Effect of Mesquite Trees on Vegetation and Soils in the Desert Grassland

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Highlight: Studies were conducted in the mesquite-desert grassland to assess effects of shade, roots, and litter of mesquite trees on understory vegetation and microenvironmental factors. Elimination of mesquite shade and root action increased foliar cover of understory vegetation in the canopy zone from 19% with intact mesquite to 24%. Replacement of mesquite shade with artificial shade screens further increased understory vegetative cover to 32%. Only forbs responded to elimination of mesquite roots in open areas. Vegetation responses indicated improved soil moisture in the canopy zone with both treatments, but there were no detectable soil moisture differences among treatments during the major part of the growing season. Greater vegetal cover with no-shade and artificial shade treatments was apparently associated with differential utilization of moisture compared with the mesquite shade treatment. Increased soil moisture made available by mesquite removal and in excess of that lost by evaporation was reflected in greater vegetative cover. With artificial shade, potential evaporation was similar to that for natural shade—thus increased moisture was utilized for growth of understory vegetation.

Invasion of trees and shrubs into grasslands of the Southwest typically results in reduced forage production, increased soil erosion, and greater livestock handling cost (Cable 1975; Martin 1975). Mesquite (*Prosopis juliflora* (Swartz) DC.)[1] is one of the most conspicuous of the trees and shrubs that have invaded ranges of the southwestern United States and Mexico; it now is a resident on about 8 million ha of former desert grassland range (Martin 1966).

Where mesquite has been eradicated, herbage yields have increased (Parker and Martin 1952; Cable and Tschirley 1961; Paulsen 1975), primarily in response to increased moisture availability. Because mesquite uses 2 to 3 times more water than herbaceous vegetation (McGinnies and Arnold 1939), killing mesquite trees was found to increase moisture supply and duration of its availability within several meters of killed trees (Parker and Martin 1952). Hughes (1966) found similar responses in soil moisture when mesquite was killed by root plowing or herbicides.

Despite benefits of mesquite eradication, presence of mesquite on desert grasslands may not be entirely detrimental. Areas under canopies of mesquite and other trees and shrubs often support dense stands of herbaceous vegetation (Went 1942; Cable and Tschirley 1961; Humphrey 1962; Halvorson and Patten 1975). Garcia-Moya and McKell (1970) suggested that shrubs help maintain the pool of soil nutrients in desert ecosystems by creating islands of fertility beneath canopies through accumulation of organic matter.

In 1966 we began studies to determine how mesquite trees modify the microenvironment and affect growth of herbaceous species beneath their canopies and in adjacent openings. Our purpose was to gain knowledge that would be useful to land managers in the design of practices for improving forage production. Results from some of these studies have been previously published (Tiedemann and Klemmedson 1973a and 1973b; Tiedemann et al. 1971). Purpose of the study reported here was to determine the effect of mesquite trees on soil moisture, soil temperature, and net radiation and to assess the importance of each in growth of vegetation under mesquite canopies and in adjacent open areas. In our experiment we attempted to evaluate separately three effects of mesquite trees on microenvironment: (1) shade, (2) action of roots, and (3) litter. Shade affects soil temperature, evaporation, and the amount of radiant energy impinging on understory vegetation. Mesquite roots extend downward and laterally and affect soil moisture under the canopy and in the open, thus possibly affecting herbage production of both locations. Litter beneath canopies alters physical and chemical properties of soil (Tiedemann and Klemmedson 1973a) which in turn affect soil temperature, infiltration, and evaporation from soil.

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[1] Plant nomenclature follows Kearney and Peebles (1960).

Study Area

The study area was a 20-ha upland desert grassland site (elevation 1,100 m) at the Santa Rita Experimental Range south of Tucson, Ariz., which has been protected from domestic livestock use since 1937.

Areas under mesquite canopies supported dense stands of herbaceous vegetation, mainly perennial grasses. Between mesquite canopies, soils were exposed and vegetation consisted of sparse herbs with scattered shrubs and half-shrubs.

Soils of the Comoro, Sonoita, and Continental series, derived from alluvium of basic and acidic igneous rocks, are coarse, deep, and well drained. The Comoro series is a member of the coarse-loamy, mixed, thermic family of Cumulic Haplustolls. The Sonoita series is a member of the fine-loamy, mixed, thermic family of typic Haplargids. The Continental series is of the fine, mixed, thermic family of typic Haplargids.

