Herbage response following control of honey mesquite within single tree lysimeters

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Abstract

Justification for controlling honey mesquite *(Prosopis glandulosa* Torr. var. *glandulosa)* on rangelands has been traditionally related to enhanced livestock production from increased herbage production. More recently, however, it has been hypothesized that control would also increase off-site water yield. The objective of this 3-year study was to quantify the effects of control of individual honey mesquite trees inside nonweighable lysimeters on herbage standing crop, leaf area, and aboveground production. Utilizing frequent harvest techniques, estimated aboveground net primary production (ANPP) in intact tree lysimeters averaged 235 g/m². Estimated ANPP in the treated lysimeters averaged 349 g/m². The increased ANPP, following removal of the trees, resulted in significantly greater amounts of herbaceous leaf area and standing crop. The increase in ANPP was relatively uniform regardless of distance from the trunk of removed trees and was the result of increased production by those herbage species present at time of control rather than a shift in species composition. The dominant species in both treatments was Texas wintergrass (*Stipa leucothrica* Trin. & Rupr.). Sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.] was a subdominant. The results, in combination with concurrent water yield studies, suggest control of honey mesquite will not enhance water yields dramatically in this region in the absence of livestock grazing.

Key Words: aboveground net primary production, Texas wintergrass, sideoats grama, leaf area index

Justification for controlling honey mesquite (*Prosopis glandulosa* var. *glandulosa* Torr.) in the Rolling Plains of Texas has been related traditionally to the enhancement of livestock production as a result of increased forage production (Scifres and Polk 1974, Dahl et al. 1978, McDaniels et al. 1978, Brock et al. 1978, Scifres 1980, Jacoby et al. 1982, Bedunah and Sosebee 1984, Heitschmidt et al. 1986). However, it has been suggested recently that control of honey mesquite will also dramatically enhance off-site water yield (Griffin and McCarl 1989) primarily through increased subsurface flow. Unfortunately, this claim has been made in the absence of any definitive supportive and/or refutable data. Moreover, this claim is founded on the underlying hypothesis that water losses via evapotranspiration processes are greater in honey mesquite-dominated grasslands supporting a sparse stand of herbaceous species than a honey mesquite-free grassland dominated by a dense stand of herbaceous species.

The objective of this study was to quantify the effects of honey mesquite control on herbaceous growth dynamics and aboveground net primary production (ANPP). This study was but one of several (Carlson et al. 1990, Hicks et al. 1990, Ansley et al. 1990) designed to quantify the potential effects of honey mesquite control on water yield in the Rolling Plains.

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Materials and Methods

Study Area

The study area was the Wagon Creek Spade Ranch located (33° 20'N, 99° 14'W) on the eastern edge of the Rolling Plains in Throckmorton County. Climate is continental and semiarid. Average annual precipitation is 682 mm and bimodally distributed (Fig. 1) with peaks in May (96 mm) and September (118 mm).

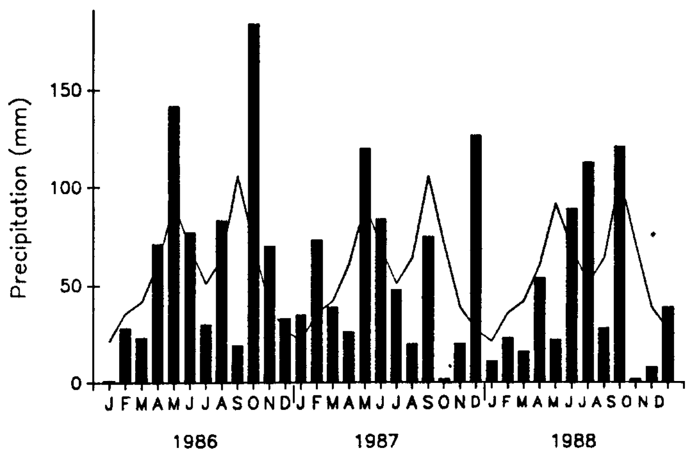

Fig. 1. Monthly precipitation (mm) during 3-year study and 28-year average (continuous line) at Texas Experimental Ranch located 1 km from study site (from Heitschmidt et al. 1985).

Average maximum daily temperatures range from 11.4° C in January to 35.8° C in July. Average minimum daily temperatures range from -2.4° C in January to 22° C in July. The average frost-free growing season is 220 days. Elevation is about 450 m.

