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Water balance in pure stand of Lehmann lovegrass

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Abstract

Lehmann lovegrass (*Eragrostis lehmanniana* Nees), an introduced warm season grass, has invaded grasslands in southern Arizona, in many areas replacing the native warm-season grasses. A water balance evaluation in a pure stand of Lehmann lovegrass showed that more soil water was used through evapotranspiration than occurred as precipitation during 2 years of a 3-year study period. During the winter season, an appreciable amount of water was used by Lehmann lovegrass or lost by evaporation from the soil surface. The remaining available soil water was used in the spring dry period. In the dry early spring the soil water contents (to depths of 120 cm) were less than the traditional wilting point tension of -1.5 MPa. The invasion of Lehmann lovegrass into grasslands of southern Arizona is partially related to its ability to utilize soil water during parts of the year when the native species are dormant and also to extract water from the soil profile to very low water contents.

Key Words: soil moisture, water content, Eragrostis lehmanniana, evapotranspiration

Lehmann lovegrass (*Eragrostis lehmanniana* Nees) is a warm-season grass that has been successfully introduced into rangelands at various places in the world. In some regions the grass has invaded and dominated new sites outside the seeded areas. This has occurred in parts of southern Arizona where the grass has completely replaced native warm-season grasses (Cable 1979, Cox et al. 1992). One specific area is the Santa Rita Experimental Range near Tucson, Arizona. In this area, native vegetation has traditionally been perennial, drought resistant woody and succulent species, adapted to conserve water during drought (Cox et al. 1982). Today much of the Experimental Range is nearly pure stands of Lehmann lovegrass.

The change in vegetation composition on the Santa Rita is believed to have been aided by drought conditions that prevailed in the 1950's and 1970's. Cox et al. (1988) reported that under favorable temperature regimes Lehmann lovegrass will persist in areas where precipitation during the active growing season >100 mm and will spread in areas where precipitation >150 mm. Observations during the 1950s' and 1970s' droughts indicated a significant decline in both native plant and Lehmann lovegrass populations. When soil water conditions improved, native grasses did not re-establish as aggressively or rapidly as Lehmann lovegrass which became the dominant species (Cox and Ruyle 1986).

To displace a native species, an intruding plant must have a competitive advantage such as the ability to effectively utilize soil water, maybe during the native species dormant season, and/or to extract soil water not normally considered available to native species (i.e., high tensions). This paper reports results of a 3-year study designed to gain a better understanding of the temporal soil water balance of a pure stand of Lehmann lovegrass located on the upper portion of the Santa Rita Experimental Range in southern Arizona. We discuss some of the characteristics that make Lehmann lovegrass a superior competitor.

Methods

Site Description

The study area was a 6-ha fenced stand of dense, shrub-free Lehmann lovegrass located on a 2-5% northwest facing slope. The site is 40 km south of Tucson, Ariz. at an elevation of 1,075 m on the Santa Rita Experimental Range (31° 41' N, 100° 37' W). Soils were a recent alluvium, weathered from granitic rocks, moderately acid (pH=6.2-6.9) with depths ranging from 0.2 to 2.5-m (Hendricks 1985) and classified as a Comoro sandy loam (thermic typic Torrifluvent). Precipitation was recorded on-site with a weighing rain gauge Average annual precipitation in the area is about 500 mm, ranging from 175 to 700 mm during the past 80 years (Cox et al. 1990). Distribution is bimodal with about 60% occurring as rain during summer (early July-September) with most of the remainder falling as either rain or snow during the late fall through early spring (October-April). Summer storms are typically intense localized thunderstorms of short duration. Winter storms are characteristically of long duration and low intensity. April, May, June and September are usually dry but exceptions do occur. Daytime temperatures average 30° C during summer with nighttime temperatures averaging 5° C during winter (Sellers 1960).