Mesquite is the dominant overstory vegetation. Catclaw (*Acacia greggii* Gray), pricklypear and cholla (*Opuntia* spp.), and barrel cactus (*Ferocactus wislizeni* (Engelm.) Britt. and Rose) are important subdominants. Important half-shrubs include: burroweed (*Aplopappus tenuisectus* (Greene) Blake) and zinnia (*Zinnia pumila* Gray). Arizona cottontop (*Trichachne californica* (Benth.) Chase), bush muhly (*Muhlenbergia porteri* Scribn.), plains bristlegrass (*Setaria macrostachya* H.B.K.), and black grama (*Bouteloua eriopoda* Torr.) are major perennial grasses. Forbs commonly encountered include spiderling (*Boerhaavia* spp.), trailing four-o'clock (*Allionia incarnata* L.), portulaca (*Portulaca* spp.), and globemallow (*Sphaeralcea* spp.). Needle grama (*Bouteloua aristidoides* H.B.K.) is the predominant annual grass.

Mean annual precipitation is 33 cm, with 40% or more occurring in July and August (Sellers 1960). Summer temperatures are moderate; they exceed 38°C on only 1 or 2 days. Maxima of 21°C occur in all winter months; frost occurs on an average of 25 days per year.

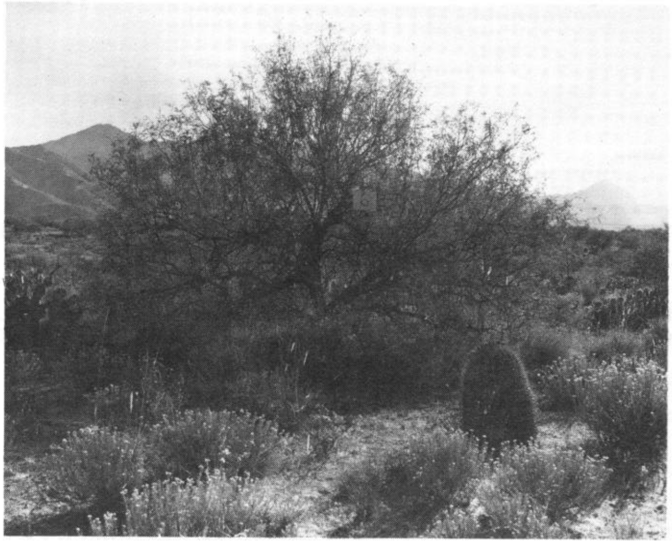
Methods

Our rationale for choosing treatments was to selectively eliminate shade, root action, and litter of mesquite so we could assess the effect of each of these on herbaceous understory vegetation, soil moisture, soil temperature, and net radiation. We selected 24 uniform mesquite trees isolated at least 30 m from other mesquite trees, and randomly applied four replications of three shade and two mulch treatments. We did not attempt to block the area for soil variations—emphasis was placed on obtaining isolated trees with similar stature. Shade treatments were mesquite shade, artificial shade, and no shade (Table 1).

Undisturbed mesquite trees served as the mesquite shade treatment (Fig. 1). The artificial shade treatment was established by cutting mesquite trees at the base and substituting artificial shade (Fig. 1). Stumps were treated with diesel oil to kill root crowns. Structures supporting saran shade cloth 3.7 × 3.7 m were centered over the cut stumps at a height of 1.2 m. These structures provided a reduction in light intensity of 55%—the approximate amount of shade actually provided when mesquite trees are in full leaf. Light quality under saran shade screen is similar to that under oak and maple trees (Gastin 1965). For the no-shade treatment, trees were cut and killed, but the area was left unshaded.

Table 1. Changes in shade and root action effected by treatments applied to mesquite trees.

	Location	
Treatment	Canopy zone	Open zone
Mesquite shade	Live shade Live roots	Live roots
Artificial shade	Artificial shade Dead roots	Dead roots
No shade	No shade Dead roots	Dead roots



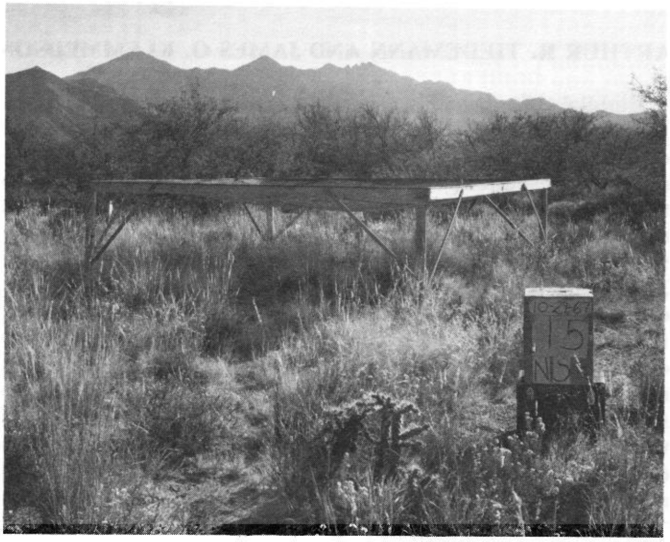


Fig. 1. *Mesquite (upper) and artificial (lower) shade treatments.*

To determine the effect of mesquite litter on microenvironmental conditions and understory vegetation, natural litter was removed from half of the plots of each shade treatment. All accumulated litter was collected on three 0.3- × 0.9-m plots radiating from the base of trees in north and south directions. Samples were washed to remove soil, ovendried at 70°C, and weighed.

