a conic frustrum (37%) or parabolid (34%) geometric shape (Table 1). The relationship between leaf biomass and crown volume of mesquite was best expressed with the log-log or quadratic regression equations based on coefficient of determination (Table 2). This finding is consistent with reports by Bryant and Kothman (1979) and Ludwig et al. (1975). In general the semilog equation based on coefficient of determination failed to predict leaf biomass as effectively as the other equations across all times and for all species.

Leaf biomass of lime pricklyash was best predicted with the quadratic equation for all sample periods. When lime pricklyash was located near the perimeter of the shrub clusters, crown volume was most frequently estimated with either a conic frustrum (22%) or parabolic frustrum (23%) geometric shape (Table 1). In contrast, when lime pricklyash was located near the center of the shrub cluster crown volume was frequently approximated with a rectangle (35%).

Texas colubrina leaf biomass was estimated best with a quadratic equation in May and January and with the log-log in November. The crown volume of Texas colubrina was approximated by either a paraboliod (37%) or parabolic frustrum (32%). Texas colubrina had dropped the majority of its leaves by August. This resulted in extreme variability and no regression equation adequately predict total leaf biomass. Texas colubrina, like mesquite, was not sampled in January.

Table 1. Frequency (%) of use for geometric shapes for determining canopy volume (cm^3) for selected shrubs on a sandy clay loam range site, La Copita Research Area, Alice, Texas.

Geometric shape	Mesquite[1]	Lime pricklyash	Texas columbrina	Texas persimmon
Cylinder	6	0	7	2
Cone	4	11	3	2
Paraboloid	34	8	37	6
Oblate spheriod	2	2	20	0
Prolate spheriod	0	0	0	0
Square	2	0	0	2
Ellipsoid	2	0	1	0
Conic fustrum	37	22	0	24
Quater shpere	2	0	0	0
Qurdrant Cylinder	4	0	0	2
Parabolic cone	1	0	0	0
Parabolic frustrum	0	23	32	14
Sphere	0	0	0	0
Rectangle	6	35	0	48

[1]Total sample numbers for mesquite, lime pricklyash, Texas columbrina, and Texas persimmon were 50, 60, 40, and 50, respectively.

Table 2. Coefficient of determination (r^2) for crown volume (cm^3) to leaf biomass (g) of selected shrub species on a sandy clay loam range site, La Copita Research Area, Alice, Texas.

Species	Date	Linear[1]	Quadratic	Log-Log	Semilog
Honey mesquite	5/85	0.85 *	0.87 *	0.94 *	0.85 *
	8/85	0.99 *	0.99 *	0.74 *	0.70 *
	11/85	0.64 *	0.71 *	0.94 *	0.44 *
	1/86	NS	NS	NS	NS
	4/86	0.98 *	0.98 *	0.98 *	0.52 *
Lime pricklyash	5/85	0.93 *	0.93 *	0.94 *	0.52 *
	8/85	0.64 *	0.65 *	0.47 *	0.52 *
	11/85	0.45 *	0.69 *	0.51 *	0.62 *
	1/86	0.85 *	0.92 *	0.88 *	0.90 *
	4/86	0.90 *	0.99 *	0.97 *	0.96 *
Texas colubrina	5/85	0.18	0.64 *	0.46 *	0.19
	8/85	NS	NS	NS	NS
	11/85	0.70 *	0.70 *	0.78 *	0.54 *
	1/86	NS	NS	NS	NS
	4/86	0.96 *	0.97 *	0.91 *	0.67 *
Texas persimmon	5/85	0.18	0.88 *	0.56 *	0.62 *
	8/85	0.63 *	0.67 *	0.40	0.28
	11/85	0.87 *	0.88 *	0.76 *	0.58 *
	1/86	0.44 *	0.51 *	0.19	0.37
	4/86	0.74 *	0.98 *	0.92 *	0.74 *

[1]No sample was collected for deciduous shrubs due to either drought or temperature-induced dormancy.

* Coefficient of determination significant ($P < 0.05$).

Leaf biomass of Texas persimmon was best estimated with the quadratic equation across all sampling times. Prediction from the linear equation closely approximated that from the quadratic relationship in August, November and January. The growth form of Texas persimmon varied depending on location within the shrub cluster. Texas persimmon was strongly phototropic when located near the center of shrub cluster, thus no single geometric shape could approximate crown volume. Crown volume was approximated by estimating the area of different portions of the canopy and then summing for total crown volume. When Texas persimmon was located along the perimeter of the shrub clusters crown volume was approximated by either a conic frustrum (24%) or parabolic frustrum (14%) geometric shape (Table 1).

The volume ratio effectively estimated total leaf biomass for honey mesquite. The May, August and April samples were predicted equally well with either the linear or the quadratic equations (Table 2). In November, the log-log equation gave the best fit. Biomass of lime pricklyash was best predicted with the quadratic equation, although the log-log equations closely approximated the quadratic equation in May, January and April. Leaf biomass of Texas colubrina was best predicted by the quadratic equation for the May, November and April samples. No equation was evaluated for the August and January sample dates because of the deciduous nature of Texas colubrina.

Texas persimmon volume ratio was poorly correlated with total leaf biomass for all but one of the sampling dates. Texas persimmon was found primarily within the center of large shrub clusters. The plants had a indeterminate growth pattern and tended to grow toward areas of higher light intensity. This resulted in a growth form for which it was difficult to assign a geometric shape and with major gaps in the canopy. The result was a poor correlation between volume ratio and leaf biomass.

other independent variables were better predictors of leaf biomass for Texas persimmon than either canopy volume or volume ratio. In all cases, one of the other independent variables explained more of the variability in total leaf biomass than did the linear equations of canopy volume or volume ratio (Table 3). For Texas persimmon the quadratic equation for leaf biomass to crown volume was significant for all sample periods and consistently explained more of the variability associated with leaf biomass than any other single-parameter equation.

Simple linear regression equations using shrub attributes (ie. tree height, basal area, canopy diameter, canopy depth, and canopy area) effectively predicted leaf biomass for the different shrub species (Table 4). All of the shrub attributes were well correlated with leaf biomass for honey mesquite. Canopy area of lime pricklyash was well correlated with leaf biomass in May, August, November, and April. Tree height effectively predicted leaf biomass in January. No single attribute effectively predicted leaf biomass for Texas colubrina across all sampling times. Basal area was well correlated with leaf biomass in May, while canopy area was well correlated in April. No attribute effectively predicted leaf biomass in August and November. Texas persimmon was like Texas colubrina in that no single attribute effectively predicted leaf biomass across all sampling times. Tree height was well correlated to leaf biomass in April, August, and November. No attribute was well correlated in May and January.

For all species and across all sampling times, the multiple regression equation predicted leaf biomass as effectively or better than did the simple linear regression equations using canopy volume or volume ratio (Table 5). In 11 of the 17 equations tested, canopy volume or volume ratio was one of the two independent variables retained by the multiple regression model.

Table 3. Coefficient of determination (r^2) for volume ratio (g) to leaf biomass (g) of selected shrub species on a sandy clay loam range site, La Copita Research Area, Alice, Texas.

Species	Date	Linear[1]	Quadratic	Log-Log	Semilog
Honey mesquite	5/85	0.95 *	0.96 *	0.89 *	0.88 *
	8/85	0.99 *	0.99 *	0.79 *	0.68 *
	11/85	0.52 *	0.66 *	0.94 *	0.92 *
	1/86	NS	NS	NS	NS
	4/86	0.98 *	0.99 *	0.94 *	0.92 *
Lime pricklyash	5/85	0.81 *	0.82 *	0.84 *	0.84 *
	8/85	0.71 *	0.82 *	0.84 *	0.85 *
	11/85	0.50 *	0.71 *	0.50 *	0.63 *
	1/86	0.60 *	0.86 *	0.89 *	0.90 *
	4/86	0.88 *	0.99 *	0.98 *	0.96 *
Texas colubrina	5/85	0.50 *	0.41 *	0.76 *	0.42 *
	8/85	NS	NS	NS	NS
	11/85	0.55 *	0.55 *	0.78 *	0.72 *
	1/86	NS	NS	NS	NS
	4/86	0.93 *	0.95 *	0.91 *	0.72 *
Texas persimmon	5/85	0.49	0.67 *	0.55 *	0.64 *
	8/85	0.35	0.37	0.39	0.40
	11/85	0.67 *	0.69 *	0.76 *	0.65 *
	1/86	0.48	0.52 *	0.19	0.29
	4/86	0.77 *	0.88 *	0.92 *	0.83 *

[1]No sample was collected for deciduous shrubs due either to drought or temperature-induced dormancy.

* Coefficient of determination significant ($P < 0.05$).

Table 4. Coefficient of determination (r^2) for simple linear relationships of selected dependent variables with leaf biomass (g) for selected shrub species on a sandy clay loam range site, La Copita Research Area, Alice, Texas.

Species	Date	Height[1] (cm)	Basal area (cm^2)	Diameter canopy (cm)	Canopy depth (cm)	Canopy area (cm^2)
Honey mesquite	5/85	0.87 *	0.74 *	0.87 *	0.81 *	0.87 *
	8/85	0.85 *	0.99 *	0.93 *	0.77 *	0.99 *
	11/85	0.96 *	0.87 *	0.84 *	0.90 *	0.81 *
	1/86	NS	NS	NS	NS	NS
	4/86	0.83 *	0.99 *	0.84 *	0.88 *	0.99 *
Lime pricklyash	5/85	0.62 *	0.96 *	0.76 *	0.54 *	0.90 *
	8/85	0.66 *	0.82 *	0.82 *	0.71 *	0.91 *
	11/85	0.61 *	0.40	0.76 *	0.50 *	0.71 *
	1/86	0.90 *	0.77 *	0.66 *	0.87 *	0.62 *
	4/86	0.65 *	0.94 *	0.88 *	0.73 *	0.97 *
Texas colubrina	5/85	0.51 *	0.79 *	0.70 *	0.47	0.71 *
	8/85	NS	NS	NS	NS	NS
	11/85	0.60 *	0.16	0.60 *	0.63 *	0.48 *
	1/86	NS	NS	NS	NS	NS
	4/86	0.72 *	0.08	0.90 *	0.80 *	0.93 *
Texas persimmon	5/85	0.53 *	0.35	0.52 *	0.67 *	0.46
	8/85	0.74 *	0.19	0.52 *	0.84 *	0.53 *
	11/85	0.88 *	0.85 *	0.85 *	0.57 *	0.80 *
	1/86	0.44	0.16	0.41	0.66 *	0.44
	4/86	0.92 *	0.89 *	0.76 *	0.89 *	0.68 *

[1]No sample was collected for deciduous shrubs due either to drought or temperature-induced dormancy.

* Coefficient of determination significant ($P < 0.05$).

Table 5. Multiple regression equations and coefficients of determination for leaf biomass (g), to crown volume (cm^3) on selected shrub species on a sandy clay loam range site, La Copita Research Area, Alice, Texas.

Species	Date	Predictive model[1]	R^2
Mesquite	5/85	Y = - 543.1 + 4.13(Height) + 0.0075(Area)	0.91 *
	8/85	Y = 61.9 + 0.00000337(Volume) + 0.0025(Area)	0.99 *
	11/85	Y = - 35.2 + 0.531(Height) - 0.0000039(Volume)	0.98 *
	1/86		NS
	4/86	Y = - 17.8 + 0.44(Basal area) + 0.0052(Area)	0.99 *
Lime pricklyash	5/85	Y = 8.1 + 10.13(Basal area) + 0.046(Volume ratio)	0.98 *
	8/85	Y = 150.0 + 0.035(Area) - 3.50(Canopy diameter)	0.95 *
	11/85	Y = - 123.1 +0.72(Height) + 41.75(Log volume ratio)	0.88 *
	1/86	Y = 13.3 + 0.000156(Volume) - 0.19(Volume ratio)	0.99 *
	4/86	Y = 10.6 + 0.000011(Volume) + 0.0056(Area)	0.86 *
Texas colubrina	5/85	Y = 66.1 + 27.23(Basal area) - 49.51(Log volume ratio)	0.85 *
	8/85		NS
	11/85	Y = - 191.9 - 36.89(Log volume ratio) + 51.02(Log volume)	0.85 *
	1/86		NS
	4/86	Y = 5.1 + 0.000142(Volume)	0.96 *
Texas persimmon	5/85	Y = - 48.3 + 1.796(Canopy depth)	0.67 *
	8/85	Y = - 61.6 + 0.93(Height) + 0.000089(Volume)	0.94 *
	11/85	Y = 0.3 + 4.24(Basal area) + 0.000037(Volume)	0.95 *
	1/86	Y = 0.6 + 0.054(Canopy depth)	0.67 *
	4/86	Y = - 24.9 + 0.52(Height) + 10.98(Canopy area)	0.94 *

* Coefficient of determination significant ($P < 0.05$).

[1] No sample was collected for deciduous shrubs due either to drought or temperature induced dormancy.

Leaf area

Leaf area was highly correlated to weight for all species and across all sample times (Table 6). Goff et al. (1985) reported satisfactory results in relating leaf area to dry weight for two herbaceous and shrub species in southern Arizona. Ganskopp and Miller (1986) found significant relationships between leaf weight and leaf arae for big sagebrush (Artemisia Tridentata) within season. However, seasonal variation required the development of different predictive equations for each season. Leaf area to weight relations could be predicted from a single equation across all sample dates for honey mesquite and lime pricklyash. Texas colubrina and Texas persimmon required two different predictive equations depending on the time of the year. The basal leaves of Texas colubrina are approximately 10 times larger than the outer canopy leaves. During the dry period in August, Texas colubrina dropped 95% of its leaves. Only a few small outer perimeter leaves were retained. These leaves had a higher ratio of specific weight (g)/surface area (cm^2) than did the basal leaves. This necessitated development of two predictive equations. The exact equation to be used depends on the proportion of leaves present in the canopy at the time of sampling.

Mooney et al. (1977) found that the specific weight of mesquite leaves increased over the growing season. The specific weight ranged from .04 mg/cm^2 in the spring to 17 mg/cm^2 in the fall. This corresponds to a leaf area change from 250 cm^2/g to 58.8 cm^2/g. Meyer et al. (1971) estimated that mesquite leaflets had a surface area of approximately 1 cm^2. The average mesquite leaf has 44 to 52 leaflets, thus the surface area of a single leaf would range between 44 to 52 cm^2 (no weight estimates were given). The rachis length of mesquite leaflets is closely correlated with leaf surface area (Went et al. 1967 A). Using regression relationships with complete and incomplete

Table 6. Coefficient of determination and linear relationships of leaf area (Y) (cm^2) to leaf biomass (g) for selected shrub species on a sandy clay loam range site, La Copita Research Area, Alice, Texas.