Experimental Design

The experimental design was a randomized-complete-block with replicated sampling over 3 years. Nine 15- by 15-m plots, grouped by 3 into 3 blocks, were established in January 1984. One plot in each block was randomly selected for biomass and gravimetric soil water sampling at 2-week intervals between 18 July 1984 and 3 July 1985. Three new plots (1 per block) were sampled between 3 July 1985 and 18 July 1986. The final 3 plots were sampled from 18 July 1986 to 3 July 1987.

Soil Characterization

Within each block, 3 soil cores were collected at 0-10, 10-20, 20-30, 30-60, 60-90, and 90-120 cm depths. Samples were composited by depth for standard hydrometer particle size distribution analysis. For 1 core in each replication, bulk density and soil water characteristic analysis were made at depth increments of 0-10, 10-20, 20-30, 30-60, 60-90, and 90-120 cm. A ring bulk density apparatus with a plastic liner, filled with water, was used to estimate the volume for the bulk density measurements (Blake 1965). Soil water content characteristics at tensions of -0.03, -0.10, and -1.5 MPa were determined using standard pressure plate techniques.

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Aboveground Biomass

On each sampling date, Lehmann lovegrass plants were clipped at the soil surface in 3 randomly located 0.25- by 0.25-m quadrats per designated plot. Each sample was separated into live (green) and dead standing biomass components. Samples were dried in a forced-draft oven at 60° C for 72 hours and weighed. Only the green biomass portion of the samples were used in this analysis.

Soil Water

After collecting biomass samples, soils core were collected for gravimetric water content determination at 3 locations within the clipped quadrat areas at 0-10, 10-20, 20-30, 30-60, 60-90, and 90-120 cm depths. Each core was weighed and dried in a microwave oven for 5 min. using the general procedures of Hankin and Sawhney (1978). Soil water estimates for each increment were averaged for the 3 cores. These estimates were converted to volumetric soil water content based on the soil bulk density for each depth increment and replication.

Water Balance

If there are no deep percolation losses below the root zone and no surface runoff or runon onto the plots during precipitation events, the change in soil water in the profile is the difference between precipitation and evapotranspiration. A water balance was calculated for each biweekly sampling period from the changes in the water contents in the 0-120 cm deep soil profile as follows:

Biweekly water use/loss = (Initial total soil water) - (Final total soil water) + (Precipitation) **(1)**

In the area, the summer rainy season which usually occurs after 1 July is considered the start of the growing season for many of the perennial range plant species. To evaluate when and where the plants were utilizing soil water, the year was divided into 3 intervals: July-October (summer growing season during period of rainfall); November-Feburary (winter period) and March-June (growing season during period of limited rainfall).