Vegetation cover and biomass were measured prior to treatment of mesquite trees to assess pretreatment uniformity of understory vegetation. Under mesquite where vegetation appeared relatively uniform, we used a 2.4- × 0.6-m transect, whereas in open areas where vegetation was sparse we used a 4.8- × 0.3-m transect. Four permanent transects were established under each mesquite canopy, radiating from the base of trees in each cardinal direction. Four transects in the open zone were established 6 m from the base of each tree at right angles to transects established under the tree. Foliar cover of each species was measured as a vertical projection of the foliage onto the ground surface using a 0.3 m^2 frame for reference. Perennial grasses were clipped 5 cm above the surface and dried at 55°C for 48 hours to estimate biomass. Vegetation was grouped into perennial grasses, annual grasses, half-shrubs, shrubs, and forbs for analysis of differences in foliar cover. Measurements were repeated in September 1967.

Table 2. Percent cover response of five classes of vegetation to shade treatments.

Class of vegetation	Canopy zone			Open zone		
	Mesquite shade	No shade	Artificial shade	Mesquite shade	No shade	Artificial shade
Perennial grasses	16.0 A[1]	16.2 A	23.4 B	3.9 a	5.8 a	5.6 a
Shrubs	0.3 A	1.1 A	0.1 A	1.6 a	1.2 a	0.8 a
Half-shrubs	1.1 A	1.0 A	0.5 A	4.2 a	5.7 a	5.1 a
Forbs	0.8 B	3.9 A	5.5 A	0.9 b	3.7 a	2.5 a
Annual grasses	0.6 A	2.2 A	2.4 A	3.9 a	4.4 a	4.3 a
Total	18.8 A	24.4 B	31.9 C	14.5 a	20.8 a	18.3 a

[1] Capital letters designate comparison among treatments in the canopy zone. Lower case are for open zone comparisons. Values in the same line with different letters aresignificantly different at $P = 0.05$.

Soil moisture was measured gravimetrically from the surface to 15 cm depth and by neutron thermalization from 0.3 to 1.5 m. Access tubes for the latter were installed 1.4 and 6.0 m due north and south from the base of trees. Gravimetric samples were collected within an 80-cm radius of access tubes 24 hours after each rainfall event. Subsequent samples were collected at intervals of 3 to 5 days in the summer and 1 to 3 weeks during the rest of the year. Soil moisture between 0.3 and 1.5 m was measured at 5- to 6-week intervals using a nuclear depth-moisture probe and scaler.

Soil temperature was measured between 10 A.M. and 4 P.M. every 4 to 6 weeks from May 1967 through January 1968 using copper-constantan thermocouples coated with epoxy resin installed permanently in undisturbed soil at depths of 2.5, 7.5, 15, and 30 cm. Temperature profiles were located at north and south sides of the canopy and open zones. Temperature was measured on each shade and litter treatment replication within a 1.5-hour period—thus requiring 6 hours to measure the four replications. The same sequence was used within and among replications each time to avoid confounding diurnal temperature fluctuations with treatments.

Differences in net radiation among treatments were evaluated from measurements taken in canopy and open zones with a Thornthwaite[2] net radiometer on a clear day in August. Air temperature and precipitation were recorded with hygrothermographs and 20-cm recording rain gages.

Design of the study was completely random for the factorial combination of three shade and two litter treatments over four replications. Sample locations (open zone or canopy zone) and side of plot were treated as subplots in a split-plot analysis. Effect of shade and litter treatments on vegetation, soil moisture, and soil temperature was evaluated using analysis of variance.

Results and Discussion

Pretreatment Vegetation Status

Prior to treatment, cover of perennial grasses under mesquite was 24% compared with 4% in the open. Cover of half-shrubs under mesquite was less than 2% compared with 8% in the open. These differences between locations were highly significant. Total cover of understory vegetation was significantly greater ($P = 0.01$) under mesquite than in the open (27% vs 14%). Shrubs and forbs did not occur on enough plots to merit statistical analysis and annual grasses had disappeared by the harvesting date.

Cover of perennial grasses on north and east quadrants under mesquite trees was 28 and 30%, respectively. The values were significantly higher ($P = 0.01$) than those for the south and west quadrants (19 and 20%, respectively). Differences among sides of the trees cannot be attributed to any single species; Arizona cottontop was the only species occurring on enough plots for a valid statistical analysis, and differences among quadrants were not significant.

Pretreatment tests for uniformity showed there were no significant differences between shade and litter treatments for crown cover of perennial grasses, half-shrubs, and total vegetation. Thus, adjustment of treatment effects for pretreatment differences was not necessary.