Species	Date	Predictive model[1]	r^2
Honey mesquite	All	Y = 87.95(Leaf biomass)	0.99 *
Lime pricklyash	All	Y = 87.51(Leaf biomass)	0.99 *
Texas colubrina	5/85	Y = 103.07(Leaf biomass)	0.98 *
	8/85		NS
	11/85	Y = 133.63(Leaf biomass)	0.99 *
	1/86		NS
	4/86	Y = 103.63(Leaf biomass)	0.98 *
Texas persimmon	5/85	Y = 103.8(Leaf biomass)	0.98 *
	8/85	Y = 103.8(Leaf biomass)	0.98 *
	11/85	Y = 103.8(Leaf biomass)	0.98 *
	1/85	Y = 103.8(Leaf biomass)	0.98 *
	4/86	Y = 126.59(Leaf biomass)	0.98 *

[1] No sample was collected for deciduous shrubs due either to drought or temperature-induced dormancy.

* Coefficient of determination significant ($P < 0.05$).

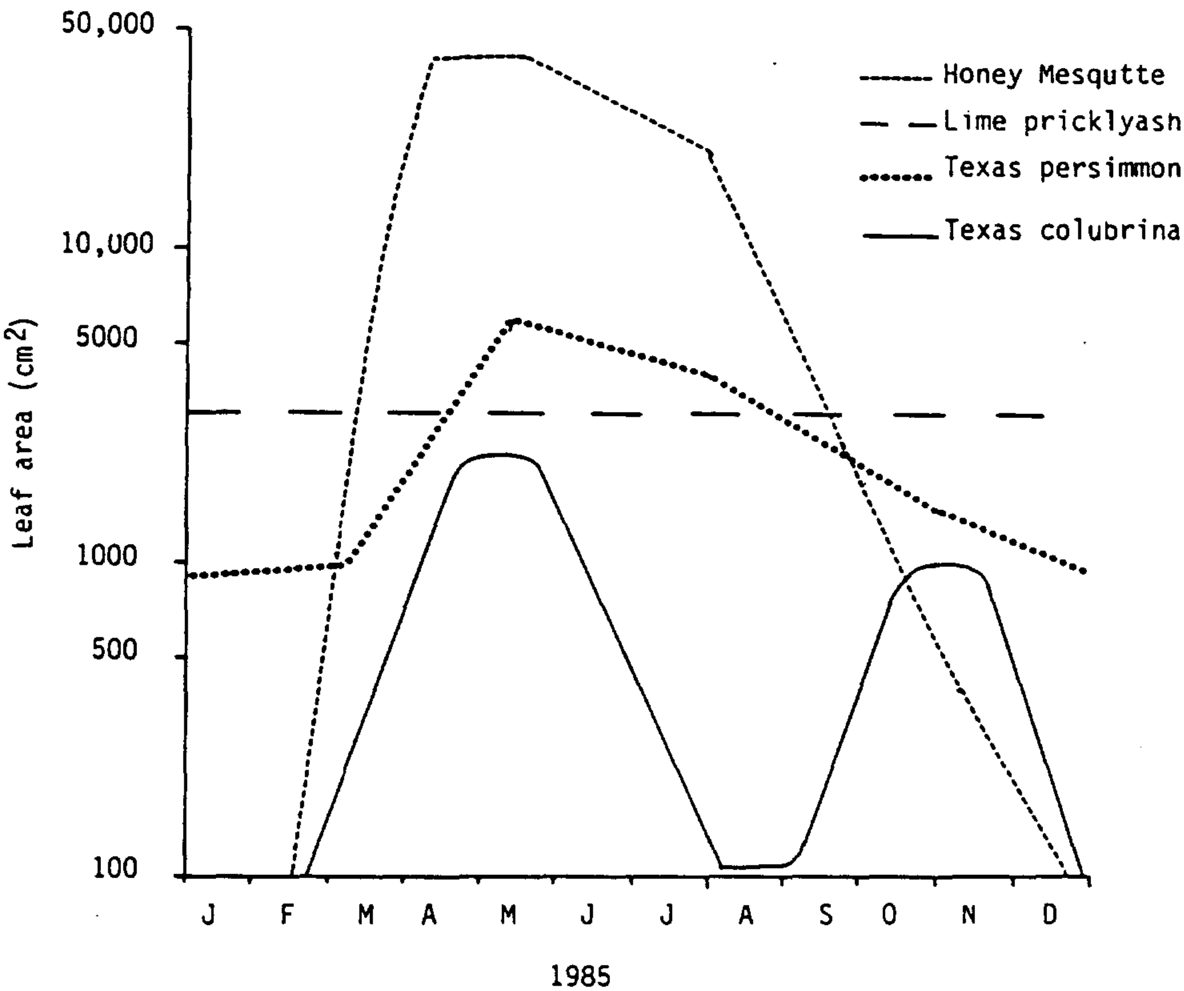

Figure 1. Generalized leaf area (cm^2) over time for honey mesquite (height 5 m; canopy volume 75.5 cm^3), lime pricklyash (height 2 m; canopy volume 13.5 cm^3), Texas colubrina (height 1.3 m; canopy volume 2.5 cm^3), Texas persimmon (height 1.8 m; canopy volume 7.5 cm^3).

leaves, they found the log of the sum of the length of the two rachises and the log of total leaf area produced a linear correlation coefficient of 0.96.

Mesquite leaf weight gradually increased from May through November 1985, though it was not significant ($P \leq 0.05$). The surface area to weight relationship was greatest in April 1986 though not significantly different ($P \leq 0.05$) than at the other sampling dates in 1985 (based on a homogeneity of slope test). The non-significant increase in weight to surface area may be partially explained in that sampling was not initiated until the leaves had been fully expanded for about 4 weeks. The leaves may have reached a stable weight by this time. With the great genetic variability of mesquite (Peacock and McMillian 1965), it is doubtful that a single estimate of leaf weight to surface area is possible over the wide range of mesquite distribution.

Most honey mesquite trees had initiated leaf growth by mid February in 1985 and 1986 and produced a single cohort of leaves (Figure 1). A few honey mesquite trees located along drainage ways and roads initiated a second cohort of leaves in October with the onset of the fall rainy period. The majority of honey mesquite trees were defoliated by mid December in 1985. However, a few trees maintained a minimal number of leaves throughout the winter. It appeared that the trees that initiated a second cohort of leaves in the fall were the ones that retained the leaves throughout the winter.

The size of mesquite leaves was positively correlated with increasing aridity from east to west across the southwestern United States (Solbrig et al. 1977). Mesquite was reported to have smaller leaves and leaflets, a larger number of leaflets, and thinner, narrower fruits with increasing aridity (Solbrig et al. 1977). Populations of mesquite demonstrated genetically-based variation in timing in leaf bud burst and time of leaf drop (Peacock and McMillian 1965). Plants from populations in northern latitudes showed late spring bud activity, active growth under long days, and early fall dormancy under short day conditions. Plants from southern populations in Mexico retained early spring bud activity and had little correlation with photoperiod at Austin, Texas (Peacock and McMillian 1965). It appeared that temperature rather than photoperiod induced fall dormancy. In other populations of mesquite, a combination of soil moisture, temperature and prior drought rather than day length induced fall dormancy (Peacock and McMillian 1965).

Area to weight relationship of Texas persimmon leaves in April 1986 was significantly different ($P \leq 0.05$) than the 1985 samples. From May through November of 1985, the surface area to weight gradually decreased though not significantly ($P \leq 0.05$). Meyer (1974) reported that Texas persimmon produces two types of leaves: a large leaf in the center of the canopy and a smaller leaf around the perimeter of the plant. The leaves are initially light green in color and glabrous after elongation has ceased. As the leaf matures, the xylem and bundle fibers become increasingly lignified and the leaf turns dark green with the underside becoming densely covered with trichomes. Leaf modification is complete by early July. The development of the trichomes and lignification of the leaf is thought to explain the difference in weight to surface area relationship between the samples in 1985 and that of April 1986.

In the growing season of 1985 there was no indication of Texas persimmon being a deciduous plant. However, at some time between January and April 1986 a complete turn-over of leaves occurred. Hoffman (1972) stated that Texas persimmon was drought deciduous. In this study no indication of leaf drop in response to weather conditions was noticed. The mild winter during 1985 may explain why Texas persimmon did not dropped its leaves until the spring of 1986.

Water Budget for South Texas Shrub Clusters and Herbaceous Interspaces

M. A. Weltz, W. H. Blackburn and C. J. Scifres

Summary

Winter and early spring precipitation was more effective than either summer or fall precipitation in recharging the soil profile. Maximum recharge of the soil profile occurred in May following an extremely wet month. High AET demand during the summer and fall prevented recharge of the soil profile below 60 cm, regardless of vegetative cover. AET rates were greatest following precipitation events and higher from the herb-dominated interspaces than from the shrub clusters through the first 50 days of a extended dry period in 1985. The greater AET rates of the interspaces was an function of the greater quantity of soil water at the beginning of the dry period. The ability of several shrub species in the clusters to conduct ET yearlong, combined with greater interception losses, resulted in the upper sections of the soil profile beneath the shrub clusters being drier than in the interspaces, while precluding deep drainage. Evaporation of water from the bare soil lysimeters was limited to the surface 60 cm of the soil profile.

Soil water was extracted first from the upper horizons of the soil profile whether the vegetative cover was herbaceous or woody. As the surface horizon dried out, the water was extracted from progressively lower horizons. Approximately 2 to 3 weeks were required following a rainstorm for soil water to reach the maximum recharge depth. This time lag indicates that a substantial amount of water moved through the profile as unsaturated flow. Once the water was beyond the active root zone in the interspaces, it continued to percolate as unsaturated flow and was not available for ET.

Increasing water yields in South Texas through vegetation manipulation may be limited to those years of above normal winter and early spring precipitation. The herb-dominated interspaces were in poor ecological

condition (dominated by shallow rooted annual grasses and forbs). Results from this study indicated a trend for greater water yield (surface runoff 9 mm and deep percolation 22 mm) with reduced ET (43 mm) for the herb-dominated interspaces compared to the honey mesquite-dominated shrub clusters. Elimination of the shrub clusters and the associated vegetation increased water yield (surface runoff 65 mm and deep percolation 78 mm) and decreased ET (238 mm) compared to the shrub clusters. If deep-rooted shrubs are replaced by perennial grasses the water yield would be expected to be less than estimated by this study. Bosch and Hewlett (1982) reviewed 94 studies concerning vegetation manipulation on ET and water yield from watersheds, and found that a 10% change in vegetation cover on scrub and shrub woodlands resulted in a 10 mm change in the water yield.

The literature concerning the water budget of rangelands dominated by woody plants is limited. Continued research is needed to understand the long-term effect of reducing ET from woody vegetation and its functional relationship between increasing surface runoff and deep percolation on different vegetation-soil complexes. Results of this study indicated that the majority (71%) of the increased water yield from herbaceous-dominated areas would be realized as deep percolation. Long-term research is needed to determine if the trends between the herb-dominated interspaces and the shrub clusters will be maintained or if differences will be amplified through time with changes in vegetative cover.

Methods

Six mature shrub clusters and three herb-dominated interspace areas within a 5-ha exclosure were encircled within non-weighing lysimeters in the summer of 1984. Three mature clusters as defined by Archer and Scifres (1986) were cleared by hand slashing and the debris removed (here-after referred to as "bare soil"). The area was sterilized with tebuthiuron N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazonal-2-yl)]-N,N'-dimethylurea (0.75 kg ai/ha) to prevent regrowth of herbaceous and woody vegetation. The remaining mature shrub clusters were left undisturbed. The mesquite-dominated shrub clusters (hereafter Refereed to as shrub clusters) averaged 30 m^2 in diameter and were organized about a central honey mesquite plant (average 20 cm basal diameter and 4.9 m tall). Mean species density was 60 plants/cluster comprised of eight shrub species.

The non-weighing lysimeters were constructed by trenching around the perimeter of the treatment area to a depth of 2 m (Figure 1 and 2). The inside wall of the trench was double lined with an impervious plastic sheet (10 mil thick) to prevent lateral water movement and to isolate the woody plants roots. The trench was then back-filled. The average surface area of the lysimeters is 35 m^2. Fiberglass sheets were placed around the perimeter of each lysimeter and attached to the plastic with a silicon sealant to prevent overland flow from entering or leaving the lysimeter. A flume was constructed on the downslope side to quantify overland flow. Water flowing through the flume passed though a filter and entered a water storage box. When the level of the water reached a depth of 3 cm in the box an automatic switch activated a 12 volt pump. Water was then pumped through an in-line filter and a water meter.

Four 2-m-long neutron access tubes were placed in the lysimeters. Soil water content was monitored with a "Troxler" moisture depth gauge on approximately 2 week intervals. Water content was measured at depth of 7.5, 15, 30, 60, 90, 120, 150, 180 cm. Treatments were installed in May of 1984. Access tubes were installed in the lysimeters in June of 1984.