The vegetation of the region is mixed grass prairie under an overstory of sparse to dense stands of honey mesquite. Dominant midgrasses are sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], a warm-seasonal perennial, Texas wintergrass (*Stipa leucothrica* Trin. & Rupr.), a cool-season perennial, and Japanese brome (*Bromus japonicus* Thumb.), a cool-season annual. Dominant shortgrasses are buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.] and common curlymesquite [*Hilaria berlangeri* (Steud.) Nash], both warm-season perennials. The dominant forbs are Texas broomweed [*Xanthocephalum texanum* (DC.) Shinners], a warm-season annual, and heath aster (*Aster ericoides* L.), a warm-season perennial.

The study site was located inside a 15-ha livestock exclosure of single-stemmed honey mesquite trees. Soils were Nuvalde clay loam (fine, silty, mixed thermic Typic Calciustolls), a deep, well-drained, slowly permeable soil located on gently sloping (1–3%) uplands. The silty clay loam surface is about 28 cm thick. The silty clay loam subsoil is about 56 cm thick. The underlying alluvial parent material is silty clay with 30–60% calcium carbonate. Range site classification is clay loam. For a more detailed description of the regional climate, soils and vegetation, see Heitschmidt et al. (1985).

Treatments

Six nonweighable lysimeters were installed in July 1985 around similar sized honey mesquite trees (mean trunk basal diameter = 18 cm, mean canopy area = 10 m^2). Trenches were cut around each tree to a depth of 2.5 m about 1 m beyond the drip line (mean area/lysimeter = 21.3 m^2). Trench walls were lined with impervious plastic and filled with soil. A fiberglass border was installed to channel surface flow into a runoff trough. Three of the trees were then harvested at 20 cm above the soil surface and stumps treated with 1 liter of diesel oil to prevent regrowth. The thrice replicated treatments are hereafter referred to as herbaceous (H) or herbaceous plus honey mesquite (H+M). For a more detailed description of the installed treatments, see Carlson et al. (1990).

Data Collection, Summarization, and Analyses

Herbaceous standing crop was estimated at various time intervals (Fig. 2) during the 3-year study using nondestructive point-sampling techniques and regression analyses. Number of hits per pin, 10 pins per vertical frame, was recorded by species/species group (hereafter referred to as species) and tissue (i.e., green lamina, senesced lamina, and stem) on each sample date. Sample frames were located at 0.5-m intervals along 4 permanent line transects radiating from the base (H+M treatment) or remaining stump (H treatment) of each tree to the lysimeter border (mean number of sample frames/lysimeter = 18). All plots were mowed to a height of about 5 cm in January of each year.

To establish biomass to frequency of hits and leaf area to biomass relationships, ten 0.25-m^2 quadrats were located in representative stands of vegetation outside the lysimeters a total of 10 times during 1986 and 1987. Samples were collected whenever a major change in the phenological growth pattern of the dominant species occurred. Each quadrat was sampled with 3 frames (i.e., 30 pins) prior to clipping the standing crop by species at ground level. Live and dead lamina and stem areas of hand separated subsamples were estimated using a digitized leaf area meter. All biomass was dried at 60° C to a constant weight before weighing.

Various linear and curvilinear functions were examined for goodness of fit for biomass to frequency of hits and leaf area to biomass relationships prior to selecting the simple linear relationship of y = bx. To determine the effect of species, class of tissue and date on biomass/frequency of hits and leaf area/biomass ratios, a series of least squares analysis of variance (AOV) models were used. When significant ($P<0.05$) effects were found, data sets were repeatedly subdivided and re-analyzed until no significant differences were present. The final regressions used are presented in Tables 1 and 2.

Various repeated measures AOV models were used to assess differences between treatments, dates, and distance from tree or remaining stump in herbage standing crop, leaf area index (LAI), species composition, and aboveground net primary production (ANPP) which was calculated in 3 manners: (1) summation of positive increases in total standing crop; (2) summation of peak standing crop by species/species group; and (3) peak total standing crop. The error term for detecting treatment differences was replication within treatment. The error term for assessing differences among tissue categories was replication within treatment by category. The residuals were used to test for date and/or year effects. Tukey Q procedures were used for mean separation where appropriate.