Perennial grass biomass was 1,146 and 239 kg/ha in canopy and open zones, respectively. Arizona cottontop accounted for about half of this biomass (665 and 120 kg/ha, respectively). Differences between canopy and open zones were highly significant for both Arizona cottontop and total perennial grasses. These results support observations alluded to earlier concerning distribution of vegetation relative to shrub and tree cover.

Biomass of perennial grasses under mesquite canopies prior to treatment (1,146 kg/ha) approached the maximum production recorded by Parker and Martin (1952) for desert grassland range (1,292 kg/ha) when all mesquite is killed. However, because Arizona cottontop and bush muhly have culms which live for more than one year (Cable 1971), and because the area had been protected from grazing for 30 years, post-treatment measurements were probably a better indicator of yearly production capability of areas under mesquite canopies.

Litter

Litter under mesquite was greater on the north side of trees (2,150 kg/ha) than on the south (1,300 kg/ha) and greatest near the trunk. Within 1.8 m of mesquite trunks, litter weights on north and south sides of trees were not greatly different (750 vs 540 kg/ha). However, in the 1.8- to 2.7-m interval from trunks, dry weight of litter differed greatly between north and south sides (650 vs 220 kg/ha). Prevailing southeasterly winds and higher temperatures more favorable for decomposition may impede accumulation of litter on the south side of mesquite trees.

Vegetal Response to Treatments

Perennial grasses and forbs were the only classes of vegetation affected by shade treatments and only annual grasses were influenced by litter. In the canopy zone, cover of perennial grass was the same for mesquite shade and no-shade treatments (16.0 and 16.2%, respectively) but significantly higher for artificial shade (23.4%) (Table 2). The killing of mesquite roots had no significant effect on cover of perennial grasses in the open zone. Response of perennial grasses in the canopy zone to elimination of mesquite competition is apparently hindered by the harsher microenvironment created when natural shade is removed. The

[2] Mention of a product by name is not an endorsement of that product by the U.S. Dep. Agr.

perennial grasses may have been stressed physiologically because of sudden changes in radiative input and soil temperature when the overstory mesquite was removed. This interpretation is suggested by the marked response in cover and biomass of perennials with the artificial shade treatment. Differences in cover of perennial grasses between shade treatments could not be attributed to any single species and apparently showed the combined response of all perennial grass species.

Cover for forbs in the canopy zone with no shade and artificial shade was significantly greater (3.9 and 5.5%, respectively) than with mesquite shade (0.8%). In the open zone, cover of forbs increased significantly when mesquite root action was eliminated. Two responses of forbs merit emphasis. First, forbs responded significantly to elimination of shade and root action of mesquite (i.e. mesquite shade vs no shade), whereas perennial grass did not. Artificial shade was needed for a response from perennial grasses. Thus, forbs appear to be less sensitive than grasses to the harsher microenvironment created with the no-shade treatment. Secondly, response of forbs in the open zone suggests an improvement in soil moisture as a result of killing the mesquite and eliminating lateral roots.

Treatments that provided shade and eliminated mesquite roots had no effect on half-shrubs or annual grasses in either location, and shrubs occurred on too few plots for a valid test. Trend of the annual grass response to treatment in the canopy zone was similar to that of forbs (Table 2). Average cover of annual grasses in the open zone was 4.1% compared with 1.7% in the canopy zone. This difference was highly significant.

In the canopy zone, cover of total vegetation reflected the response of perennial grasses and forbs to shade treatments. Cover increased significantly (P = 0.05) from 18.8% with mesquite shade to 24.4% with no shade and 31.9% with artificial shade. However, neither treatment had an effect on cover of total vegetation in the open zone. Response of total vegetation in the canopy zone suggests that removal of competition by mesquite roots benefitted vegetation directly beneath the canopy, but this was partially offset by the harsher microenvironment created when the mesquite crown was removed. When shade was replaced (artificial shade treatment), the microenvironment was less severe and growth of understory vegetation was further enhanced.

Annual grass was the only vegetation that was affected by litter. Cover in the canopy zone with litter was 2% compared with 1% without, a significant difference (P = 0.10). Removal of litter to establish the no-litter treatment may have removed some annual grass seed. This may account for greater cover of annual grass in the open zone than in the canopy zone.

Shade treatments affected biomass of perennial grasses as they affected cover. Production of perennial grasses in the canopy zone was 10 times greater (P = 0.01) than in the open zone (672 kg/ha vs 64 kg/ha).

Biomass of perennial grasses in the canopy zone was significantly greater (P = 0.05) with artificial shade (908 kg/ha) than with mesquite shade (516 kg/ha) or no shade (626 kg/ha). Only Arizona cottontop showed a difference (P = 0.05) in biomass among shade treatments: it produced 313 kg/ha more herbage under artificial shade than with mesquite shade, but there was no significant difference for any other shade treatment comparison. Neither shade nor litter treatments affected perennial grass biomass in the open zone.