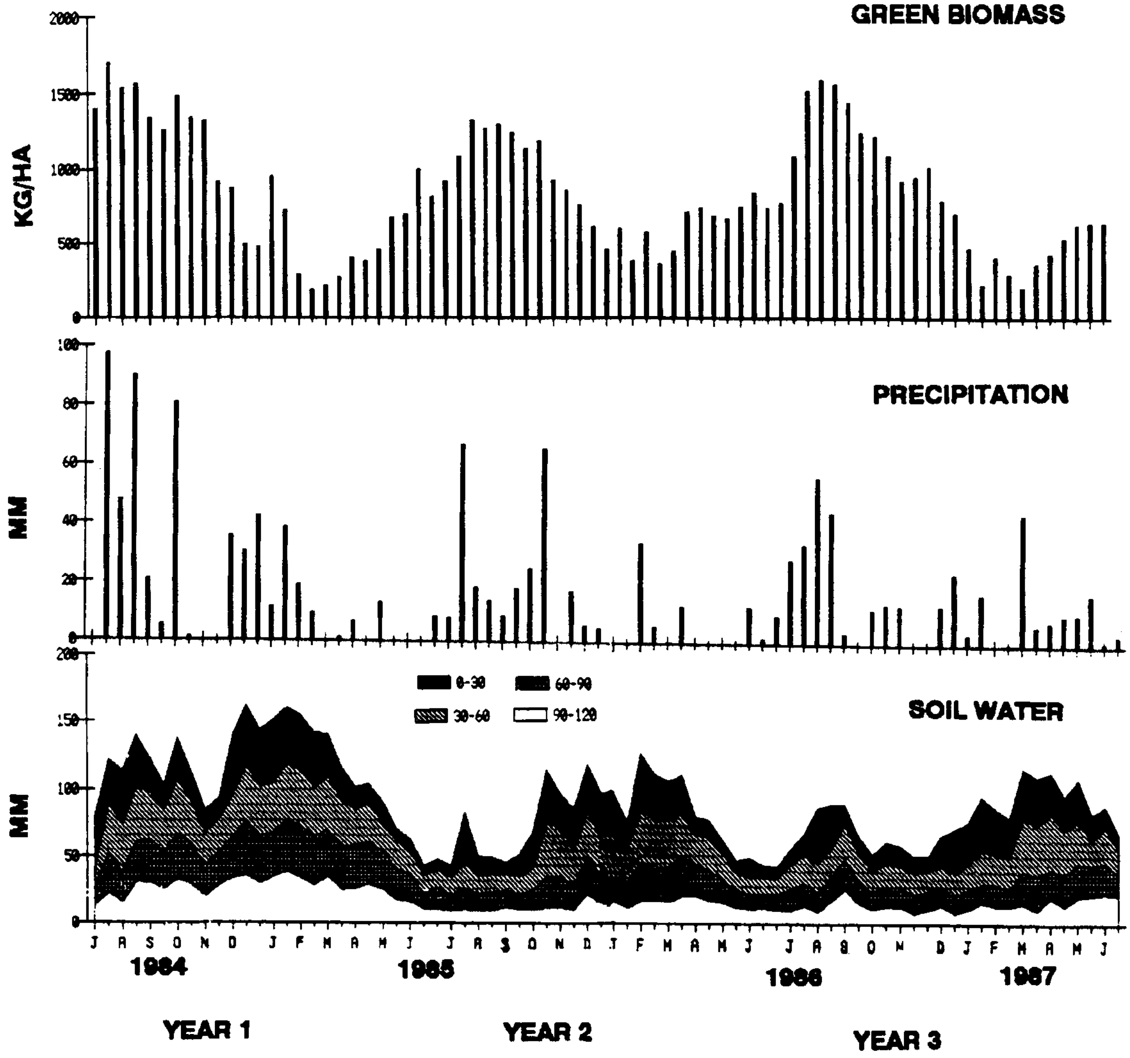

Fig. 1 (top) Biweekly total standing green biomass, middle) biweekly precipitation, and bottom biweekly soil water contents by depths.

Table 1. Soil characteristics.

Rep	Depth	Texture				Bulk density	Water holding capacity		
		Sand	Silt	Clay			Tension-MPa		
							0.03	0.10	1.5
	(cm)	(%)	(%)	(%)			(%)	(%)	(%)[2]
1	0-10	87	9	4	(Sand)	1.714	9.85	5.91	3.85
	10-20	85	6	9	(L. sand)	1.796	9.03	5.27	3.76
	20-30	87	4	9	(L. sand	1.821	9.88	5.11	3.56
	30-60	87	4	9	(L. sand)	1.738	8.11	5.01	3.60
	60-90	92	4	4	(Sand)	1.580	7.45	5.62	3.98
	90-120	89	7	4	(Sand)	1.714	6.93	5.37	3.90
2	0-10	87	4	9	(L. sand)	1.765	10.51	7.09	4.37
	10-20	89	7	4	(Sand)	1.843	7.85	6.25	3.71
	20-30	87	4	9	(L. sand)	1.740	7.44	4.91	4.13
	30-60	84	7	9	(L. sand)	1.698	7.30	5.19	5.05
	60-90	86	4	9	(L. sand)	1.587	8.18	5.51	4.73
	90-120	88	7	4	(Sand)	1.269	7.84	5.81	4.36
3	0-10	88	7	5	(Sand)	1.622	9.69	7.78	3.81
	10-20	80	14	5	(L. sand)	1.507	11.00	8.16	4.71
	20-30	75	9	16	(Sandy L)	1.472	13.39	10.00	5.76
	30-60	62	17	21	(Sandy CL)	1.458	17.67	14.29	8.32
	60-90	73	8	19	(Sandy L)	1.267	19.21	11.21	7.29
	90-120	65	3	33	(Sandy CL)	[1]	24.46	14.57	11.00

[1]Not determined
[2]By weight

Statistical Analysis

Statistical analysis of the data consisted of computing the means and standard deviations among replications.