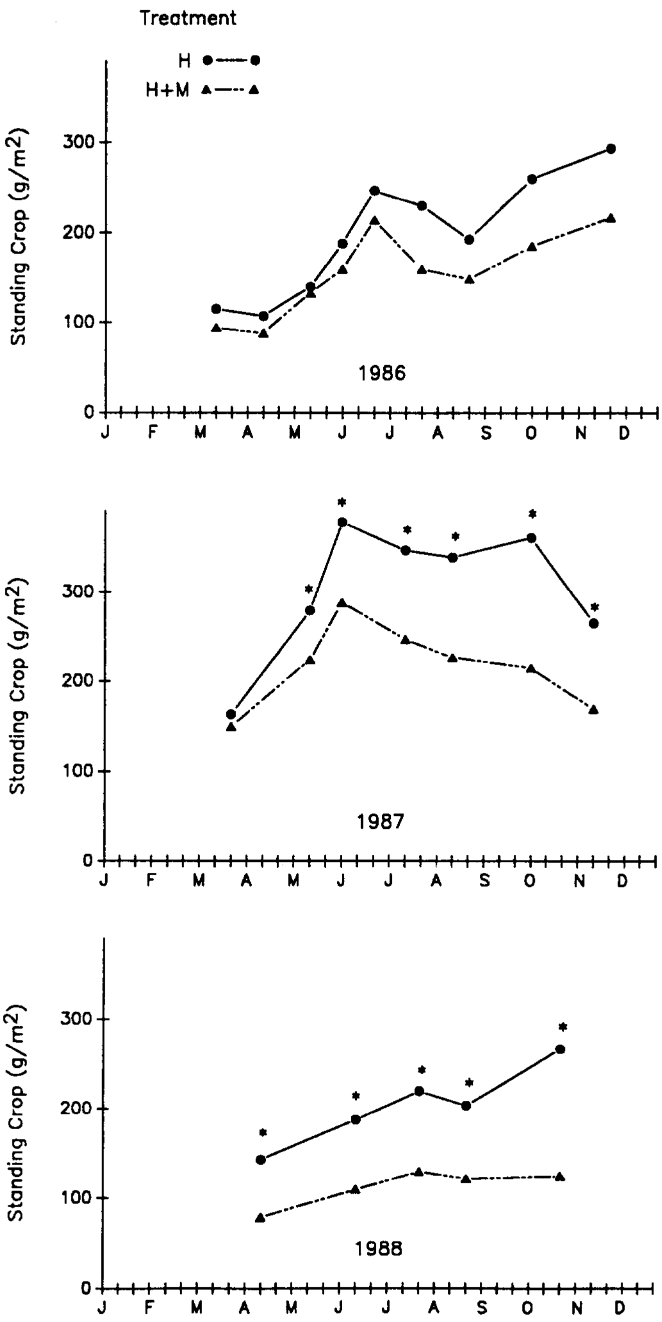

Fig. 2. Herbage standing crop (g/m^2) in herbaceous (H) and herbaceous plus honey mesquite (H+M) treatments during 3-year study. Asterisks identify dates when treatment means were significantly different at $P<0.05$.

Results

Biomass Dynamics

Biomass dynamics (Fig. 2) during the 3 years of study were linked closely to seasonal patterns of precipitation (Fig. 1). Growth during 1986 was slow during early spring, as a result of below normal winter precipitation, near normal during late spring and early summer, and rapid during fall as a result of above average fall rains. There were no significant ($P = 0.16$) differences between treatment standing crops although biomass in the H treatment was greater on all dates than in the H+M treatment. Peak standing crop occurred in November and averaged 294 g/m^2 in the H plots and 217 g/m^2 in the H+M plots. The date by treatment interaction was

Table 1. Linear regressions used to estimate herbage standing crop as a function of frequency hits.

Species/species group	Coefficient[1]	Tissue[2]	Dates[3]	r^4	n^3
Annual grasses	68.3	l+d+s	4	.86	21
Annual grasses	137.4	l+d+s	2	.96	13
Sideoats grama	124.6	l+d	10	.96	57
Sideoats grama	300.4	s	10	.85	53
Shortgrasses[5]	117.3	l+d+s	10	.97	50
Texas wintergrass	120.6	l+d	10	.96	82
Texas wintergrass	59.5	s	3	.93	20
Texas wintergrass	197.0	s	2	.92	16
Texas wintergrass	146.3	s	5	.93	39
Other midgrasses	157.7	l+d+s	5	.99	8
Forbs	120.5	l+d+s	8	.87	61

[1]y = bx where y = g/m² and x = frequency of hits (%).
[2]l = live (green) lamina, d = dead (senesced) lamina and s = stem.
[3]Number of dates and total n values vary as a result of variation among sample dates in presence or absence of certain species and/or class of tissue.
[4]All regressions were significant at $P<0.01$.
[5]Buffalograss and common curlymesquite.

not significant ($P = 0.24$).