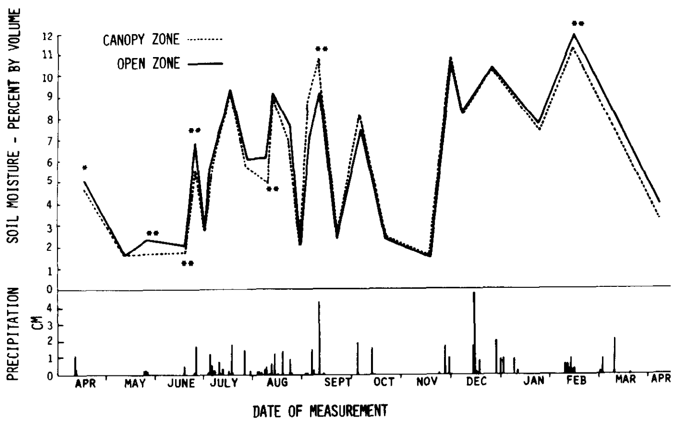


Fig. 2. *Soil moisture fluctuations in the surface 15 cm in the canopy and open zones (average of shade treatments). Soil moisture is significantly different between zones at the 5% level on dates with a single asterisk and at the 1% level with double asterisks.*

Soil Moisture

During the study, soil moisture in the surface 15 cm fluctuated between 1.5 and 11.6% (Fig. 2). Using 4.6% as the lower limit of available moisture (Cable 1966), there was available moisture for plant growth on 16 of 28 sampling dates. In summer and fall when plants grew actively, available moisture was depleted within 7 to 10 days of replenishment. Rate of depletion was so slow during late fall and winter that soil moisture was continuously available from December 1967 to March 1968.

There were only seven dates when soil moisture differed significantly between canopy and open zones (Fig. 2). On six of those dates, moisture was higher in the open zone. Lower soil moisture in the canopy zone probably resulted from interception of precipitation by mesquite trees, shade structures, and understory vegetation, and greater use of moisture by understory vegetation.

We detected no difference in soil moisture among treatments in the open zone. This is contrary to the results of Parker and Martin (1952), who found significant increases in soil moisture at distances of 6 m from the base of killed mesquite trees compared with live mesquite trees. In our study, lateral roots of nearby mesquite may have confounded treatment effects in the open zone.

There were significant differences in soil moisture among shade treatments in the canopy zone on nine dates (Table 3). On eight of these dates, soil moisture was higher with artificial shade than with mesquite shade or no shade. Soil moisture differences between mesquite shade and no shade showed no consistent pattern.

Soil moisture did not differ among shade treatments in the canopy zone during the major summer growing season (mid-July through mid-September). Thus, effect of low humidity and high air temperature on evaporation rate was probably too great to be offset by mesquite or artificial shade. This agrees with Shreve's (1931) conclusion that the sparse shade of *Parkinsonia,* a tree similar to mesquite, was not sufficient to reduce the evaporative power of the air during the summer.

Soil moisture in the surface 15 cm was significantly greater (P = 0.05) with litter than without litter on 5 of 28 individual dates and significantly greater (P = 0.10) for five additional dates. Because the above differences occurred immediately following rains and at times when soil moisture was very low, litter apparently affected both infiltration and evaporation.

Table 3. Soil moisture (percent by volume) in the surface 15 cm of the canopy zone for three shade treatments.

Date	Mesquite shade	No shade	Artificial shade	F-test among treatments
4-17-67	4.8	4.4	4.5	
5-11-67	1.6	1.3	1.8	*
5-26-67	1.5	1.8	1.4	*
6-20-67	1.5	1.8	1.8	
6-27-67	5.2	5.5	5.7	
7-01-67	2.3	2.7	3.1	
7-05-67	4.5	5.8	5.5	
7-08-67	5.3	6.6	6.6	**
7-10-67	6.3	7.3	7.9	*
7-18-67	9.0	9.3	9.2	
7-28-67	5.5	5.6	6.0	
8-10-67	4.6	5.3	4.8	
8-14-67	8.0	8.6	9.6	
8-24-67	7.0	6.1	7.4	
8-31-67	2.1	1.9	2.0	
9-06-67	8.7	7.8	9.1	
9-12-67	10.9	9.6	11.1	
9-23-67	2.4	2.0	2.7	**
10-07-67	7.1	7.7	9.2	**
10-22-67	2.0	2.1	3.0	**
11-18-67	1.4	1.3	1.8	
12-02-67	10.2	9.8	10.8	
12-09-67	7.1	8.1	8.7	**
12-27-67	10.2	9.6	10.2	
1-25-68	6.5	7.8	7.4	
2-17-68	10.9	10.4	11.1	
3-22-68	6.4	6.3	7.0	*
4-09-68	2.9	3.1	3.4	
Average	5.6	5.7	6.2	

*Significant at $P = 0.05$.
**Significant at $P = 0.01$.