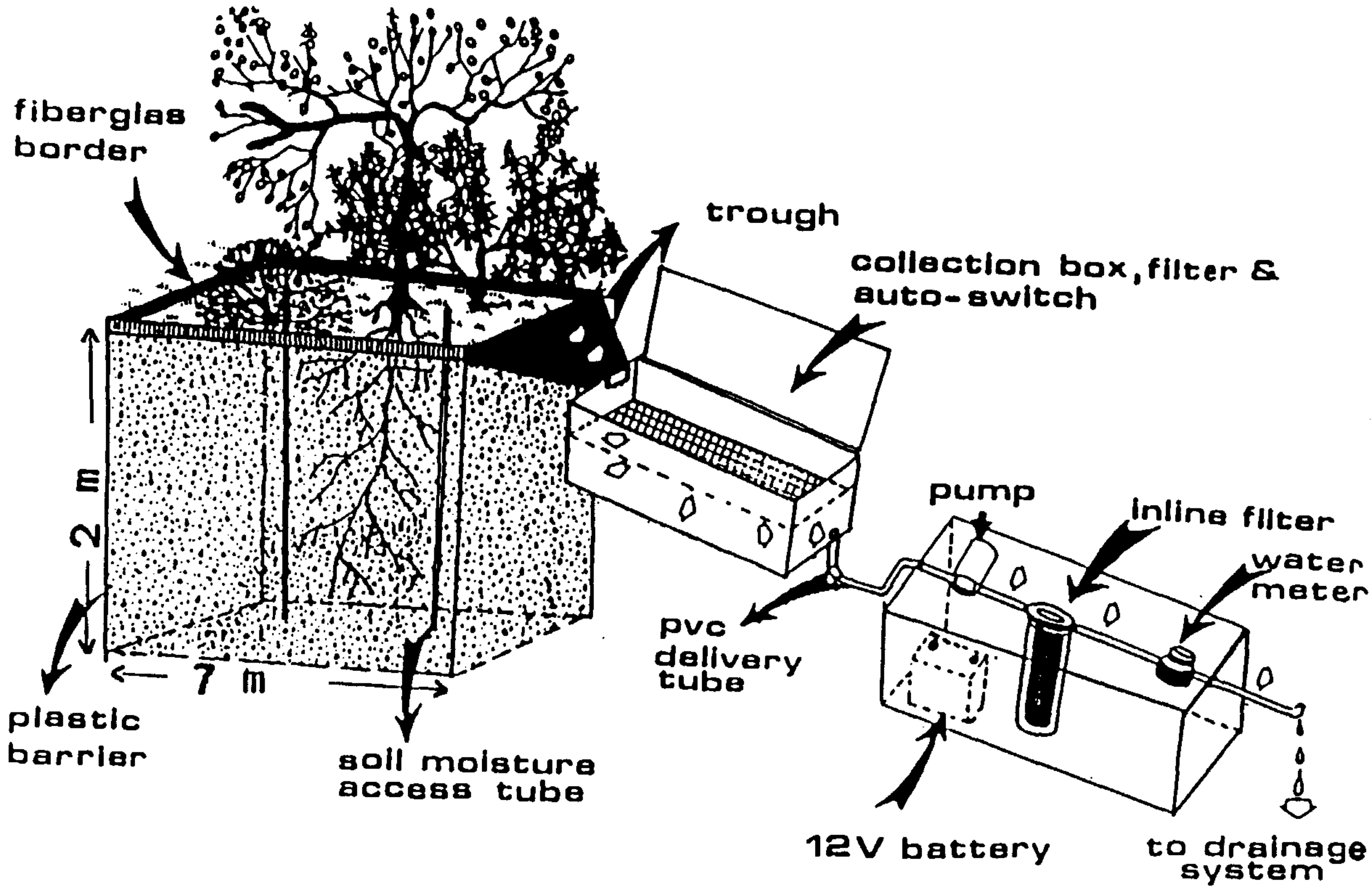

Figure 1. Generalized components of non-weighing lysimeters for mesquite-dominated shrub clusters on the La Copita Research Area, Alice, Texas.

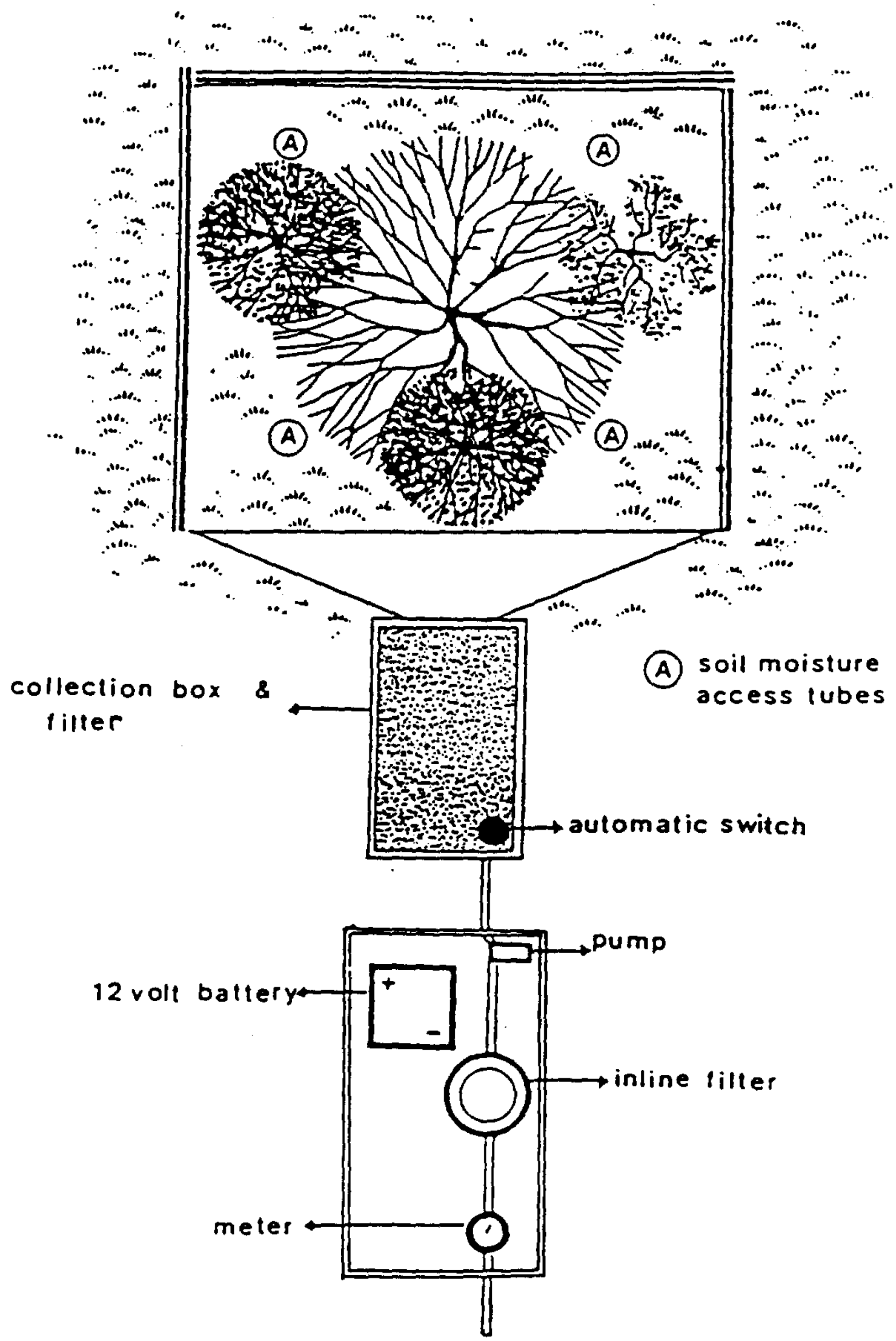

Figure 2. Generalized pland view of the non-weighing lysimeters for determing the water budget from mesquite-dominated shrub clusters, herb-dominated interspaces, and bare soil on the La Copita Research Area, Alice, Texas.

A weather station (Campbell CR-21) was installed in a herbaceous vegetation clearing near the lysimeters. Weather variables measured were total precipitation (PPT) with a tipping bucket and a 20 cm standard raingauge; total wind run; maximum and minimum temperature; relative humidity; net radiation; photosynthetically active radiation; and soil temperature at 10 and 50 cm. Normal precipitation based on the period of record from 1950-1980 was calculated from data collected from Alice, Texas.

Potential evapotranspiration (ETp) was estimated with the Jensen-Haise equation (1963).

$$ETp = (0.014 * F - 0.37) * RS / 580 \qquad (3.1)$$

Were $\underline{ETp}$ is potential evapotranspiration; $\underline{F}$ is degree in fahrenheit; and $\underline{RS}$ is solar radiation in langleys.

Actual evapotranspiration (AET) was calculated by the water budget method:

$$\frac{dAET}{dt} = P - R \pm S - D \qquad (3.2)$$

where $\underline{ET}$is actual evapotranspiration over the period of time (t) considered; $\underline{P}$ is precipitation; $\underline{R}$ is runoff; $\underline{S}$ is the change in soil water; and $\underline{D}$ is deep percolation of water. Percolation of water was calculated using a one dimensional Darcy's law equation.

$$\frac{dJW}{dt} = K * \frac{\Delta Y}{\Delta Z} \qquad (3.3)$$

where $\underline{JW}$ is the total water movement over the period of time (t) considered; $\underline{K}$ is the unsaturated hydraulic conductivity of the soil; $\Delta \underline{Y}$ is the difference in volumetric water content at 150 cm and 180 cm; and $\Delta \underline{Z}$ is the difference in height at the two depths. In this case the difference in height was a constant 30 cm. Unsaturated hydraulic conductivity was determined as outlined by Campbell (1974).

Soil attributes such as particle size distribution (texture), organic carbon, bulk density, desorption curves, and hydraulic conductivity were measured for each horizon in the lysimeters. Approximately 3 kg of homogenized soil, integrated over the entire soil horizon, was collected form the outside wall of the lysimeters. The soil was then air dried and passed through a 2-mm sieve. The mean of two subsamples of the soil was used to test if differences existed in organic matter, hydraulic conductivity, and gravimetric water content under various tensions between treatments within each horizon. Gravimetric water content was determined at 0.01, 0.03, 0.1, 0.3, 0.5, and 1.5 MPa. Bulk density was determined from a single 107.5-cm^3 soil core removed from the center of each horizon along the outer wall of the lysimeters. A single subsample of the homogenized soil was used to determine particle size distribution.

Particle size distribution was measured by the hydrometer method (Bouyoucos 1962). Organic carbon and bulk density were determined by the Walkley-Blake method (Broadbent 1965) and the core method (Blake 1965), respectively. Desorption curves were determined by the pressure plate method (Klute 1965 A). Hydraulic conductivity was determined as outlined by Klute (1965 B).

Root densities in the soil profiles were estimated by counting the number of roots in a single 100 cm^2 quadrat. The quadrat was located in the center of each horizon along the outside wall of the lysimeter. To facilitate the counting, the roots were divided into four size classes. The size classes: (1) were very fine (< 1 mm in diameter); (2) fine (> 1 to 2 < mm in diameter); (3) medium (> 2 to 5 < mm in diameter), ; and (4) course (> 5 mm in diameter) (USDA 1975).

The soil profile was divided into three soil layers for analysis of soil water content. The soil layers were 0-60 cm, 60-120 cm, and 120-195 cm.

Additionally total soil water (0-195 cm) was analyized. Multiple analysis of variance and analysis of variance was used to test for differences in treatment means for total soil water, ($P \leq 0.05$). Analysis of variance was used to test for differences in treatment means for evapotranspiration, runoff, drainage, and changes in soil water, ($P \leq 0.05$). If analysis of variance indicated a significant treatment effect, means were separated at the ($P \leq 0.05$) using a Tukey's studentized range test (Steel and Torrie 1980).

Results and Discussion

Soils

There were minimal differences in physical attributes of the soils from bared areas, herb-dominated areas and from areas occupied by shrub clusters (Tables 1 and 2). The only significant difference attributable to location occurred with bulk density. Soils of lysimeters in the herb-dominated interspaces had significantly higher bulk density in the third soil horizon than did soil from either the shrub clusters or the bared areas. The greater soil bulk density in the herb-dominated lysimeters supports field observations of a more highly developed argillic horizon beneath the herb-dominated interspaces.

Evapotranspiration

There was no significant difference in soil water content among lysimeters containing shrub clusters, herb-dominated interspace, and bare soil on July 30, 1984 (Table 3). Between August 1 and January 9, 1985, 310 mm of precipitation were recorded at Alice (Figure 3). An approximate water balance for each treatment was calculated for the last 5 months (August-December) of 1984. No drainage of water occurred through deep percolation. Although runoff is often assumed to be zero on arid and semiarid rangelands (Lauenroth

Table 1. Physical characteristics and organic matter contents of bare sandy clay loam and from beneath herb-dominated interspaces, and mesquite-dominated shrub clusters by horizon, La Copita Research Area, Alice, Texas.

			Soil fraction				
Horizon	Treatment	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Bulk density[1] (g/cm^3)	Organic matter (%)
1	Bare soil[2]	0- 38	73	3	14	1.22	0.90
	Herbaceous interspaces	0- 43	75	7	18	1.32	0.87
	Shrub clusters	0- 35	73	7	19	1.22	1.02
2	Bare soil	38- 69	60	11	28	1.39	0.68
	Herbaceous interspaces	43- 75	60	7	33	1.38	0.84
	Shrub clusters	35- 62	69	7	24	1.25	0.67
3	Bare soil	69-103	59	6	35	1.34 b	0.56
	Herbaceous interspaces	75-105	60	9	31	1.54 a	0.50
	Shrub clusters	62- 84	64	8	28	1.34 b	0.59
4	Bare soil	103-146	56	11	33	1.40	0.37
	Herbaceous interspaces	105-144	58	7	35	1.40	0.25
	Shrub clusters	84-122	60	9	31	1.39	0.39
5	Bare soil	146-165	57	10	32	1.39	0.21
	Herbaceous interspaces	144-164	57	9	34	1.41	0.18
	Shrub clusters	122-146	57	10	32	1.43	0.29
6	Bare soil	165-195	58	11	31	1.34	0.09
	Herbaceous interspaces	164-195	51	12	37	1.32	0.09
	Shrub clusters	146-195	55	11	34	1.33	0.10

[1] Means for bulk density in the third horizon are significantly different ($P \leq 0.05$) based on Tukey's mean seperation test.

[2] Originally occupied by shrub clusters.

Table 2. Hydraulic conductivity and soil water retention of bare sandy clay loam and soil from beneath herb-dominated interspaces, and mesquite-dominated shrub clusters, La Copita Research Area, Alice, Texas.