Results and Discussion

Soil Water

The soil in the area of Replicate 3 had a lower bulk density and was finer textured at the 20-120 cm depths than the other 2 replicates. These differences are reflected in the greater water holding capacity of the soils in Rep. 3 at depths below 30 cm (Table 1). Precipitation during the first year (July 1984-June 1985) resulted in a wet summer and fall followed by a dry spring (Fig. 1). This was the begining of a 2-year drought which resulted in below normal precipitation during July- October and November-Feburary periods of the last 2 years of the study.

The biweekly gravimetric water content data by depth indicate similar values among replications. Water content changes were almost identical in the top 0-30 cm soil layers with standard deviations of the volumetric water content among replications of less than 2% and frequently less than 1% (Fig. 2). At deeper soil depths the standard deviations of the volumetric water contents among the replications were larger (2-4%).

Total soil water content increased after major precipitation events (> 15 mm) and decreased during dry periods through evaporation and plant water use (Fig. 1). Cox et al. (1992) reported that greater than 80% of the Lehmann lovegrass roots are in the top 30-cm layer of the soil profile. The data indicate the remaining roots at the deeper depths were very efficient in extracting soil water. Soil water potentials were less than -1.5MPa at all depths, especially in the dry March-June periods (Fig. 2). Lehmann lovegrass appears able to extract soil water at tensions much greater than the measured traditional wilting point of - 1.5 MPa. In a study of seasonal soil water use of several native and introduced perennial grasses, and native shrubs at the Santa Rita Experimental Range near Tucson, Arizona., Cable (1980) reported that soil water accumulated at the deeper levels of the soil profile during the winter periods and was used by deep rooted shrubs during the early spring and summer. In our study area, shrubs or other plants which could utilize deep stored water were not present. Any soil water changes at the deeper depths were the result of Lehmann lovegrass usage.

Biomass

Lehmann lovegrass initiates spring growth 2-3 weeks before most native grasses with a major growth period during the spring and summer growing season. Much of this summer growth remains green throughout fall and winter periods (Cox et al. 1990). Even with the extreme variation in precipitation quantities and patterns the biweekly green biomass production of Lehmann lovegrass showed similar trends at comparative times over the 3 year study (Fig. 1). Standing green biomass at each harvest date ranged from a high of over 1,500 kg ha^{-1} in July-September. to a low of 200 to 500 kg ha^{-1} in Febrary - March sampling periods. Even at the high soil moisture tensions in dry spring periods Lehmann lovegrass continued to produce green biomass.

Water Balance

Over 50% of the total water use/loss occurred during the summer rainy period (July-October) (Fig.3). Appreciable water use/loss also occurred during the winter period (November-Feburary). Some of this water may have been used by the plant for growth during warm portions of the winter. Total water use/loss in the spring (March-June) depended, to some extent, upon the amount and timing of the late winter and early spring precipitation events. In year 1 and year 3, total water use/loss during fall-winter period (November-Feburary) was less than the total precipitation for the period. This excess water was stored in the soil profile. In spring, considerably more water was used/lost than resulted from precipitation (Fig. 3). A portion of this was from deeper depths of the soil profile, water which had accumu-