North sides of the canopy zone had greater soil moisture than south sides ($P = 0.05$) in the surface 15 cm on eight dates. These differences became pronounced in early fall, thus supporting the conclusion that shade during summer is not sufficient to reduce evaporation.

Soil moisture between 0.3- and 1.5-m depths remained constant from March through July (Fig. 3). In August, soil moisture increased throughout the entire profile, but the change was greatest in the upper 0.9 m and coincided with summer rains. By November, soil moisture was depleted to early summer levels—6.4 cm of moisture in the entire 1.5-m profile. Rains in December doubled this value and caused a further increase in January.

Soil moisture between 0.3 and 1.5 m depths did not differ among shade and litter treatments at any sampling depth or date. Soil moisture was slightly higher in the canopy zone than open zone, but differences were significant only at 0.6 m for three sampling dates.

Soil Temperature

Soil temperatures at the 2.5- and 7.5-cm depths rose sharply from May to a peak in June in both canopy and open zones, regardless of treatment, then declined sharply in July at the 2.5-cm depth coincident with summer rainfall (Fig. 4). Except for the artificial shade treatment, this was followed by a second temperature peak in August.

At 15 and 30 cm, temperature fluctuated less than at the 2.5-cm depth, and the maximum temperature occurred in July. The second peak temperature observed in August at 2.5 cm was not transmitted to the 15- and 30-cm depths.

Temperatures at 2.5 and 7.5 cm were significantly higher ($P = 0.01$) in the open than in the canopy zone (average of treat-

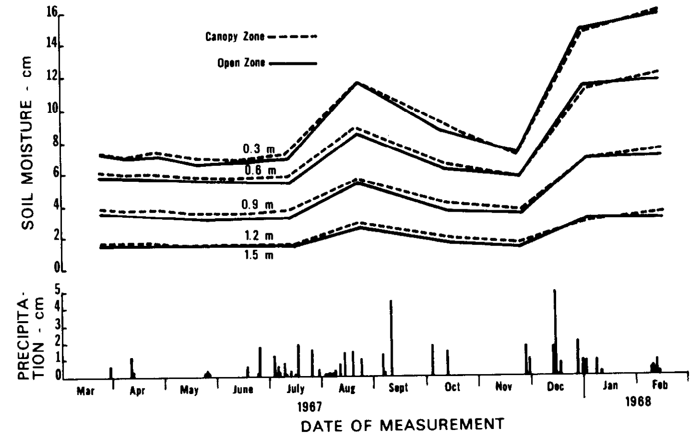


Fig. 3. *Soil moisture trends from 0.3 to 1.5 m for areas in open and canopy zones.*

ments) on all dates sampled. At 15 cm, temperature in the open zone was significantly higher ($P = 0.01$) than in the canopy zone from May through October. At 30 cm, temperature differences between locations narrowed considerably but were still significantly higher ($P = 0.01$) in the open zone from May through September and November and higher at $P = 0.05$ in October.

Soil temperatures did not differ among treatments in the open zone. This is reasonable; shade treatments had no significant effect on soil moisture and affected only crown cover of forbs in that location.

In the canopy zone, mesquite and artificial shade treatments reduced soil temperature at the 2.5-cm depth by 4 and 6°C, respectively, compared with the no-shade treatment. At 30 cm, the difference between the two shaded treatments and no shade had narrowed to 1°C.

Differences in soil temperature among shade treatments were significant ($P = 0.05$) from June through September at all depths. For these dates, soil temperatures of the no-shade treatments were significantly higher ($P = 0.05$) than those for mesquite shade and artificial shade; no differences occurred between the latter treatments. Temperature differences among the three shade treatments disappeared in November and January for all depths.

Differences in temperature among shade treatments are indicative of overstory shade effect on radiative flux at the soil surface. Both natural and artificial shade reduced net radiation by about one-half (Table 4). Vegetative cover usually causes soil temperature to decline in spring and summer and to rise in winter compared to bare areas. We did not observe an increase in winter temperature. Shade of mesquite stems, branches, and understory vegetation in winter is probably too sparse to appreciably affect re-radiation from soil. Even artificial shade did not cause an increase in winter soil temperature.

Comparisons of soil temperature between canopy and open zones for the no-shade treatment provides a means of assessing

Table 4. Net radiation (langleys/min) between 10 A.M. and 3 P.M. on August 28, 1967, for shade and litter treatments.