Horizon	Treatment	Depth (cm)	Hydraulic conductivity (cm/hr)	Soil moisture retention (g) 0.01 (MPa)	0.03	0.1	0.3	0.5	1.5	Air dry (g)
1	Bare soil[2]	0- 38	3.49[1]	0.14	0.07	0.063	0.039	0.038	0.033	0.004
	Herbaceous interspaces	0- 34	4.04	0.13	0.07	0.055	0.041	0.038	0.034	0.005
	Shrub clusters	0- 35	6.72	0.19	0.09	0.069	0.056	0.052	0.049	0.008
2	Bare soil	38- 69	1.92	0.28	0.15	0.140	0.130	0.125	0.108	0.019
	Herbaceous interspaces	43- 75	2.13	0.30	0.21	0.177	0.147	0.144	0.129	0.026
	Shrub clusters	35- 62	3.03	0.21	0.13	0.108	0.086	0.080	0.070	0.015
3	Bare soil	69-103	1.64	0.13	0.21	0.181	0.145	0.131	0.112	0.026
	Herbaceous interspaces	75-105	1.68	0.33	0.24	0.179	0.153	0.150	0.130	0.029
	Shrub clusters	62- 84	2.49	0.24	0.15	0.131	0.101	0.098	0.089	0.021
4	Bare soil	103-146	1.16	0.32	0.21	0.177	0.140	0.133	0.106	0.020
	Herbaceous interspaces	105-144	1.54	0.34	0.23	0.188	0.153	0.150	0.139	0.022
	Shrub clusters	84-122	2.21	0.27	0.18	0.154	0.118	0.112	0.098	0.027
5	Bare soil	146-165	0.40	0.31	0.20	0.164	0.123	0.114	0.097	0.016
	Herbaceous interspaces	144-164	0.73	0.31	0.21	0.168	0.129	0.122	0.113	0.022
	Shrub clusters	122-146	1.26	0.27	0.19	0.151	0.116	0.114	0.094	0.021
6	Bare soil	169-195	0.39	0.28	0.18	0.147	0.108	0.098	0.080	0.012
	Herbaceous interspaces	161-195	0.75	0.24	0.19	0.144	0.109	0.103	0.069	0.016
	Shrub clusters	146-195	1.24	0.25	0.17	0.140	0.099	0.096	0.095	0.016

[1]There was no significant difference between variables within horizon ($P \leq 0.05$).

[2]Originally occupied by shrub clusters.

Table 3. Initial soil water (0-195 cm) for bare sandy clay loam and soil from beneath herb-dominated interspaces, and mesquite-dominated shrub clusters on July 30, 1984, La Copita Research Area, Alice, Texas.

Treatment	Soil Water[1] (mm)
Bare soil[2]	420
Herbaceous interspace	435
Shrub cluster	389

[1] Means are not significantly different ($P \leq 0.05$) based on Tukey's means separation test.

[2] Originally occupied by shrub clusters.

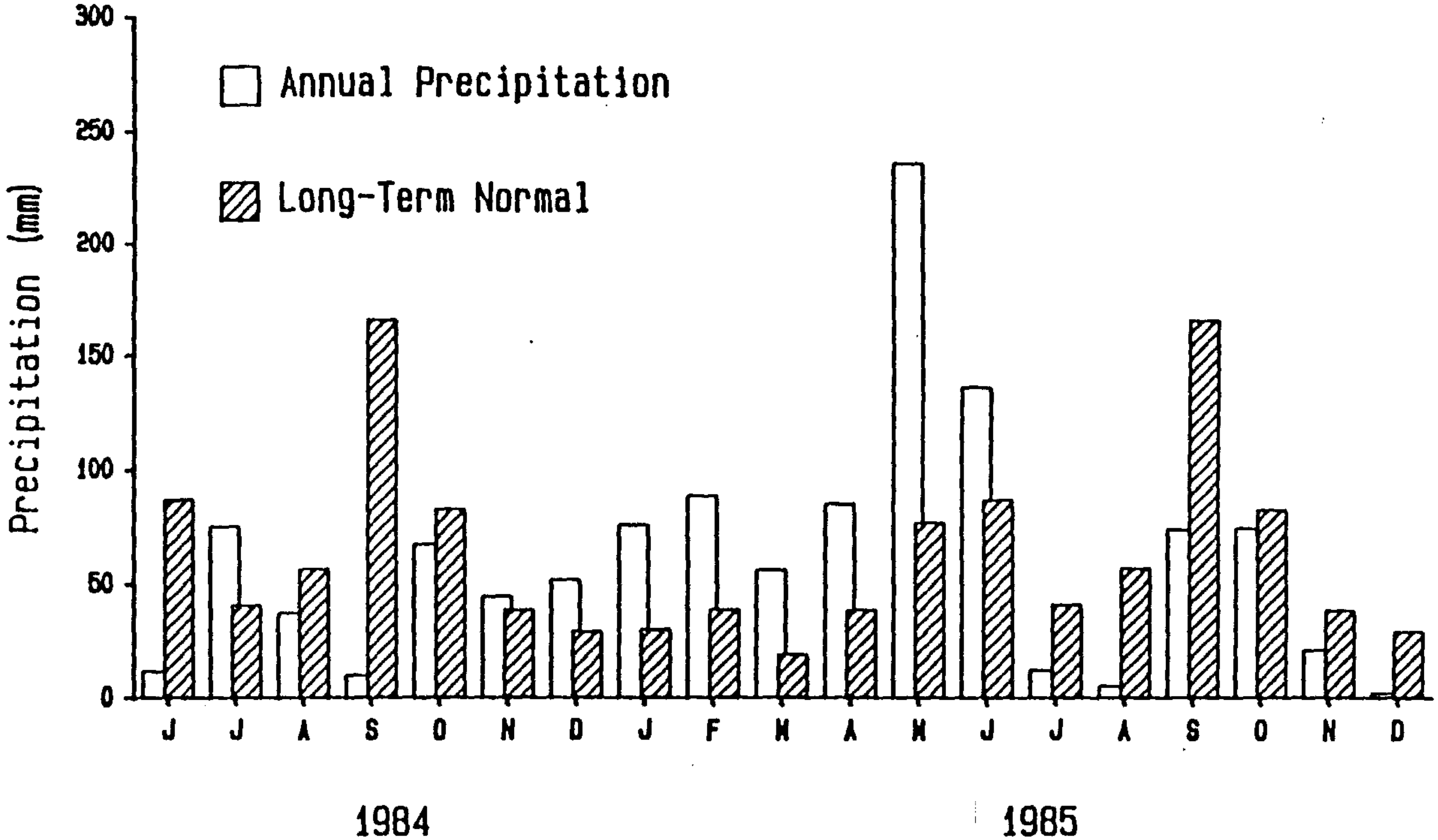

Figure 3. Long-term Normal and precipitation during the study period for the La Copita Research Area, Alice, Texas.

and Sims 1976, Wight et al 1986, Gee and Kirkham 1984), annual runoff accounted for 2 to 10% of annual precipitation in 1985. Estimated runoff based on the rainfall-runoff relationships of 1985 was used to calculate annual AET for 1984. Annual AET values for shrub clusters, herbaceous interspaces and bare soil were 330, 297 and 208 mm, respectively (Table 4). Average daily ET values between August 1, 1984 and January 9 1985, were 1.8, 1.6, and 1.1 mm/day for the shrub clusters, herbaceous interspaces, and bare soil, respectively (Table 5).

Annual precipitation for 1985 was 189 mm above the normal and in January, February and May 1985, PPT exceeded ETp (Figure 4). The period from January 10 through June, 1985 was considerably higher than normal (394 mm). However, July and August were considerably drier than normal with only 19 mm of PPT. From September 1985 through January 9, 1986, 185 mm of PPT occurred but was still less than normal. This bimodal distribution provided the opportunity to determine the effect of daily AET during periods of above soil moisture (January-June), during a drought (July and August), and a period of below normal rainfall (September-January) within 1 year (1985).

AET accounted for 94% of the annual precipitation received by the interspaces, 99% of that received by the shrub clusters, and 73% of the total rainfall received on the bare soil. ET accounted for 90 to 100% of annual PPT from Pinyon-Juniper woodlands in Utah (Gifford 1975). In California ET as a percentage of annual PPT varied from 89 to 122% from shrub dominated-rangeland, 23 to 100% for annual grasses, and 147% for annual grasses and forbs (Rowe and Reimann 1961).

Table 4. Water budget (mm) for bare sandy clay loam and soils from beneath herb-dominated interspaces, and mesquite-dominated shrub clusters, La Copita Research Area, Alice, Texas[1].

Year	Treatment	PPT	ET[2]	Runoff[3]	Drainage	Soil Water
1984	Bare soil[4]	310	207 b	31 a	0 a	+ 71 a
	Herbaceous interspaces	310	297 a	3 b	0 a	+ 9 b
	Shrub clusters	310	330 a	3 b	0 a	- 23 c
1985	Bare soil	887	643 b	84 a	78 a	+ 247 a
	Herbaceous interspaces	887	833 a	28 b	22 b	+ 5 b
	Shrub clusters	887	881 a	19 b	0 b	- 13 b

1 Means followed by the same letter are not significantly different ($P \leq 0.05$) based on Tukey's mean seperation test.

2 Evapotranspiration for the period of August through December, 1984.

3 Runoff for 1984 was estimated from rainfall-runoff relationships in 1985.

4 Originally occuppied by shrub clusters

Table 5. Annual and seasonal daily evapotranspiration rates (mm/day) for bare soil, herb-dominated interspaces, and mesquite-dominated shrub clusters on a sandy clay loam range site, La Copita Research Area, Alice, Texas, from January 1985 through January 1986.

	Precipitation regime[1]			
Treatment	Above normal (1/85 - 6/85)	Drought (7/85 - 8/85)	Below normal (9/85 - 1/86)	Annual
Bare soil[2]	2.36 b	1.06 c	1.34 a	1.8 a
Herbaceous interspace	2.86 ab	2.9 a	1.22 a	2.3 a
Shrub clusters	3.36 a	1.8 b	1.49 a	2.4 a

[1]Means in the same column followed by the same letter are not significantly different ($P \leq 0.05$) based on Tukey's mean seperation test.

[2]Originally occupied by shrub clusters.

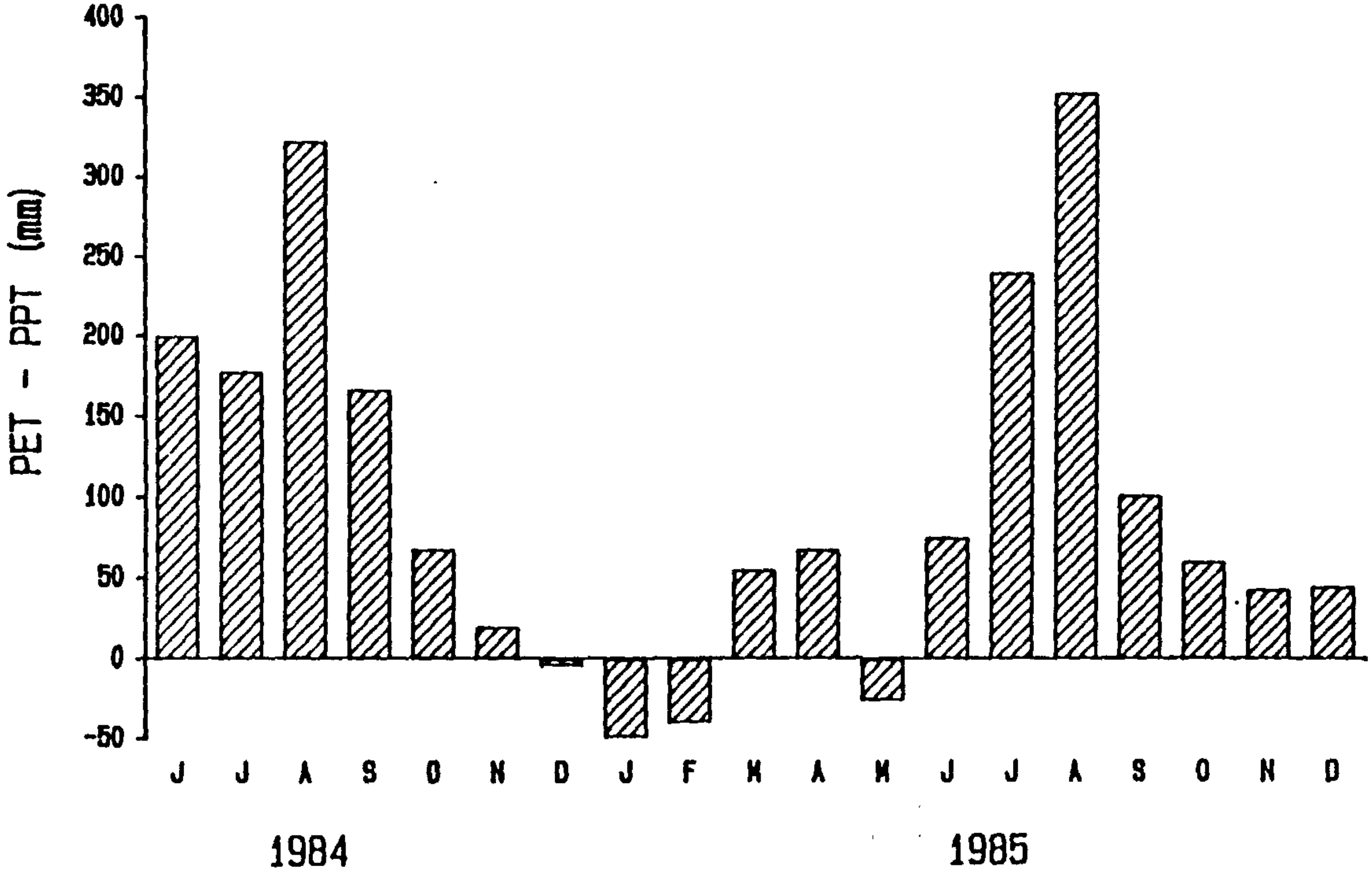

Figure 4. Potential evapotranspiration (PET) minus precipitation (PPT) during the study period for the La Copita Research Area, Alice, Texas.

The installation of the runoff monitoring devices was completed during December of 1984, and collection began on January 10, 1985. The mean soil water content in the profile beneath bare surfaces initially were significantly greater than beneath the shrub clusters. Soil water contents of interspace soils were intermediate and not significantly different from those of the soils beneath shrub clusters (Figure 5). The greater soil water content beneath the bare soil areas in January was a function of the lower AET in 1984 (Table 4).

Seasonal dynamics of cumulative ET reflect differences in seasonal precipitation over the 2 years and differences in soil water (Figure 6). There was no significant difference between annual AET for the shrub clusters and the interspaces during 1984 and 1985. The annual AET values for the bare soil were significantly lower than for either the interspaces or the shrub clusters during 1984 and 1985.