Biomass dynamics in 1987 (Fig. 2) varied from 1986 in that early spring growth was more rapid and fall regrowth was limited. The rapid growth during spring was the result of ample fall and winter precipitation during 1986 and near normal spring precipitation (Fig. 1). Biomass in the H treatment was significantly greater than in the H+M treatment on all dates except March. Peak standing crops occurred in early June and averaged 378 and 288 g/m² in the H and H+M treatments, respectively.

Table 2. Linear regressions used to estimate leaf area as a function of tissue biomass.

Species/species group	Coefficient[1]	Tissue[2]	Dates[3]	r^4	n^3
Annual grasses	87.7	l	4	.93	38
Annual grasses	161.9	d	2	.99	8
Annual grasses	69.9	d	3	.99	17
Sideoats grama	88.1	l+d	6	.98	58
Sideoats grama	107.3	l+d	4	.99	40
Sideoats grama	32.0	s	10	.97	90
Shortgrasses[5]	93.7	d	10	.99	96
Shortgrasses[5]	82.0	l	10	.98	96
Shortgrasses[5]	36.6	s	10	.96	87
Texas wintergrass	49.0	l	3	.96	23
Texas wintergrass	92.6	l	8	.97	87
Texas wintergrass	67.5	d	2	.99	19
Texas wintergrass	101.4	d	2	.99	20
Texas wintergrass	80.8	d	7	.98	77
Texas wintergrass	40.9	s	10	.99	101
Other midgrasses	53.0	l+d+s	5	.98	6

[1]y = bx where y = cm/m² and x = g of tissue.
[2]l = live (green) lamina, d = dead (senesced) lamina and s = stem.
[3]Number of dates and total n values vary as a result of variation among sample dates in presence or absence of certain species and/or class of tissue.
[4]All regressions were significant at $P<0.01$.
[5]Buffalograss and common curlymesquite.

Biomass dynamics in 1988 were similar to 1986 although growth rates and peak standing crops during the spring and fall of 1988 were much less than in 1986. Differences were related primarily to differences in amounts and temporal distribution of precipitation (Fig. 1). Biomass in the H treatment was significantly greater on all dates than in the H+M treatment. Peak standing crop in the H treatment occurred in November and averaged 267 g/m². This was in contrast to the H+M treatment wherein peak standing crop of 130 g/m² occurred in July.

The gradual delineation of treatment effects over years (Fig. 2) was the result primarily of changes in the absolute abundance of all species. This was evidenced in that species composition changed little from 1986 to 1988 within a given distance from a tree (H+M treatment) or stump (H treatment) (see ANPP section).