	Litter		No litter	
Treatment	Open zone	Canopy zone	Open zone	Canopy zone
Mesquite shade	0.49	0.20	0.53	0.22
No shade	0.53	0.54	0.51	0.50
Artificial shade	0.48	0.24	0.54	0.26

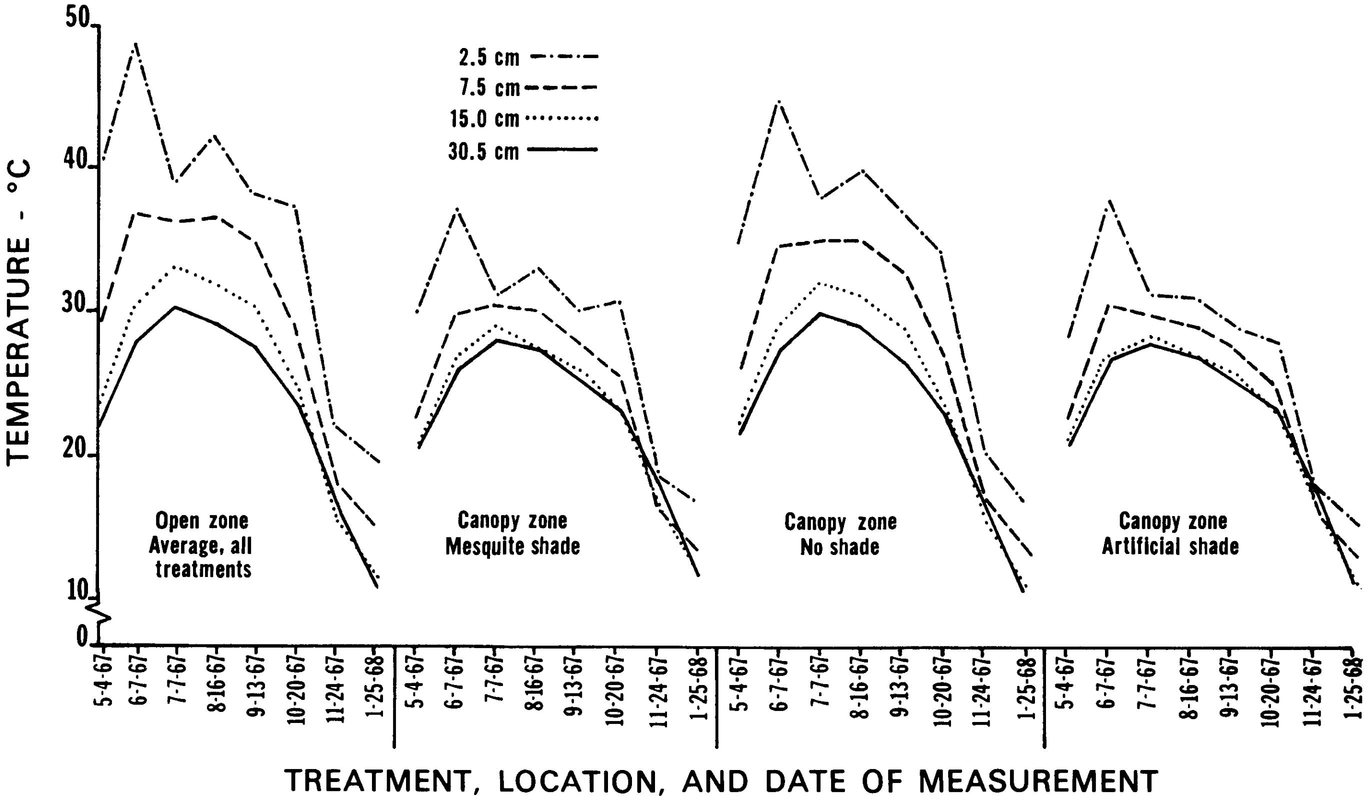


Fig. 4. *Soil temperature variation for areas in the open zone and for three shade treatments in the canopy zone.*

the influence of understory vegetation and soil organic matter on soil temperature (Fig. 4). Average differences of 2.2°C and maximum differences of 4.4°C in soil temperature at 2.5 cm depth between canopy and open zones are probably closely associated with vegetal cover and soil organic matter differences between the two areas (Tiedemann and Klemmedson 1973a). Julander (1945) stressed the importance of understory cover in moderating soil temperatures. He associated increases in temperature of 14°C at 2.5 cm and 3°C at 20 cm with a reduction in understory cover from 65% to 6% in desert grassland. Julander did not try to evaluate the effect of litter and soil organic matter differences, which surely existed with such a great difference in vegetal cover.

Average soil temperature was greater on the south side of the canopy zone than on the north from September through January at 2.5- and 7.5-cm depths. Differences between north and south sides ranged from 1.8°C to 5.6°C at 2.5 cm and from 1.3°C to 3.6°C at 7.5 cm. Temperature differences between north and south sides of the canopy zone narrowed at 30 cm but were significant in all months except July. Soil temperature on the north was lower than on the south by 0.3 to 2.1°C. Duncan's test showed mesquite and artificial shade treatments accounted for most of the difference in soil temperature between sides of the canopy zone.

Lower soil temperatures on the north side of the canopy zone were probably the combined result of: (1) more litter and understory vegetation, (2) higher soil moisture, and (3) the low angle of the sun in fall and winter.

Litter had a negligible effect on soil temperature—the difference due to litter being significant on only one date. Thus, shade from overstory and understory vegetation and changes in specific heat of soil associated with organic matter differences were the key factors influencing soil temperature.