Average annual daily AET values were 2.4, 2.3 and 1.8 mm/day for the shrub clusters, herb-dominated interspaces, and the bare soil during 1985, respectively (Table 6). Average daily AET for the herbaceous interspaces compares favorably with daily ET rates from shortgrass prairies (1.4-4.2 mm/day) in Colorado (Lauenroth and Sims 1976). The daily AET rates of the shrub clusters are comparable to the daily ET rates reported for velvet mesquite woodlands in the Safford valley of Arizona for May (2.5 mm/day) (Gatewood et al. 1950), and for Walnut Gulch in Arizona 1.6 mm/day (Tromble 1977).

The higher annual daily AET rate for 1985 compared to 1984 was attributed to the greater amount of precipitation during 1985. PET is usually twice AET, and PET may be greater than three times AET during dry years (Dugas and Aniswworth 1983). Lauenroth and Sims (1976) reported that average ET/PPT ratio was 0.9 under natural PPT. Increasing PPT with supplemental irrigation

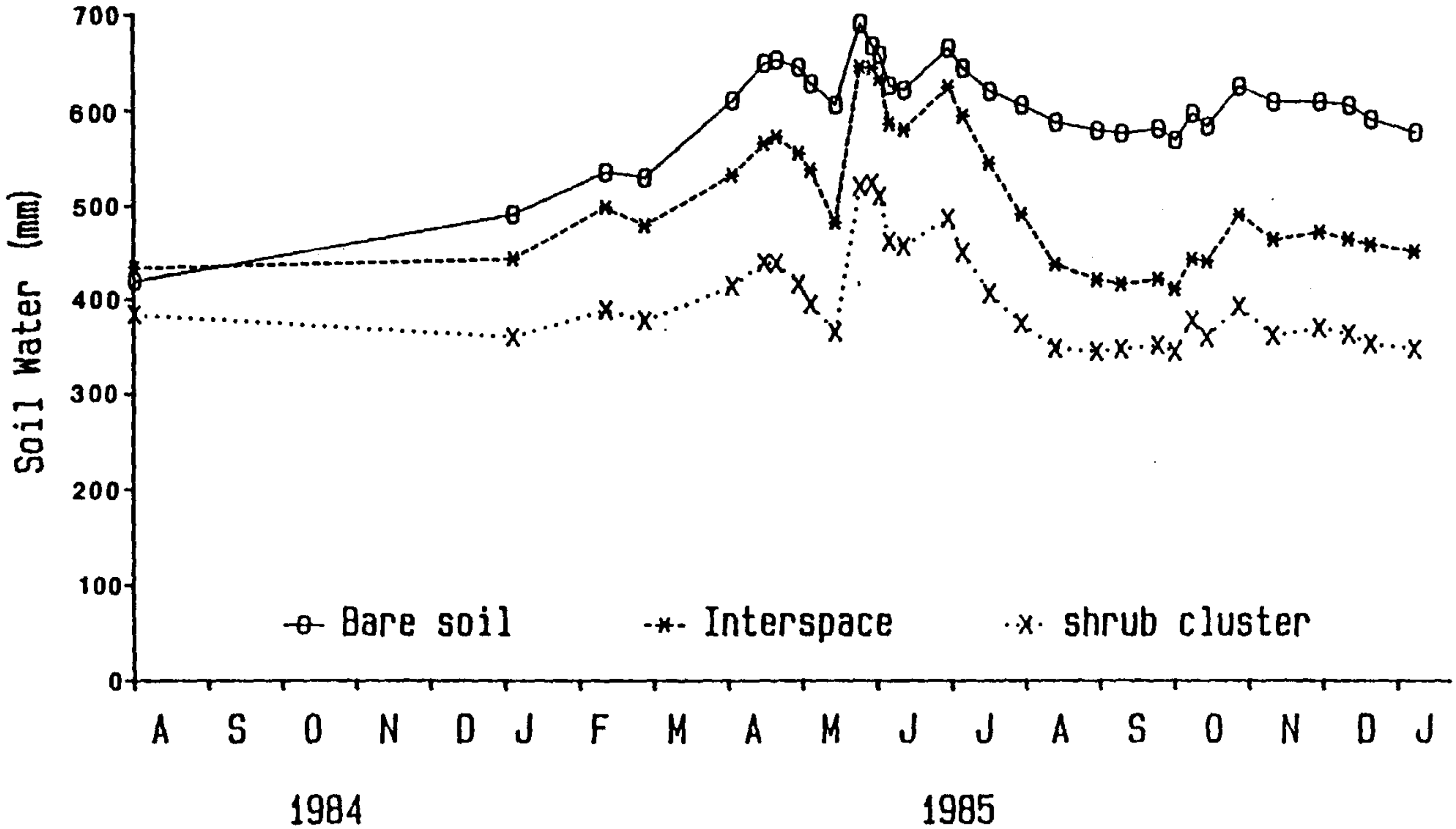

Figure 5. Soil water content (0-195 cm) for mesquite-dominated shrub clusters, herb-dominated interspaces, and bare soil on a sandy clay loam soil, La Copita Research Area, Alice, Texas.

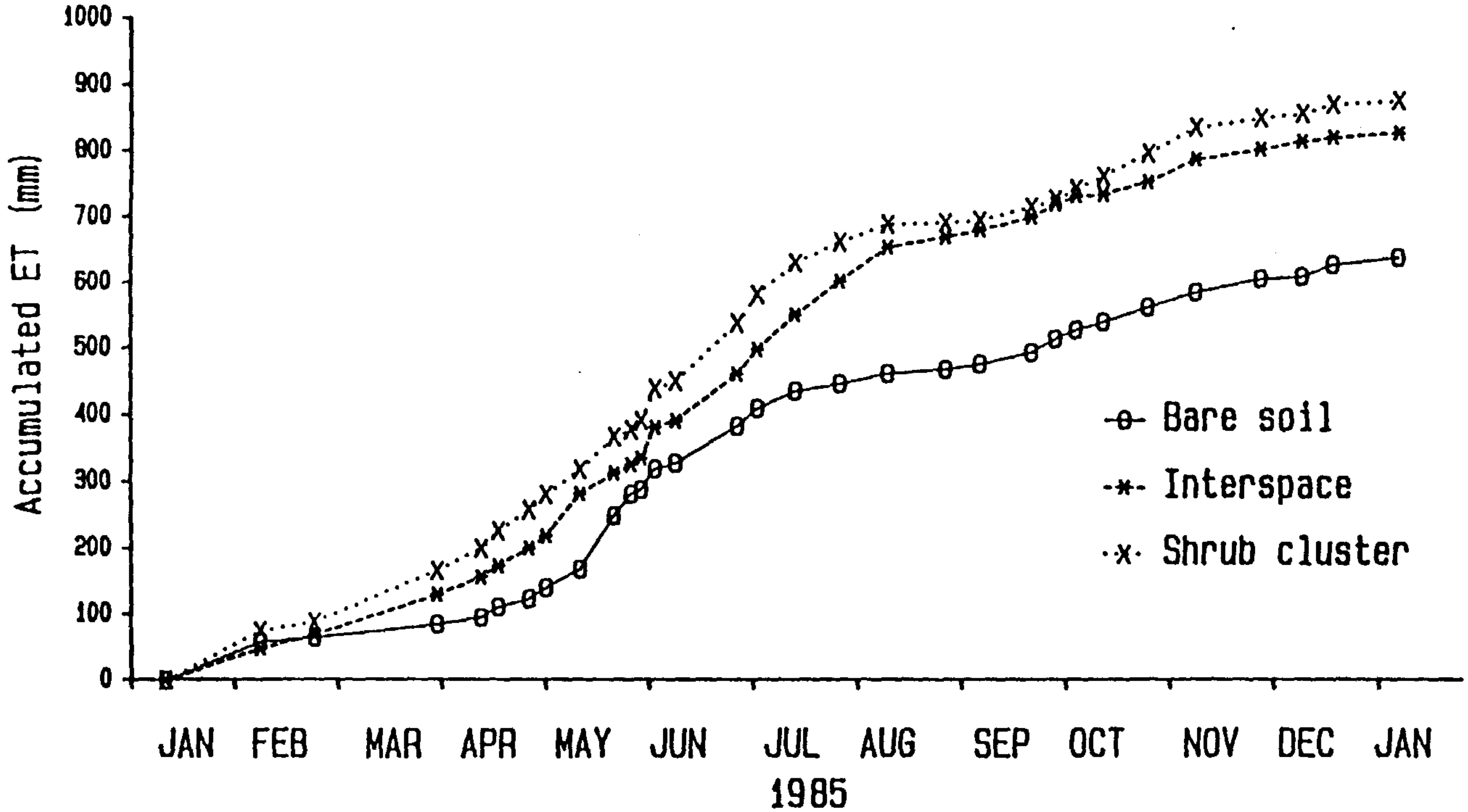

Figure 6. Accumulated evapotranspiration (ET) for mesquite-dominated shrub clusters, herb-dominated interspaces, and bare soil on a sandy clay loam soil, La Copita Research Area, Alice, Texas.

Table 6. Daily evapotranspiration rates (mm/day) for bare soil, herb-dominated interspaces, and mesquite-dominated shrub clusters on a sandy clay loam range site, La Copita Research Area, Alice, Texas.

	Daily evapotranspiration rates[1]	
Trearment	8/84 - 12/84	8/85 - 12/85
Bare soil[2]	1.13	1.24
Herbaceous interspaces	1.62	1.59
Shrub clusters	1.79	1.79

[1] No significant difference ($P < 0.05$) among means within years based on Tukey's mean seperation test.

[2] Originall occupied by shrub clusters.

(313 mm) increased the ET/PPT ratio to 0.97 on the shortgrass prairies. Annual ET depends on the availability of soil water. Saltgrass (Distichlis spp.) annual ET varied from 1016 mm when the water table was at 30 cm to 254 mm when the water table was at 122 cm below the soil surface (Anonymous 1942). Tromble (1977) and Gatewood et al. (1950) reported that mesquite with access to ground water had an estimated maximum ET rate of 10 to 12 mm/ day.

During the period of above normal PPT (January-June 1985), the average daily AET rate from shrub clusters was significantly greater than from the bare soil (Table 5). Average daily AET rate from the interspaces was similar to the shrub clusters and bare soil. Althought there was no siginificant difference in AET between the shrub clusters and the interspaces during this period, the higher AET rate of the shrub clusters was attributed to its greater leaf area. Average daily ET from the interspaces during the dry months of July and August were significantly greater than from the shrub clusters or bare soil (Table 5). The decrease in average daily ET from the shrub clusters during this period was attributed to the decrease in leaf area of honey mesquite and Texas colubrina and the decreased availablity of soil water. Average daily ET of shrub clusters and bare soil were similar during this dry period. AET of shrub clusters was significantly higher than AET for the bare soil from September 1985 through January 9, 1986 and values for herb-dominated interspaces were intermediate (Table 5). The increased AET from the herbaceous vegetation during this period was attributed to the increased leaf area and the increased availablity of soil water. The leaf area of the shrub clusters continued to decrease. The increased AET of the shrub clusters was attributed to the increased availability of soil water.

Daily ET rates were 1.6, 1.8, and 1.2 mm/day for the shrub clusters, interspaces, and bare soil, respectively, from August 1, 1985 through January 9, 1986. PPT for this period was 233 mm. Although the PPT in 1985 was 77 mm below that of 1984 the average daily ET rates for interspaces and shrub clusters in 1984 and in 1985 were similar, averaging 1.6 to 1.8 mm/day. ET rates of interspaces and the shrub clusters in 1984 approximated PPT. At the initiation of the dry period in 1985 the soil water content was substantially higher than in 1984. Annual grasses and forbs in the interspaces and shrubs in the clusters utilized this stored soil water to compensate for the reduction in PPT.

The evergreen shrubs in the clusters responded more rapidly to available soil water in both the spring and fall than did the annual grasses and forbs. Evergreen shrubs have the capacity to remove water through ET whenever soil water, air temperature and solar radiation are favorable. The high AET rate of the shrub clusters following rainfall events probably resulted from interception losses and was not due solely to transpiration and evaporation of water from the soil surface.

Annual interception losses for chaparral communities in California range from 4.3 to 9.9 cm (8 to 20% of the annual rainfall) (Rowe 1964, Hamilton and Rowe 1949, Corbett and Crouse 1968). It is reasonable to assume that interception rates of shrub clusters, with their dense multilayered canopies, would approximate that of chaparral.

Runoff

Surface runoff from the interspaces, shrub clusters, and bare soil was 1, 3, and 10%, respectively, of PPT in 1985. Two large rainfall events (> 100 mm) occurred within a 5-day period in May. The surface runoff from the herbaceous interspace areas was 60% greater than the surface runoff from the shrub cluster areas (Figure 7). Infiltration capacity of the herb-dominated interspace areas were lower (4.04 cm/hr) than the shrub cluster areas (6.72 cm/hr), although not significant.