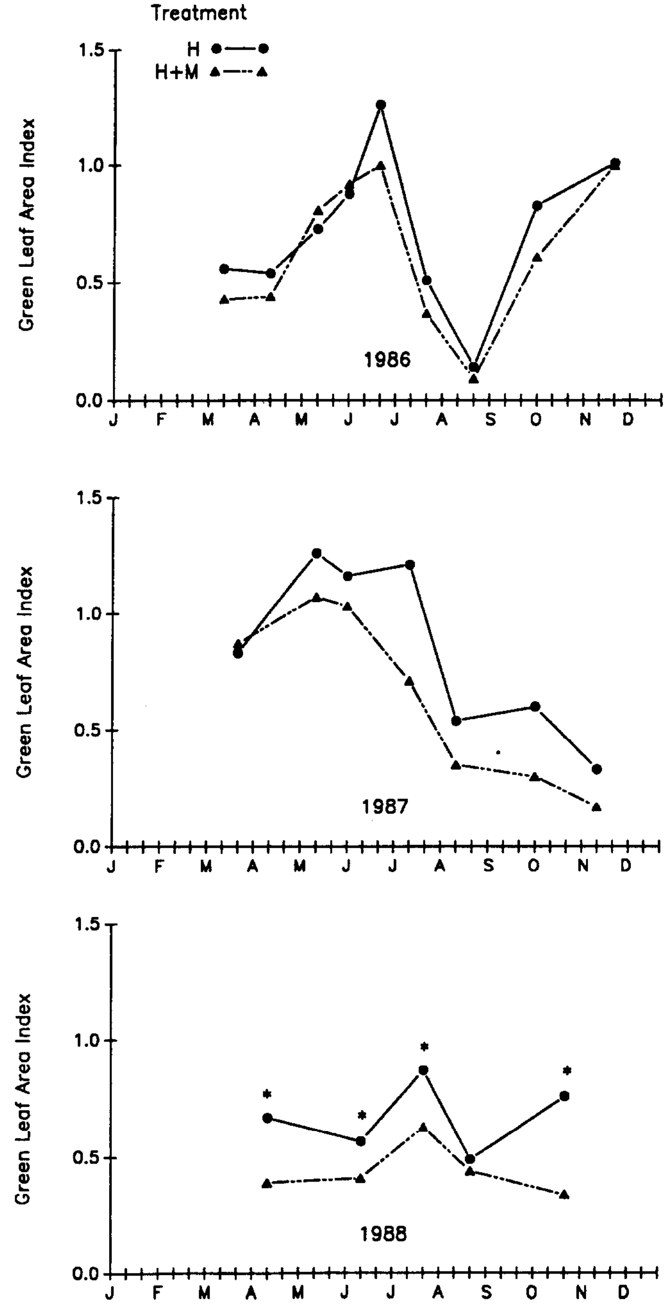

Fig. 3. Green (live) leaf area index for grasses in herbaceous (H) and herbaceous plus honey mesquite (H+M) treatments during 3-year study. Asterisks identify dates when treatment means were significantly different at $P<0.05$.

Leaf Area Index (LAI)

The dynamics of total (live lamina + dead lamina + stem) surface area indices were similar (data not presented) to total biomass dynamics (Fig. 2). Likewise, live (i.e., green) biomass dynamics (data not presented) were similar to live leaf area dynamics (Fig. 3). Live leaf area indices did not vary significantly between treatments in either 1986 (P=0.43) or 1987 (P=0.15) although differences were considerable on most dates in 1987. However, in 1988 there was a significant difference in LAI between treatments in that LAI in the