Interpretation of Combined Effects

Mesquite trees exerted a strong influence on net radiation and soil temperature in the area directly beneath the canopy. This improved conditions for establishment and growth of vegetation compared to surrounding open areas. This study did not convincingly explain why perennial grasses are more abundant under mesquite than in open areas. However, our observations do show the degree to which mesquite canopies moderate their microenvironment and the magnitude of change that occurs when the canopy is removed.

Although we did not demonstrate a marked changed in soil moisture status by eliminating mesquite (i.e. mesquite shade vs no shade comparison), there are good reasons for this. Eradication of mesquite does not eliminate the use of water that mesquite roots had been absorbing: it merely results in a shift in relative moisture use. The available soil moisture under a mesquite tree is allocated to transpiration by mesquite and understory vegetation, and loss by evaporation. When we eliminated moisture use by mesquite and removed its canopy (no-shade treatment), understory vegetation increased significantly in abundance and in turn used soil moisture formerly used by mesquite. Using Dalton's formula (Geiger 1965), the estimated May through October potential evaporation of the no-shade treatment was 124×10^5 kg/ha compared to only 82×10^5 kg/ha for the intact mesquite. Thus, the gain in moisture from removal of mesquite appears to have been more than offset by increased herbage growth and the harsher environment of the unshaded canopy zone.

With restoration of artificial shade, further shifts in moisture use occurred. Evaporational loss was much reduced (potential evaporation = 73×10^5 kg/ha) because of shading, but moisture use by the more abundant understory vegetation was increased. We estimate from our biomass data and water requirement data (McGinnies and Arnold 1939) that moisture use by perennial grasses increased from 26×10^4 kg/ha with mesquite shade to 45×10^4 kg/ha for artificial shade. This additional moisture available for growth of understory vegetation is approximately 7% of the May-October precipitation.

We had only one indication of improved moisture availability in open areas after mesquite removal. That was the response of forbs in the open zone. This is in contrast to findings of Parker and Martin (1952). They found significant increases in soil moisture beyond mesquite canopies after killing the mesquite trees—and increased moisture was found in subsoils (30–46 cm) where we noted no increase in soil moisture. One important difference distinguished their study from ours. Individual mesquite trees were isolated by trenching; our trees were not trenched. We believe the open space between trees in fairly dense stands is probably occupied by roots of several trees. Hence, the effect of treating one individual tree without isolating other trees may exert only a small influence on moisture in soil of the open areas.

Our results do not show the long-term response of these treatments. This would be desirable to determine the relative importance of physiological stress and evaporational loss of moisture on the response of understory vegetation in the no-shade treatment (compared with artificial shade). Information on the longevity of herbage yield response obtained in this study also would be useful to land managers contemplating mesquite removal programs.

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THESIS: TEXAS A&M UNIVERSITY

Correlation of Net Aerial Primary Production with Selected Environmental Parameters in *Andropogon-Paspalum* Grassland Ecosystem, by Carlton Moss Britton, PhD, Range Science. 1975.

Net aerial primary production in relation to selected environmental parameters was evaluated in an *Andropogon-Paspalum* grassland ecosystem of east-central Texas. Production was estimated by harvesting three compartments of the aerial biomass during the growing seasons of 1973 and 1974. The compartments were ground litter, standing litter, and green biomass. Green biomass was separated by species and species groups. Production also was estimated by harvesting regrowth that occurred after the initial harvests. Harvest dates were determined by major phenologic events within the ecosystem. These events occurred 3 weeks earlier in 1974 than in 1973.

Environmental parameters, correlated with production over both growing seasons, were similar in magnitude for equivalent harvest intervals, except for precipitation and available soil water. Changes in increments of production followed a monomodal pattern similar to that of air temperature, soil temperature, and photosynthetically active radiation. Deviation from this monomodal pattern were related to changes in available soil water and soil water deficit.

Total production in 1973 (ca. 400 g/m^2) was approximately 100 g/m^2 higher than in 1974. This difference was due to the drier conditions during early spring growth and a 4 weeks longer summer dry period.

Energy values of species and species groups were generally higher during the dry year (1974), while energy values of standing litter and ground litter were lower than in 1973. Relative changes within a growing season for species and species groups followed a trend of high values during initial growth stages and flowering and low values at other stages. This trend was inverse to ash content of the plant material.

The photosynthetically active portion of shortwave irradiance increased as shortwave irradiance decreased, usually due to cloudiness. This occurrence was more evident during long photoperiod days (April 21–August 21) than short photoperiod days (October 21–February 21). Based on measurements of photosynthetically active radiation, energy values, and production, the conversion efficiency was 0.34% in 1973 and 0.23% in 1974. The highest conversion efficiencies for any harvest interval were 0.87% and 0.59% in early June 1973 and 1974, respectively.