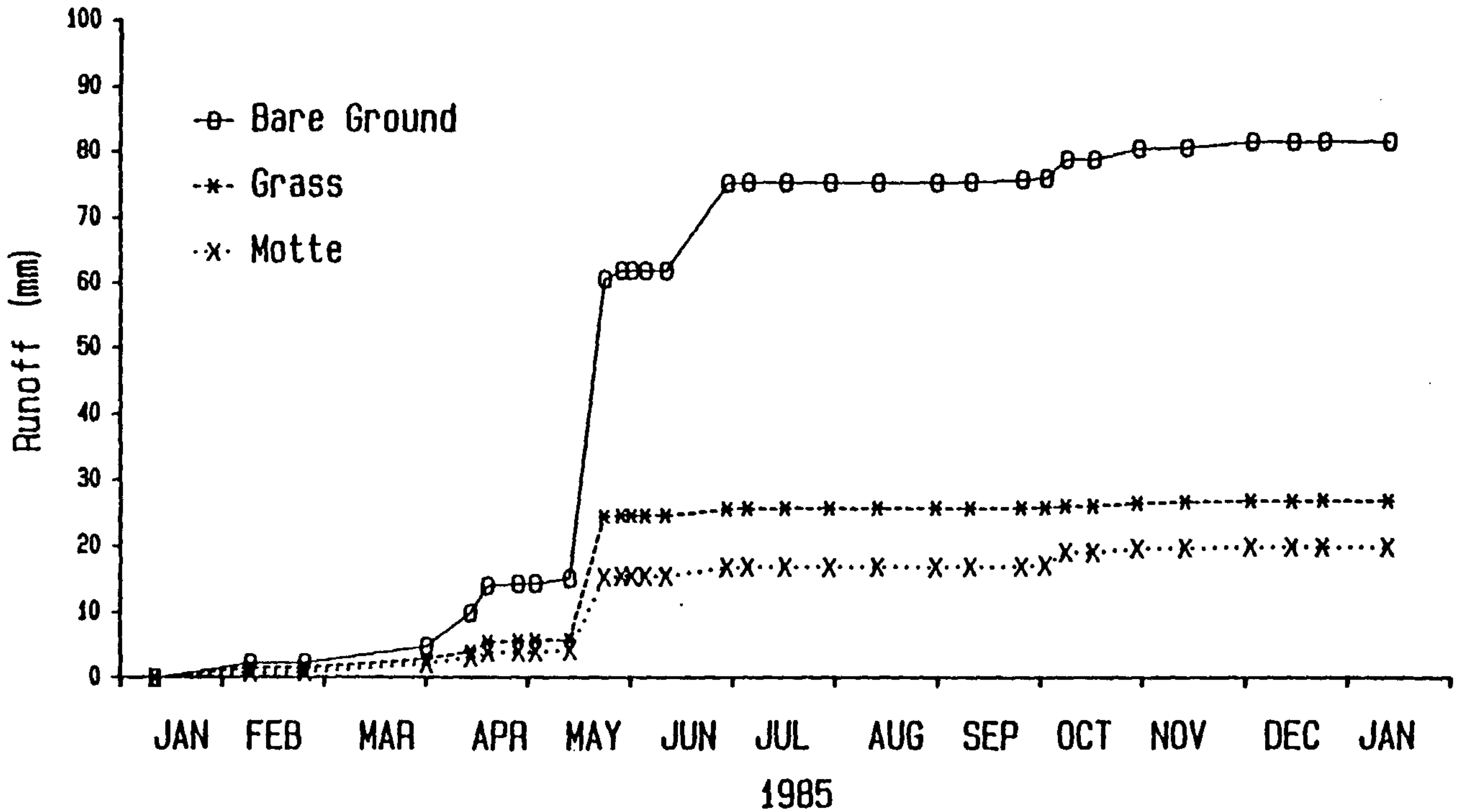

Figure 7. Accumulated runoff for mesquite-dominated shrub clusters, herb-dominated interspaces, and bare soil on a sandy clay loam soil, La Copita Research Area, Alice,

Over 90% of the rainfall events during this study occurred when the soil was dry (antecedent moisture class I based on the SCS (1972) procedure for estimating runoff). The highest storm rainfall intensity was 4.8 cm/hr for a duration of 30 min. in 1985. Infiltration capacity of the herbaceous interspaces and the shrub clusters were probably never reached for most of the storms in 1985. If the storm intensities and duration of the rainfall events would have been of sufficient magnitude to exceed the infiltration capacity of the interspace areas, then there would probably have been significantly greater surface runoff from the interspaces than from the shrub clusters. Surface runoff was significantly greater from bare soil than from either the herb-dominated interspaces or the shrub clusters. Surface runoff was similar from the interspaces and the shrub clusters. More than 50% of the surface runoff, regardless of vegetation cover, was the result of two large rainfall events in May.

Richardson et al. (1979) reported that during the dormant season runoff from honey mesquite dominated-watersheds was similar to herbaceous dominated-watersheds. During the growing season the herbaceous dominated-watersheds yielded significantly more runoff. They attributed the increase in runoff to the increased soil water content in the herbaceous dominated-watershed.

Standing crop in the herb-dominated interspaces and leaf biomass in the shrub cluster were significantly correlated with runoff (Table 7). Grass and shrubs may intercept a significant portion of incident rainfall (Burgy and Pomerory 1958, Corbett and Crouse 1968, Hamiltion and Rowe 1949) and thus reduce the impact of falling raindrops. Raindrops impinging directly on a bare soil surface may dislodge soil particles which clog soil pores and increase surface runoff (Osborn 1954). Depending on the plants morphological characteristics and growth form, much of the intercepted rainfall may be channeled to the base as stemflow (Glover et al. 1962, Gwynne 1966) where

Table 7. Simple correlation coefficents for rainfall characteristics, herbacious standing crop, and shrub leaf biomass with runoff from bare soil, herb-dominated interspaces, and mesquite-dominated shrub clusters on a sandy clay loam range site, La Copita Research Area, Alice, Texas.

	Runoff[1]		
Independent variable	Bare soil	Herbaceous interspaces	Shrub clusters
Rainfall erosion index (metric ton-m/ha/cm of rain)	0.97 *	0.85 *	0.87 *
Total rainfall (cm)	0.87 *	0.74 *	0.76 *
Maximum 5-minute intensity (cm/hr)	0.92 *	0.74 *	0.78 *
Rainfall duration (hr)	0.56 *	0.45 *	0.48 *
Rainfall duration intensity (cm/hr)	0.38 *	0.38 *	0.36 *
Storm duration (hr)	0.33 *	0.18	0.21
Storm duration intensity (cm/hr)	0.02	0.04	0.02
Herbaceous standing crop (g)	NS[2]	0.38 *	NS
Shrub leaf biomass (g)	NS	NS	0.35 *

[1]Correlation coefficient significant ($P < 0.05$).

[2] No data available for analysis

plant roots and litter accumulation create a porous soil characterized by higher infiltration rates (Blackburn 1975).

Rainfall characteristics were highly correlated with runoff. The rainfall erosion index (EI) (metric ton-meter/ha/cm of rain) value was highly correlated with runoff. The EI value was calculated based on procedure used in the universal soil loss equation (Wischmeier and Smith 1978). Rainfall events of less than 13 mm and separated from other rainfall events by more than 6 hours were omitted from the analysis. EI values for such periods are usually to small for practical use and generally contribute little to the monthly and yearly total EI value (Wischmeier and Smith 1978).

Maximum rainfall intensity (mm/hr) for a 5-minute period, duration (hours) that rainfall was actually recorded, intensity of rainfall (mm/hr) for the period that rainfall was recorded were significantly correlated with runoff. Duration of the entire storm (hours) and storm intensity (mm/hr) for the duration of the rainfall event were poorly correlated with runoff. There were significant differences among treatments and no single regression equation effectively predicted runoff. For each treatment the EI value explained more of the variability than any other variable (Table 8). The EI values calculated for the bare soil areas explained more of the variability of runoff than in either the herb-dominated interspace or shrub cluster areas.

Since the EI value was initially developed for use on cropland, it is not surprising that runoff from the bare soil areas was well correlated with the EI value. Surface crust of aggregated sand particles bound by organic matter formed shortly after removal of the shrubs on the bare soil. Initially, there were micro-depressions throughout the bare soil lysimeters. The micro-depressions were filled within months after clearing the shrubs creating a uniform gradient to the flume. In the herb-dominated interspaces and shrub

8

Table 8. Simple linear regression equations and coefficients of determination for runoff (mm) from bare soil, herb-dominated interspaces, and mesquite-dominated shrub clusters on a sandy clay loam range site, La Copita Research Area, Alice, Texas.

Treatment	Regression equation[1]	r^2
Bare soil	Y = 0.012 + 0.015(EI)[2]	0.94 *
Herbaceous interspaces	Y = 0.003 + 0.006(EI)	0.72 *
Shrub clusters	Y = 0.004 + 0.004(EI)	0.76 *

[1]Simple linear regression significant ($P \leq 0.05$).

[2]EI is rainfall erosion index (meteric ton-meter/ha/cm of rain).

clusters the plants aided microrelief development and stability. Numerous debris dams were noted in both the interspace and shrub cluster lysimeters after the two large rainfall events in May. Micro-depressions and debris dams increase the retention time of water on the soil surface and decrease surface runoff. The relationship between standing crop and litter was constantly changing in the herb-dominated interspaces and shrub clusters. The lower correlation of the EI value to runoff for vegetated lysimeters than for the bare soil lysimeters was attributed to variability associated with the seasonal dynamics of plant growth and decay.

Infiltration rates on shrub-dominated areas are commonly higher than for herbaceous interspaces. The infiltration rate of big sagebrush (*Artemisia* spp.)-dominated rangelands in eastern Nevada was three times higher in the shrub coppice dune than in the interspace areas (Blackburn 1975). Infiltration rates of grasslands were lower than those of undisturbed oak shrub clusters near Sonora, Texas (Knight et al. 1983). Infiltration rates of soils dominated by mesquite, lime pricklyash, Texas persimmon, and spiny hackberry were 2 to 3 times higher than the interspaces on a clay loam range site near the research site (unpublished data Weltz).

Drainage

Deep drainage beneath bared soil areas was significantly greater than soils with vegetative cover. The quantity of water lost through deep percolation was similar beneath the herb-dominated interspaces and the shrub clusters from January through May 1985. Deep drainage occurred in the interspaces on May 21 and continued until August 4 (Figure 8). Essentially no deep drainage occurred beneath the shrub clusters during 1985. Deep drainage in the interspaces was attributed to the 239 mm of rain in May. Deep drainage beneath the bared soil areas began in late February and continued throughout the remainder of the year. As with the interspaces, the majority of drainage from the bared soil areas was a result of the high rainfall in May.

That water reaches depths below active root uptake in the herbaceous interspaces can be further deduced from the presence of soil mottling in the lower portions of the profile. Soil mottling indicates periods of either a perched water table or periods when deoxygenated water is slowly moving through the soil profile. No soil mottling was present beneath the shrub clusters or the bare soil.

Conditions favorable for percolation would be prolonged periods of above normal precipitation during the dormant season. An increase precipitation above normal in association with reduced ET demands would recharge the soil profile. The increased the soil water content would increase the hydraulic gradient and the quantity of water percolating below the active root zone. When the soil water content was above 35% (by volume) at 120 cm in the bare soil and herb-dominated interspaces deep percolation occurred.

Root density

Use of soil water by vegetation is a function of root density and rooting depth. The shrubs developed both surface lateral roots and relatively deep tap roots. The roots of the woody plants penetrated to 2 m, although the majority (83%) of their roots were in the top 122 cm of the soil profile (Table 9). Annual grass and forb roots extended to a depth of 120 cm. The majority (95%) of the annual grasses roots were in the upper 75 cm of the soil profile, and no grass or forb roots were found below 144 cm. Gee and Kirkham (1984) reported that roots were limited to the surface 60 cm in annual grasslands, and that no roots occurred below 1 m. There was no significant difference in root densities of the shrub cluster and herb-dominated interspaces in the first two horizons. The density of woody plant roots

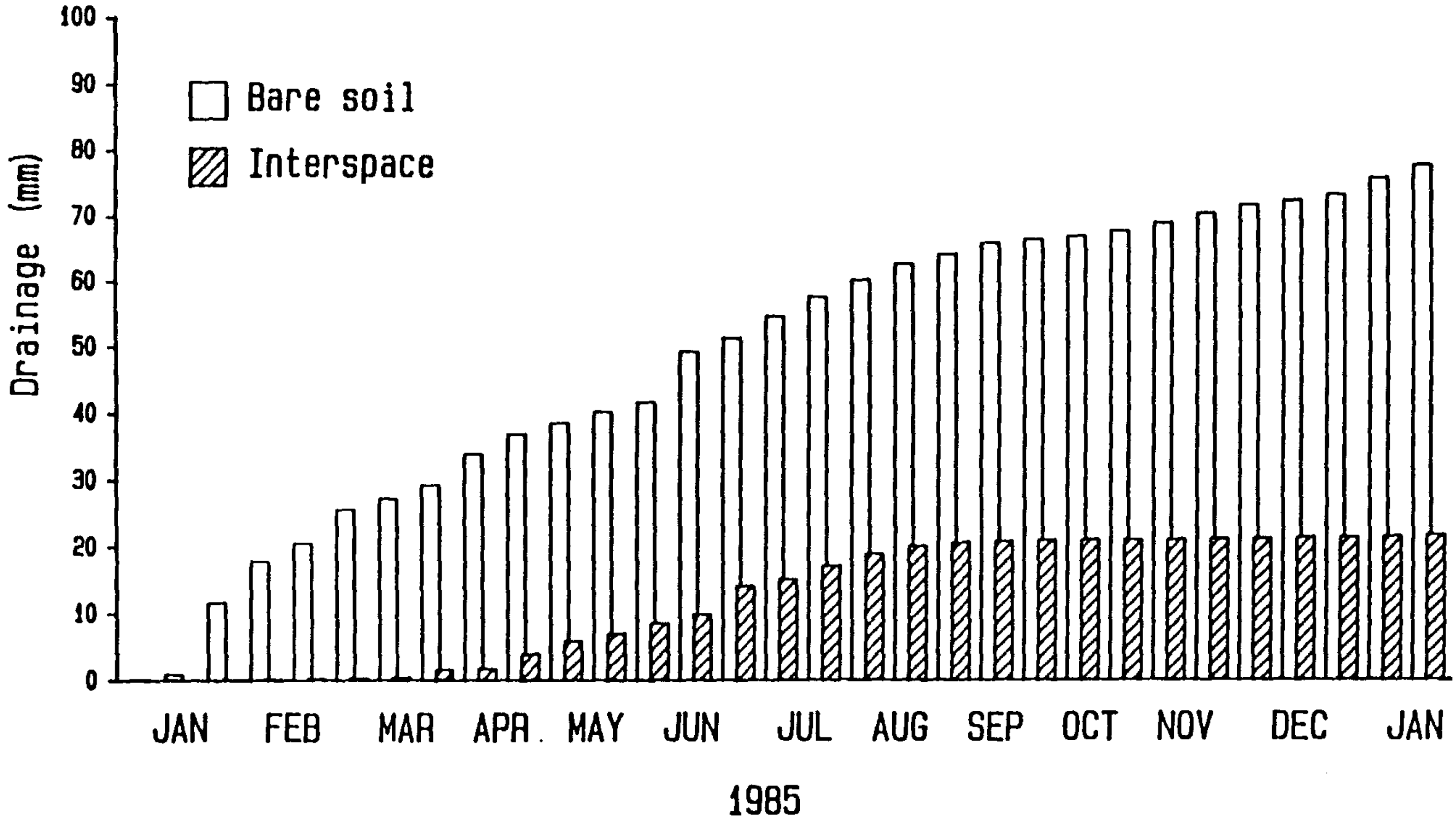

Figure 8. Accumulated drainage for herb-dominated interspaces and bare soil on a sandy clay loam soil, La Copita Research Area, Alice Texas.