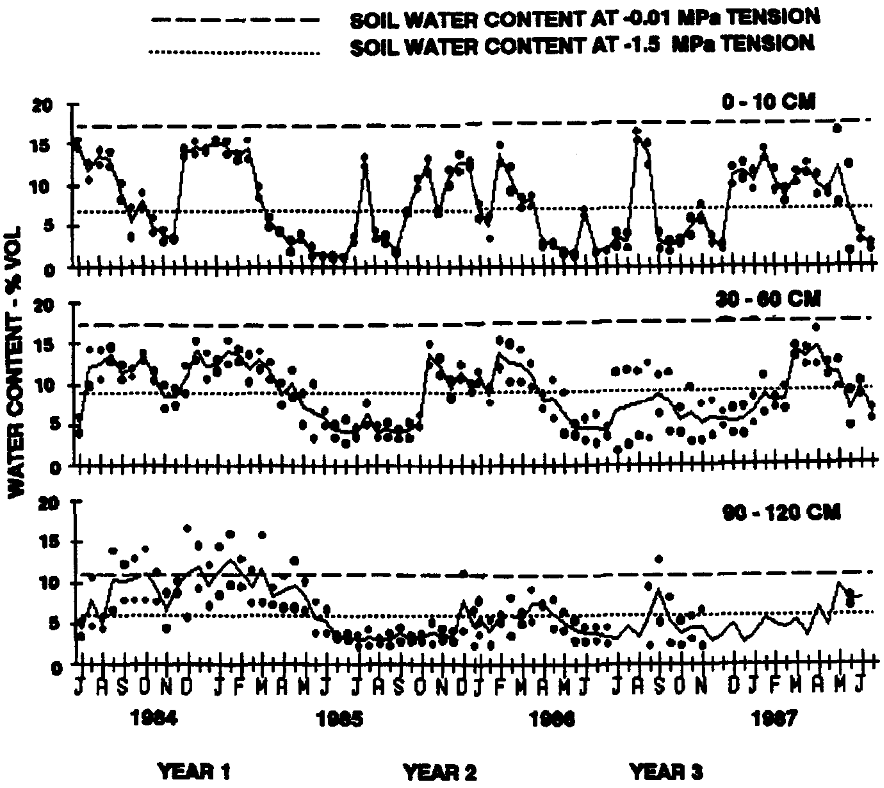

Fig. 2. Three year means and standard deviations of the biweekly water contents at top) 0-10 cm, middle) 30-60 cm, and bottom 90-120 cm depths. The dots of each biweekly period indicate +/- 1 standard deviation from the mean.