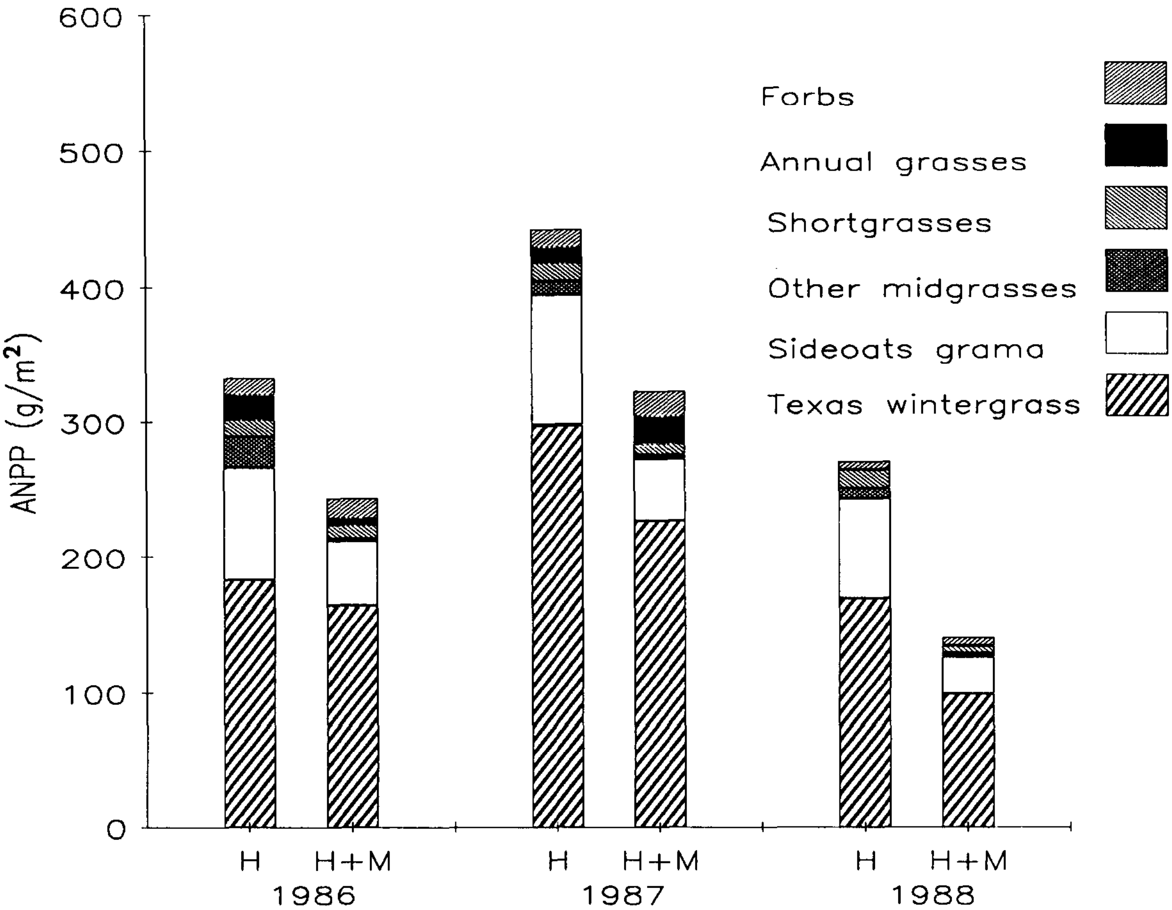

Fig. 4. Estimated aboveground net primary production (ANPP) in herbaceous (H) and herbaceous plus honey mesquite (H+M) treatments during 3-year study. Differences among years (1987>1986>1988) were significant at $P<0.01$. Differences among treatments (H>H+M) were significant at $P = 0.08$. Year by treatment interaction effect was not significant ($P = 0.67$).

H treatment was significantly greater than in the H+M treatment on all dates except 24 August. The absence of a significant difference in August was most likely related to difference between treatments in soil water in that water in the top 130 cm of the soil profile was generally less during summer in the H than H+M plots (Carlson et al. 1990). As a result, rates of senescence during periods of drought, such as August 1988 (Fig. 1), were usually greater in the H than H+M treatment. This is reflected by the rather dramatic decline in live LAI in the H treatment from 18 July to 24 August 1988.

Aboveground Net Primary Production (ANPP)

Aboveground net primary production was significantly ($P<0.10$) greater in the H than H+M treatment in all years regardless of method of calculation. Likewise, ANPP was significantly ($P<0.05$) greater in 1987 than 1986 and in 1986 than 1988. Utilizing the summation of species' peak standing crop method (Fig. 4), estimated ANPP averaged 349 g/m^2 in the H treatment and 235 g/m^2 in the H+M treatment. Estimates for 1986, 1987, and 1988 were 289, 383, and 205 g/m^2, respectively.

There were no major shifts in species composition during the 3 years regardless of treatment. Texas wintergrass was the dominant species in both treatments and sideoats grama the subdominant. In 1986, percent composition in the H treatment was 55% Texas wintergrass, 25% sideoats grama, and 20% other species. By 1988, composition had shifted only slightly to 62% Texas wintergrass, 27% sideoats grama, and 11% other species. Likewise only minor shifts were noted in the H+M treatment in that percentage composition of Texas wintergrass changed from 67 to 71%, sideoats grama from 20 to 19% and other species from 13 to 10%.

Examination of the effects of distance from tree (H+M treatment) or remaining stump (H treatment) revealed significant ($P<0.01$) year, distance, and year by distance interaction effects (Fig. 5). The year effects were similar to those reported for the entire plots (1987>1986>1988) (Fig. 4). Greatest production occurred within 0.5 and 1.0 m of the trees (distances 1 and 2) and averaged 367 and 337 g/m^2, respectively. This was significantly (P =0.05) greater than estimated ANPP (245 g/m^2) within 0.5 m of the borders of the lysimeters (distance 4). Estimated ANPP between 1.0 m of the trees or stumps and 0.5 m of the lysimeter border (distance 3) averaged 323 g/m^2 and was not significantly different from the 3 other locations. We attribute the reduced ANPP near the lysimeter borders primarily to disturbance factors associated with the installation of the lysimeters. This was evidenced by the absence of any significant differences in ANPP among the 4 areas (Fig. 5) 3 years after treatment installation. The absence of significant treatment by distance ($P = 0.17$) and treatment by year by distance ($P = 0.57$) interaction effects showed responses were similar in both treatments.