Table 9. Estimated root densities by soil horizon for herb-dominated interspaces and mesquite-dominated shrub clusterson a sandy clay loam range site, La Copita Research Area, Alice, Texas.

Horizon	Vegetation	Depth[1] (cm)	Root density[2] (number/100 cm^2)
1	Herbaceous interspaces	0 - 43	36 a
	Shrub clusters	0 - 35	44 a
2	Herbaceous interspaces	43 - 75	29 a
	Shrub clusters	35 - 62	28 a
3	Herbaceous interspaces	75 - 105	12 b
	Shrub clusters	62 - 84	28 a
4	Herbaceous interspaces	105 - 144	4 b
	Shrub clusters	84 - 122	28 a
5	Herbaceous interspaces	144 - 164	0 b
	Shrub clusters	122 - 146	17 a
6	Herbaceous interspaces	164 - 195	0 b
	Shrub clusters	146 - 195	9 a

[1] Sampling followed genetic soil horizons rather than predetermined intervals.

[2] Means in the same horizon followed by the same letter are not significantly different ($P \leq 0.05$) based on Tukey's mean seperation test.

beneath the shrub clusters was significantly greater than the density of herbaceous roots in the interspaces in horizons 3 through 6 (Table 9).

Young et al. (1984) reported that western juniper (Juniperus occidentalis) had 90% of its roots in the top 75 cm of the soil profile. Even though juniper roots were found to extend out to 6 m from the trunk, 62% of the roots occurred within 1 m of the trunk.

The density of herbaceous and woody plant roots was probably under estimated as a function of how the root data was determined. Trenches were dug through the center of three shrub clusters near the lysimeters in June of 1986. Qualitative estimates of roots from visual inspection indicated that the majority of roots from individual plants were in the first 1 m^3 of the soil in a manner similar to western juniper (Young et al. 1984). Visual estimates indicate that the proportions of roots through the profile was similar to the measured values, although the actual density was underestimated.

Soil water content

Total soil water (0-195 cm) beneath the bare soil areas was significantly greater than in the soil beneath shrub clusters in January 1985. Soil water contents beneath the herb-dominated interspaces and the bare soil areas were similar in January. Soil water contents beneath bare soil and herb-dominated interspaces were significantly greater than in soils of the shrub clusters from February through early August. Soil water content of bare soil was significantly greater than in soils of either the shrub clusters or the herb-dominated interspaces from the middle of August through early January 1986. From the middle of August through early September, soil water content beneath the shrub clusters and the herb-dominated interspaces were similar. Soil water content beneath the herb-dominated interspaces was significantly higher

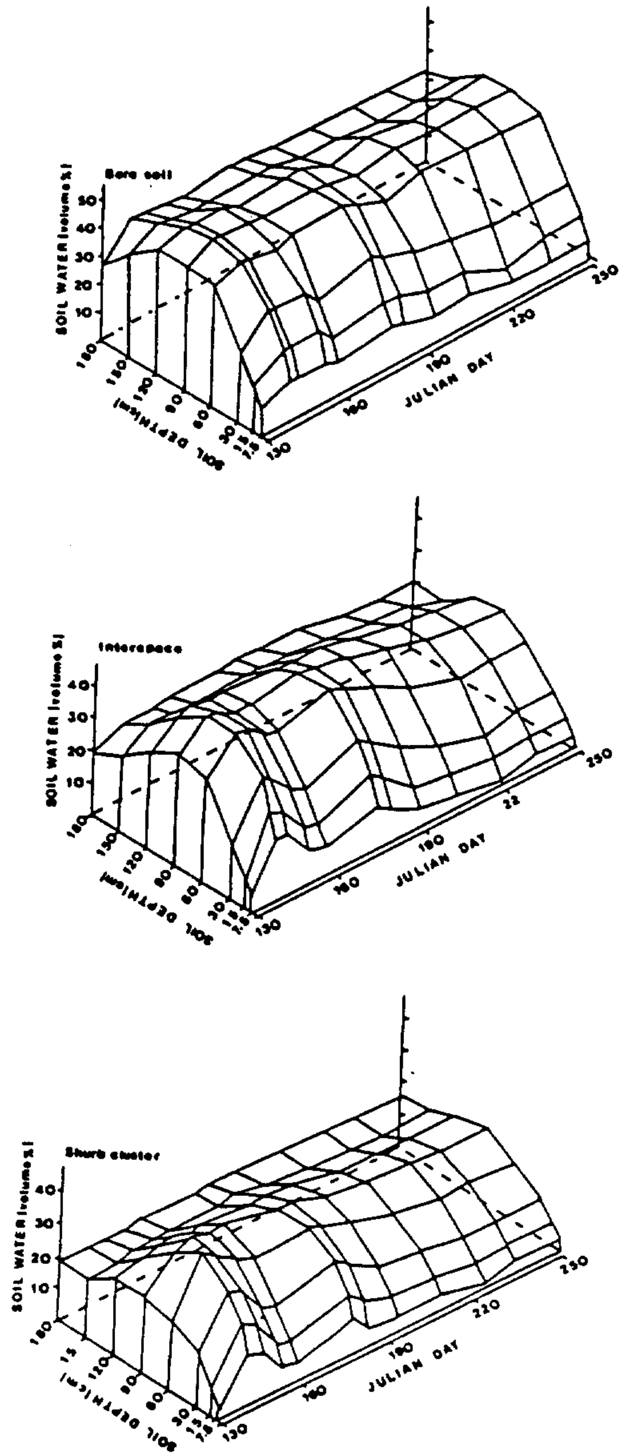

Figure 9 . Relationship of soil water content, depth and time beneath bare soil, herb-dominated interspaces, and mesquite-dominated shrub clusters from May through August 1985, on a sandy clay loam soil, La Copita Research Area, Alice, Texas.

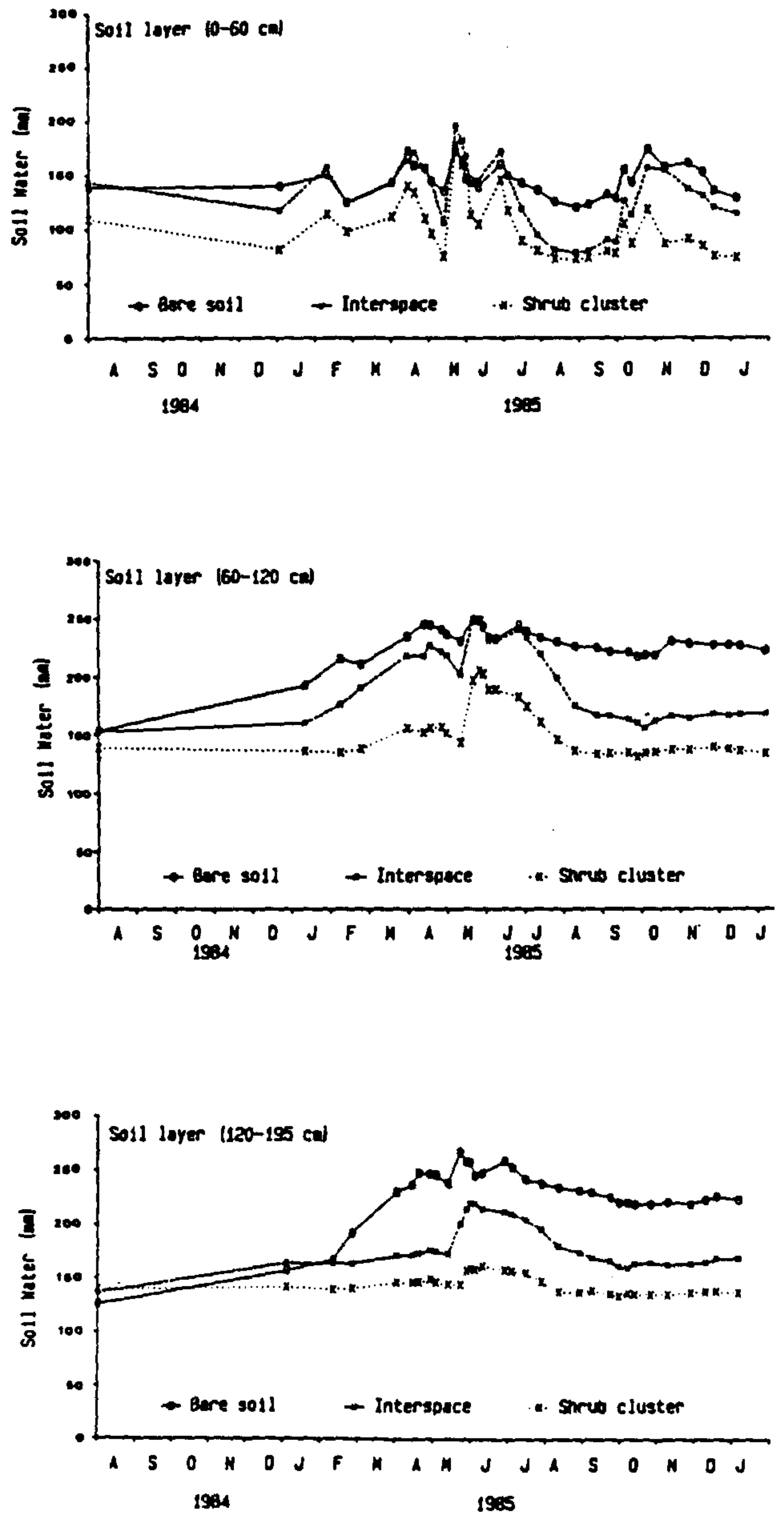

Figure 10. Soil water content for mesquite-dominated shrub clusters, herb-dominated interspaces, and bare soil on a sandy clay loam soil, La Copita Research Area, Alice, Texas.

than in soils of the shrub clusters from the middle of October through the end of the study in January 1986. The distribution of soil water throughout the soil profile from May 12 through September 7 is depicted in Figure 9.

Although total AET did not differ significantly between the shrub clusters and the herb-dominated zones, there was a difference in the pattern of soil water use. Soil water content at 0 to 60 cm deep in the herb-dominated interspaces was significantly greater than beneath the shrub clusters from January through mid-July 1985 (Figure 10). Soil water contents beneath herbaceous interspaces and shrub clusters were similar from July through early September. When the second rainy season began in September, the herb-dominated interspaces began to accumulate soil water faster than did the shrub clusters. By mid-September, the herbaceous interspaces and bare soil had accumulated significantly more water than soil of the shrub clusters. Water content of the herbaceous interspaces soil was similar to that of the bare soil. This pattern continued throughout the remainder of the study.

The bare soil contained significantly more water at 60 to 120 cm deep than soils beneath the shrub clusters for the entire year (1985) (Figure 10). Soil water contents in the interspaces and beneath shrub clusters were similar at the beginning of 1985. However, more soil water accumulated by February in the herb-dominated interspaces than in soils of the shrub clusters and soil water contents in the interspaces were significantly greater than beneath shrub clusters until the end of August. Soil water contents beneath the herbaceous interspaces and the shrub clusters were similar through September.

From October through the end of the study soil water contents beneath the herb-dominated interspaces were significantly higher than shrub clusters in the 60 to 120 cm zone. It took approximately 2 weeks after a 45 mm precipitation event for soil water increases to be detected in the 60 to 120 cm zone. This time delay in soil water increase indicates that a substantial quantity of water moves as unsaturated flow through the soil beneath the herb-dominated interspaces. The shrubs extracted soil water at a rate exceeding the unsaturated flow rate, thus precluding any substantial downward movement of water.

Water content of the lower soil profile (120-195 cm) did not differ significantly among vegetative covers in January and February 1985 (Figure 10). The bare soil accumulated significantly more water in March 1985 than soils beneath shrub clusters, and this difference was apparent for the the remainder of the study. Water contents of the herb-dominated interspaces soils and the bare soil were similar in January. The bare soils began to accumulate more water than the interspaces in February. Accumulated soil water in April was significantly greater beneath the bare soil than in the herbaceous interspaces.

As a result of heavy rainfall during May, water contents in the herb-dominated interspace soils and those beneath the bared soil surfaces were similar from late May through the middle of July. The soil profile beneath the bared surface maintained greater water content than did the interspaces during the remainder of the study. Soil water content of herb-dominated interspaces were consistently, although not significantly, greater than beneath shrub cluster throughout 1985. Only 20 mm of water were added to the soil (120-195 cm) of shrub clusters during 1985. Beneath the interspaces, more than 80 mm was added, including 22 mm of water lost through deep percolation.

Sturges (1983) found that grass in areas where sagebrush had been controlled used more water from the 0 to 90 cm soil layer than did vegetation on the untreated sagebrush area. However, the sagebrush used more water than did the grass from in the total soil profile (0-180 cm). Johnston (1970) reported that aspen (in Utah) extracted water from the soil to a depth of 3 m, while the herbaceous-covered area extracted water to a depth of only 1.2 m, and from bare soil evaporation was limited to the surface 60 cm.

Literature Cited

Anonymous. 1942. Use of water by native vegetation. Calif. Dep. of Public Works, Division of Water Resour. Bull. 50.

Archer, S., and C.J. Scifres. 1986. Autogenic succession in a subtropical thronwoodland, Texas: Implications for the conversion of grasslands to shrublands. (In press).

Blackburn, W.H. 1975. Factors influencing infiltration and sediment production of semiarid rangelands in Nevada. Water Resour. Res. 11:929-937.

Blake, G.R. 1965. Bulk density. p. 374-392. In: C.A. Black (ed), Methods of Soil Analysis. Amer. Soc. of Agron. Agron. Ser. No. 9.

Bosch, J.H., and J.D. Hewlett. 1982. A review of catchment experiments to determine the effect of vegetation changes and water yield and evapotranspiration. J. Hydrology. 55:3-23.

Bouyoucos, C.J. 1962. Hydrometer method improved for making particle size analysis of soil. Agron. J. 54:464-465.

Broadbent, F.E. 1965. Organic matter. p. 1397-1400. In: C.A. Black (ed), Methods of Soil Analysis. Amer. Soc. Agron. Ser. No. 9.

Bryant, F.C., and M.M. Kothmann. 1979. Variability in predicting edible browse from crown volume. J. Range Manage. 32:144-146.

Burgy, R.H., and C.R. Pomeroy. 1958. Interception losses in grassy vegetation. Trans. Amer. Geophys. Union. 39:1095-1100.