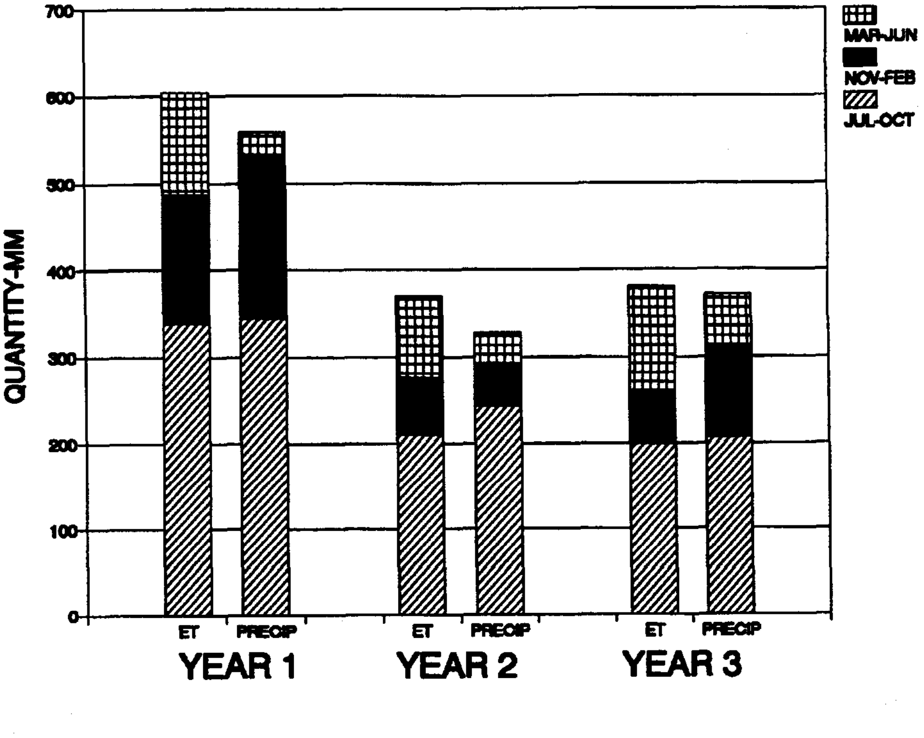

Fig. 3. Total evapotranspiration and precipitation by years.