The dominant species in all zones was Texas wintergrass (Fig. 5) regardless of the presence or absence of honey mesquite. The subdominant was sideoats grama and there were only minor changes in composition during the 3 years of the study regardless of location (Fig. 5). A notable exception to this was the area nearest the border of lysimeters which had a subdominance of annual forbs during the first year (1986). We believe this subdominance was a

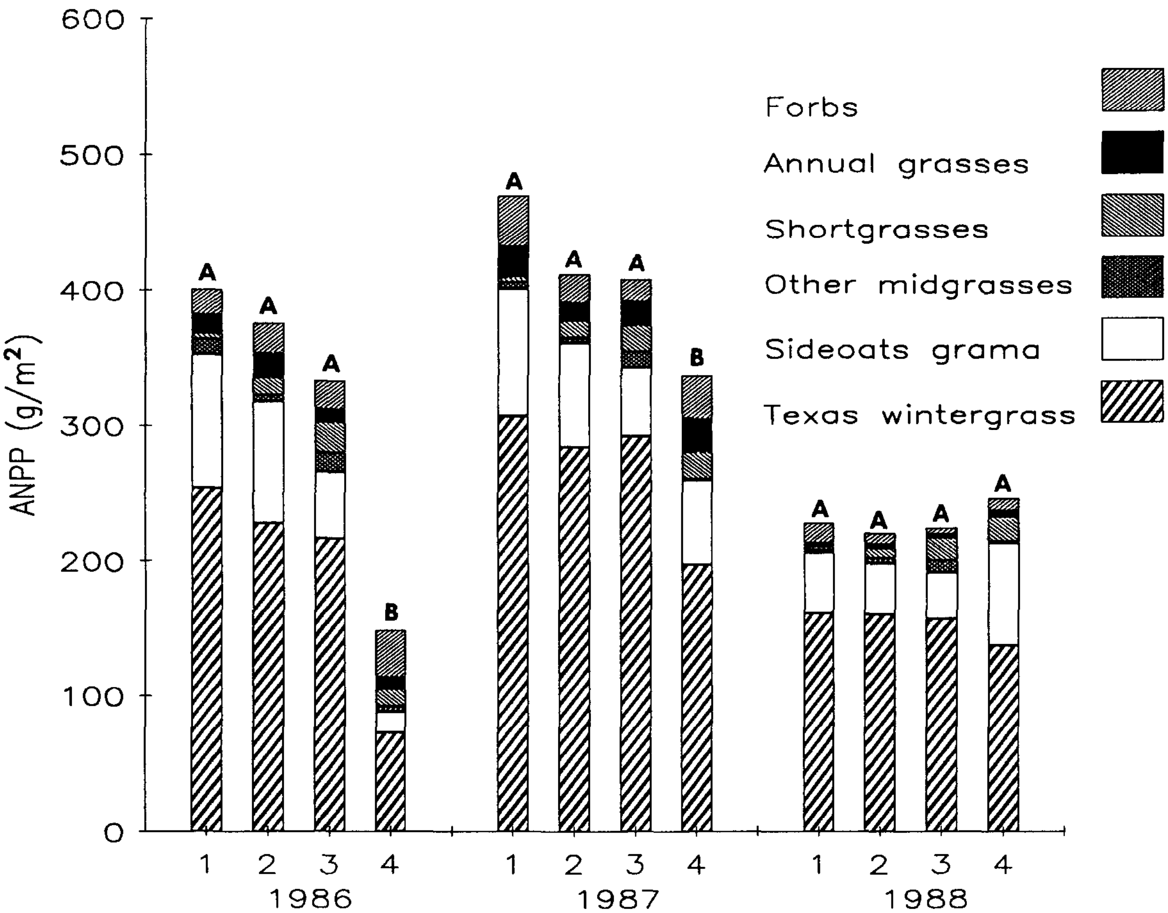

Fig. 5. Estimated aboveground net primary production (ANPP) in herbaceous (H) and herbaceous plus honey mesquite (H+M) treatments during 3-year study at various locations from trunks of trees (1=0.5 m, 2=1.0) to edge of lysimeters (3=1.0–4.0 m, 4=within 0.5m of edge). Histograms within a year superscripted by different letters are significantly different at $P<0.05$.

reflection of the disturbances incurred during installation of the lysimeters because by 1988, forbs were only a minor component in this area and ANPP was equal to that in the other zones.