Campbell, G.S. 1974. A simple method for determining unsaturated conductivity from moisture retention data. Soil Sci. 117:311-314.

Corbett, E.S., and R.P. Crouse. 1968. Rainfall interception by annual grass and chaparral . . . Losses compared. USDA, For. Ser. Res. Paper PSW-48. Pacific Southwest For. and Range Exp. Sta., Berkely, CA.

Dugas, W.A. Jr., and C.G. Ainsworth. 1983. Agroclimatic Atlas of Texas. Part 6. Potential Evapotranspiration. Texas Agr. Exp. Sta. Pub. MP 1543, College Station, TX.

Ganskopp, D., and R. Miller. 1986. Estimating leaf area of big sagebrush from measurement of sapwood. J. Range Manage. 39:338-340.

Gatewood, J.S., T.W. Robinson, B.R. Colby, J.D. Helm, and L.C. Halpenny. 1950. Use of water by bottom-land vegetation in the lower Safford Valley of Arizona. U.S. Geol. Surv. Water Supply Pap. 1103.

Gee, G.W. and R.R. Kirkham. 1984. Transport assessment--Arid: Measurement and prediction of water movement below the root zone. Presented at the sixth Annual DOE LLWMP, Participants information meeting, Denver, CO. September 11-13.

Gifford, G.F. 1975. Approximate annual water budget of two chained pinyon-juniper sites. J. Range Manage. 28:73-74.

Glover, P.E., J. Glover and M.D. Gwynne. 1962. Light rainfall and plant survival in east Africa. II. Dry grassland vegetation. J. Ecol. 50:199-206.

Goff, B.F., J.J. Stone, and K.K. Simaton. 1985. Leaf area and dry matter relationships of several grass and shrub species of the southwest. Presented at 38th Annual Meeting Soc. for Range Manage. February 11-15, Salt Lake City, UT.

Gwynne, M.D. 1966. Plant Physiology and the future, p. 59-64. In: W. Davis and C.L. Skidmore (ed), Tropical Pastures. Faber and Faber. London.

Hamilton, E.L. and P.B. Rowe. 1949. Rainfall interception by chaparral in California. USDA For. Ser. In cooperation with Calif. Dep. of Nat. Res., Div. of For.

Hoffman, G.O. 1972. Texas Persimmon. A pesky problem. Texas Agr. Prog. 18:8-9.

Johnston, R.S. 1970. Evapotranspiration from bare, herbaceous, and Aspen plots. A check on a former study. Water Res. 6:324-327.

Kaufmann, M.R. and C.A. Troendle. 1982. The relationship of leaf area and foliage biomass to sapwood. For. Sci. 27:477-486.

Kirmse, R.D. and B.E. Norton. 1985. Comparison of the reference unit method and dimensional analysis methods for two large shrubby species in the Caatinga woodlands. J. Range Manage. 38:425-427.

Knight, R.W., W.H. Blackburn and C.J. Scifres. 1983 A. Infiltration rates and sediment production following herbicide/fire brush treatment. J. Range Manage. 38:283-287.

Knight, R.W., W.H. Blackburn, and L.B. Merrill. 1983 B. Characteristics of oak mottes, Edwards Plateau, Texas. J. Range Manage. 37:534-537.

Klute, A.L. 1965 A. Laboratory measurement of hydraulic conductivity of saturated soils. p. 210-221. In: C.A. Black (ed), Methods of Soil Analysis. Amer. Soc. of Agron. Ser. No. 9.

Klute, A.L. 1965 B. Water diffusivity. p. 262-274. In: C.A. Black (ed), Methods of Soil Analysis. Amer. Soc. of Agron. Ser. No. 9.

Lauenroth, W.K. and P.L. Sims. 1976. Evapotranspiration form a shortgrass prairie subjected to water and nitrogen treatments. Water Resour. Res. 12:437-442.

Ludwig, J.A., J.F. Reynolds and P.D. Whitson. 1975. Size-biomass relationships of several Chihuahuan desert shrubs. Amer. Midl. Nat. 94:451-461.

Minzenmayer, F.E. 1979. Soil survey of Jim Wells County, Texas. USDA, Soil Con. Ser.

Meyer, R.E. 1974. Morphology and anatomy of Texas persimmon (Diospyros tenana scheele). Texas Ag. Ex. Sta. Bull. 1147. College Station, TX.

Meyer, R.E., H.L. Morton, R.H. Haas, E.D. Robison and T.E. Riley. 1971. Morphology and anatomy of honey mesquite. USDA, Ag. Res. Ser. Tech. Bull. No. 1423.

Mooney, H.A., B.B. Simpson, and O.T. Solbrig. 1977. p. 26-44. In: B.B. Simpson (ed), Mesquite its biology in two ecosystems. Dowden, Hutchinson and Ross Inc. Stroudsburg, PA.

Orton, R.B. 1969. The Climate of Texas. p. 871-891. In: Climate of the States, volume II - Western States including Alaska and Hawaii. Water Information Center, Inc., Port Washington, NY.

Osborn, B. 1954. Soil splash by raindrop impact on bare soil J. Soil and Water Conserv. 9:33-49.

Peacock, J.T. and C. McMillan. 1965. Ecotypic differentiation in Prosopis (mesquite). Ecol. 46:35-51.

Richardson, C.W., E. Burnett and R.W. Bovey. 1979. Hydrologic effect of brush control on Texas rangelands. Amer. Soc. Ag. Eng. Trans. 22:315-319.

Rowe, R.B. and L.F. Reimann. 1961. Water use by native brush, grass, and grass-forb vegetation. J. For. 17:175-181.

SAS. 1982. SAS Users Guide: Basics. SAS Institute, Inc. Cary, NC.

Soil Conservation Service. 1972. National engineering handbook. Sec. 4, Hydrology, Washington, DC.

Solbrig, O.T., K. Bawa, N.J. Carmon J.H. Hunziker, C.A. Naranjio, R.A. Palacios, L. Poggio and B.B. Simpson. 1977. p. 44-61. In: B.B. Simpson (ed), Mesquite its biology in two desert ecosystems. Dowden, Hutchinson and Ross Inc., Stroudsburg, PA.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics a Biometeric Approach. McGraw-Hill Book Co., New York, NY.

Sturges, D.L. 1983. Long-term effect of big sagebrush control on vegetation and soil water. J. Range Manage. 36:760-765.

Tomble, J.M. 1977. Water requirements for mesquite (Prosopis juliflora). J. Hydrol. 34:171-179.

USDA. 1975. Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys. USDA. Handbook 436.

Wendt, C.W., J.R. Runkles and R.H. Hass. 1967 A. The measurement of water lost by mesquite (Prosopis glandulosa var. glandulosa) using thermoelectric methods. Soil Sci. Soc. Amer. Proc. 31:161-164.

Wight, J.R., C.L. Hanson, and K.R. Cooley. 1986. Modeling evapotranspiration from sagebrush-grass rangeland J. Range Manage. 39:81-85.

Wishmeier, W.H. and D.D. Smith. 1978. Predicting rainfall erosion losses. USDA. Ag. Handbk. 537.

Young, J.A., R.A. Evans and D.A. Eash. 1984. Stemflow on western juniper (Juniperus occidentalis) trees. Weed Sci. 32:320-327

TEXAS AGRICULTURAL EXPERIMENT STATION - UVALDE

Lyles Ranch Study Site

The Lyles Ranch is located adjacent to the Nueces River about 30 km southwest of Uvalde, in Uvalde and Zavala Counties. The gentle slopes of the study site are typical of the Rio Grande Plain land resource area. Normal precipitation for the area is 547 mm of which 60% usually falls in April through September. The heaviest 1-day rainfall on record for the area was 173 mm at Crystal City on Oct. 4, 1959. Thunderstorms occur on about 45 days each year, mostly during spring. Soils are in the Duval-Webb-Brystal map unit. Honey mesquite and blackbrush are the dominate shrubs with a sparse understory of grasses and forbs.

Annandale Ranch Study Site

The Annandale Ranch is located 32 km north of Uvalde near the Firo River and in the recharge area of the Edwards Aquifer. The study site is located in the Edwards Plateau, which is characterized by rough steep terrain. In much of the study area elevations increases 65 to 125 m within short distances. Normal precipitation for the area is 602 mm, rainfall amounts vary greatly from month to month and from year to year. Annual precipitation varies from a low of 345mm to a high of 900mm. Sixty-eight percent of the rain falls between may and October. Maximum precipitation usually falls during late spring and during September. Mean annual lake evaporation is 1778mm. The average length of the growing season is 256 days. Soils are classified as limestone rock land, which consists of exposed limestone bedrock with the ector or kavett soil series found between the exposed bedrock. The site is characterized by a dense overstory of shrubs, mostly juniper and oaks, with a sparse understory of grasses and forbs.

The influence of Vegetation Manipulation on the Water Budget - Rio Grande Plains and Edwards Plateau

W.H. Blackburn, R.W. Knight, C.A. Call, J.W. Holloway, and B.O. Spoonts

Summary and Status

The equipment to instrument the 18 watersheds, 12 weighable and 12 non-weighable lysimeters has been purchased and delivered. The nine watersheds (0.6 ha each) on the Lyles Ranch have been located, topographic map made, and the watershed boarders and down slope drains constructed. The non-weighable lysimeters have been walled to 2.5 m, drainage equipment installed and back filled. The soil monoliths for the 12 weighable lysimeters have been encased. The nine watersheds (4 ha each) on the Annandale Ranch have been located and a topographic map for six of the watersheds completed. The instrumentation of the 18 watersheds will be completed by Aug. 1987, and the 24 lysimeters will be completed by May, 1987.

Methodology

The water balance in a stand of plants and in the soil penetrated by their roots is expressed by the water balance equation as:

$$WY = P - ET \pm S$$

where: WY = water yield of surface and subsurface flows, and and percolation to groundwater
P = total precipitation
ET = evapotranspiration, including interception losses by vegetation and litter
S = change in soil water storage

Components of the water balance equation will be determined for a characteristic brush-grassland sites using instrumented watersheds, weighable and non-weighable lysimeters in conjunction with plant water relations measurements.

Twelve weighable and twelve non-weighable lysimeters in addition to nine small watersheds (0.6 ha) will be instrumented at the Lyles Ranch. Twelve mature honey mesquite trees and associated grass vegetation will be encircled in non-weighable lysimeters by trenching around a 6 by 6 m area to a depth of 2.5 m. Honey mesquite trees in six of the non-weighable lysimeters will be removed by hand slashing and the stumps treated with a herbicide to prevent resprouting but allow growth of the seeded sideoats grama. One half of the honey mesquite and one half of the honey mesquite removed lysimeters at the end of each month will have simulated rainfall applied in an amount equal to the mean five year maximum precipitation. In addition twelve weighable lysimeters will be instrumented and the following treatments, replicated three times will be applied: 1) soil sterilized with Atrazine to maintain a bare soil surface, 2) buffelgrass, 3) kleingrass, and 4) sideoats grama. Treatments (replicated three times) for the small watersheds will be: 1) undisturbed control, 2) 70% brush control with seeding of sideoats grama, and 3) 100% brush control with seeding of sideoats grama. Nine small watersheds (4ha) will be instrumented on the Annandale Ranch, and the following treatments applied: 1) undisturbed control, 2) 70% removal of brush and seeding of side oats grama, and 3) 100% removal of brush and seeding of side oats grama.

A weather station located at each site will record precipitation, wind speed, maximum and minimum atmospheric temperature, relative humidity, net radiation, vapor pressure deficit, total sunlight, and soil temperature at two depths. Precipitation falling on the watersheds will be measured in Forest Service type rain gauges located in a network to provide a minimum of one gauge for every 2 ha. Rainfall intensities will be obtained from recording rain gauges. Timing, rates and volumes of runoff will be measured with H-flumes equipped with FW-1 type water level recorders.

Soil water content of each watershed and lysimeter will be measured with a neutron probe. Availability of soil water will be determined by plotting soil water content against soil water potential.

Soil texture, soil structure, desorption curves, hydraulic conductivity, and bulk density will be determined for each soil horizon in the watersheds and the lysimeters. Soil texture will be determined by particle size distribution and soil structure will be determined by USDA soil taxonomy guidelines. Bulk density will be determined by a pressure plate apparatus. Hydraulic conductivity will be determined by standard methods. Total water loss from plants in the lysimeters will be determined by measuring transpiration losses and canopy and litter interception losses. Water loss per unit area of transpiring grass and shrub leaves will be measured with a steady-state porometer. Interception losses and leaf area of the shrub and grass canopy will be determined by stand and methods.

PROJECT PUBLICATIONS/PAPERS PRESENTED

Weltz, M. A. 1987. Observed and estimated (ERHYM-II model) water budget for south Texas rangelands. Ph. D. Dissertation, Texas A & M University, College Station, Tx. p 173.

Franklin, J. D. 1987. Hydrologic aspects of honey mesquite and herbaceous areas on the Rolling Plains of Texas. M.S. thesis, Texas A & M University, College Station, Tx. p 154.

Weltz, M. A., W. H. Blackburn, C. J. Scifres, and B. Kurth. 1986. Water budget for mesquite-mixed shrub mottes in south Texas. Society for Range Management 39th annual meeting abstract of papers, no. 352. Kissimmee, Fl.

Franklin, J. D., R. W. Knight, W. H. Blackburn, and R. K. Heitschmidt. 1986. Use of lysimetric methodology for measuring water use on rangelands. Society for Range Management 39th annual meeting abstract of papers, no. 140. Kissimmee, Fl.

Ansley, R. J., C. A. Call, and R. Hicks. 1987. Diurnal variation in photosynthesis and conductance within honey mesquite canopies. Society for Range Management 40th annual meeting abstract of papers, Boise Id.

Hicks, R. A., C. A. Call, and R. J. Ansley. 1987. Photosynthesis and water use efficiency of two dominant warm-season grasses in the rolling plains region of north central Texas. Society for Range Management 40th annual meeting abstract of papers, Boise Id.

Franklin, J. D. 1986. Water budget of honey mesquite and herbaceous area in the Rolling Plains of Texas. Paper presented to State Soil Conservation Service workshop, Temple, Tx.

Franklin, J. D. 1986. The influence of vegetation manipulation on the water budget. Paper presented to Area Soil Conservation Service workshop, Vernon, Tx.

Call, C. A. 1986. Water budget research on Texas rangelands. Paper presented to Utah State University Faculty, Invited seminar series.