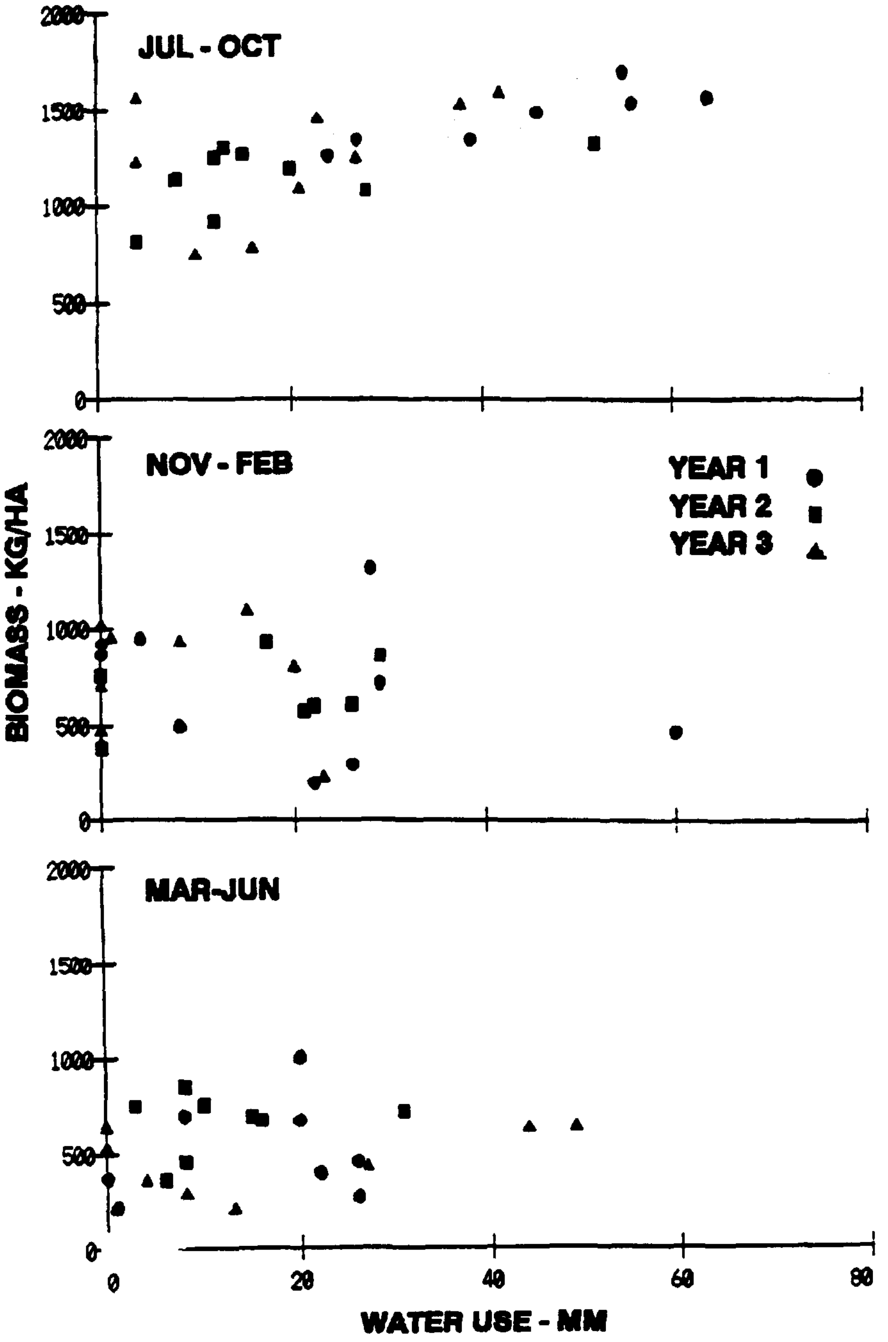

Fig. 4. Water use vs. green biomass production.

lated during previous summer and winter precipitation events. This is in contrast to the results reported by Cable (1980) who found that all available soil water was used each growing season by Lehmann lovegrass plants or evaporated from the soil surface during the dry nongrowing periods. This essentially exhausted available moisture from the top 75-cm of soil within 2 weeks after recharge from the summer rains.

Total water use/loss during each of the 3 years in our study consistantly exceeded yearly precipitation (Fig. 3). Within the fluctuations from the biweekly precipitation, total available water gradually declined within the soil profile during the 3-year study. A large portion of this water was extracted from the soil at tensions greater than -1.5 MPa. If the total annual water use/loss continued at this rate, it would be resonable to assume there would be an eventual decline in grass production.

A consistent relationship was not found between green biomass production and water use/loss (Fig.4). In the hot summer growing period, green biomass increased slightly with a corresponding increase in soil water use/loss. During the remainder of the year, the standing green biomass remained relatively constant, irrespective of the soil water use (Fig. 4). This may indicate that Lehmann lovegrass uses a relatively constant amount of water with the remainder of the soil water being evaporated from the soil surface. It is possible that Lehmann lovegrass utilizes some threshold water quantity with very little benefit from any additional water. The absence of a supplemental measure of evaporative losses from the soil profile prevented us from quantifying actual water needs of the grass.

Soil Water Dynamics

Temporal evaluations of the water content within the soil profile shows a considerable change in the top 0-60 cm layers (Fig. 1 and Fig. 2). Except for high precipitation periods at the beginning of the study, only subtle changes in soil water contents occurred at the 90-120 cm level (Fig. 1 and 2). Water accumulated in the upper layers of the soil profile during winter, was depleted during the March-June growing period (Fig. 2). These findings suggest that upper soil layers provide a major portion of the plant water needs during much of the year with the lower depths providing water during the dry portions of the year.

Some of the differences between our results and Cable (1980) may be attributed to the soil water measurement techniques. Cable (1980) used neutron probe techniques which are limited in assessing soil water in the surface layer (approximately 0-15 cm). In contrast, our gravimetric technique measured soil water in the surface layers more accurately but is limited to obtaining representatives samples from deeper depths if the soil is too dry and crumbly to stay in the sampler. Our results may also be influenced by the below normal precipitation in the winter period during the last 2 years of the study.

Conclusions and Implications

During a 3 year Lehmann lovegrass water balance study in southern Arizona more soil water was extracted from the soil profile than occurred as precipitation. During this period of below normal precipitation the total amount of water stored in the soil profile gradually declined. An appreciable amount of water was removed from the soil profile by plant growth or evaporation during the winter season. Much of the remaining available water was exhausted in the spring dry period. The soils often dried in the early spring to soil moisture tensions greater than -1.5 MPa to depths of 120 cm.

Lehmann lovegrass appears to require some threshold water level for growth. Soil water availability above this threshold does not result in a major increase in biomass production. Any extra soil water either passes directly through the plant without contributing to growth or is lost by evaporative processes from the soil surface.

The invasion of Lehmann lovegrass into grasslands of Southern Arizona may be partially attributed to a combination of events related to water. We hypothesize Lehmann lovegrass has the ability to utilize soil water during parts of the year when native species are dormant, to utilize water stored at relatively deep depths in the soil profile, and to extract water from the soil profile at very low water contents.

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