Discussion and Conclusions

The results of this study show aboveground herbage production increased following control of individual honey mesquite trees (Fig. 4). This increase was relatively uniform regardless of distance from the trunk of removed trees (Fig. 5) and was the result of increased production by herbage species present at time of control rather than a shift in species composition.

These results are in general agreement with the findings of others examining the effects of honey mesquite control on herbage production (Scifres and Polk 1974, Dahl et al. 1978, Brock et al. 1978, McDaniels et al. 1978, Jacoby et al. 1982, Bedunah and Sosebee 1984). Moreover, the absence of a major shift in species composition within the canopy area is in general agreement with the findings of Jacoby et al. (1982), in the Trans Pecos region of Texas, and with Brock et al. (1978) on a study site located about 60 km from our study area. Jacoby et al. (1978) reported a minor shift in species composition 3 years post-treatment as leatherweed croton [(*Croton pottsii* (Croizat) Muell. Arg.], a warm-season perennial forb, decreased from 41 to 24% and hooded windmillgrass (*Chloris cucullata* Bisch.), a warm-season perennial grass, increased from 26 to 34%. Although Brock et al. (1978) suggested a major shift in species composition had occurred by 3 years post-treatment, close examination of their data provides minimal support for such a conclusion. For example, they suggested species composition had shifted from a Texas wintergrass dominance to a warm-season midgrass dominance. This conclusion was based, however, on end-of-summer standing crop estimates, which probably substantially underestimate ANPP of Texas wintergrass because peak standing crop of Texas wintergrass seldom occurs during late summer in this region. For example, in our study Texas wintergrass peak standing crops of 169, 260, and 132 g/m² peaks were recorded in late November 1986, early June 1987, and late October 1988, respectively. These estimates were in contrast to late summer estimates of 134, 196, and 114 g/m² in 1986, 1987, and 1988, respectively. Moreoever, McDaniels et al. (1978), working in cooperation with Brock et al. (1978), concluded from standing crop estimates collected during spring that Texas wintergrass increased on the area following control.

Variation between treatments in growth dynamics (Fig. 2) and LAI (Fig. 3) among seasons and years was minimal in this study because differences between treatments in species composition were minor. These results, in combination with ANPP estimates (Figs. 4 and 5), emphasize that the major factors affecting herbage production within the canopy area of honey mesquite are climatic factors, particularly precipitation, rather than presence or absence of honey mesquite. This is in agreement with previous research in this region, which has shown patterns of post-treatment rainfall and grazing intensity affect both the magnitude and duration of herbage response following control of honey mesquite (Scifres et al. 1974, McDaniels et al. 1982, Heitschmidt et al. (1986).

The results of this study also reveal why removal of honey mesquite may not dramatically alter off-site water yields in this region. Concurrent research in these same lysimeters showed annual 3-year average evapotranspiration losses were 2.4% greater (95.0 vs. 97.4%), surface runoff 3.0% less (4.6 vs. 1.6%), and deep drainage 0.6% greater (0.4 vs. 1.0%) in the H than H+M lysimeters (Carlson et al. 1990). Presumably, the absence of any major effects on water yields following removal of the honey mesquite was in part related to the increased standing crop (Fig. 2) and photosynthetically active (i.e., green) leaf area (Fig. 3) stemming from the increased herbage production (Fig. 4). Other research at this study site showed transpirational water loss by Texas wintergrass (Hicks et al. 1990), the dominant herbaceous species, and honey mesquite (Ansley et al. 1990) are similar on a per unit area of leaf surface basis. Moreover, these data in combination with knowledge of the regional effects of amount of herbage standing crop on water infiltration rates and surface runoff (Wood and Blackburn 1981, Pluhar et al. 1987), infer that heavy livestock grazing may be required to effectively increase water yields in this region following removal of honey mesquite. Caution should be exercised, however, in any attempt to extend these data to other regions because: (1) growth form of the honey mesquite trees was single-stemmed rather than multi-stemmed regrowth; (2) study was conducted in the absence of any livestock grazing; and (3) no attempt was made to determine herbage response in the interstitual areas.

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