CANOPY RAINFALL INTERCEPTION AND THROUGHFALL IN BURNED AND UNBURNED TALLGRASS PRAIRIE

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ABSTRACT—Interception of precipitation by grass canopies in annually burned and unburned tallgrass prairie was measured for individual precipitation events from 1983 to 1984. Seasonal patterns of interception closely reflected differences in grass canopy development throughout the growing season in burned but not unburned prairie. Mean interception for the study period was 38 and 19% for unburned and burned prairie, respectively, indicating that throughfall volume in burned prairie was approximately 1.3 times that of unburned prairie on an annual basis. Thus, water availability for plant uptake may be initially higher in burned prairie, especially early in the growing season.

Availability of water is one of the predominant factors influencing productivity in tallgrass prairie (Knapp, 1984). Variation in total annual precipitation and seasonal distribution of precipitation are important in controlling plant production. Studies in forest and prairie systems have demonstrated that canopy interception can substantially decrease the amount of water reaching the ground (Clark, 1940; Parker, 1983; Seastedt, 1985). The objective of this study was to examine the seasonal dynamics of interception of precipitation by a tallgrass prairie canopy.

Periodic fires are required for the maintenance of tallgrass prairie (Bragg and Hulbert, 1976), and spring burning is a common management practice. These fires greatly alter canopy structure by removing the previous year's standing dead biomass and litter. We compared precipitation interception by canopies in annually burned tallgrass prairie to that in unburned prairie to quantify the effect of fire-caused changes in canopy structure on the amount of water which reaches the soil.

MATERIALS AND METHODS—Research was conducted on the Konza Prairie Research Natural Area, located in the northeast Kansas Flint Hills, 15 km south of Manhattan, Kansas. Konza Prairie is 3490 ha of bluestem (tallgrass—or true) prairie (Küchler, 1964), dominated by big bluestem (*Andropogon gerardii* Vitman), Indiangrass (*Sorghastrum nutans* (L.) Nash), and little bluestem (*Schizachyrium scoparium* Michx.). The soil at the study sites is a Tully silty clay loam (Jantz et al., 1971).

The climate of this region is classified as humid continental (Brown and Bark, 1971), with a mean annual temperature of 13°C, ranging from a mean January low of −3°C to a mean July high of 27°C. Annual precipitation is 835 mm; snowfall is common in January and February. The seasonal pattern of precipitation is distinctly bimodal, with peaks in June and September (Fig. 1). Seasonal precipitation patterns, however, vary greatly from year to year (Brown and Bark, 1971).

Measurements of interception were made from May 1983 to November 1984. Sampling took place on two watersheds: one unburned and one annually burned. The latter watershed was burned on 18 April 1983 and 19 April 1984. Bulk precipitation volumes were measured at each site with plastic funnel collectors and standard rain gauges approximately 1.5 m above the grass canopy. Throughfall volumes were measured with plastic collector jugs attached by Tygon tubing to 5- x 100-cm V-shaped metal troughs. In the burned watershed, these troughs were installed within 2-3 weeks following fire. Six troughs were placed at the base of the canopy at each site

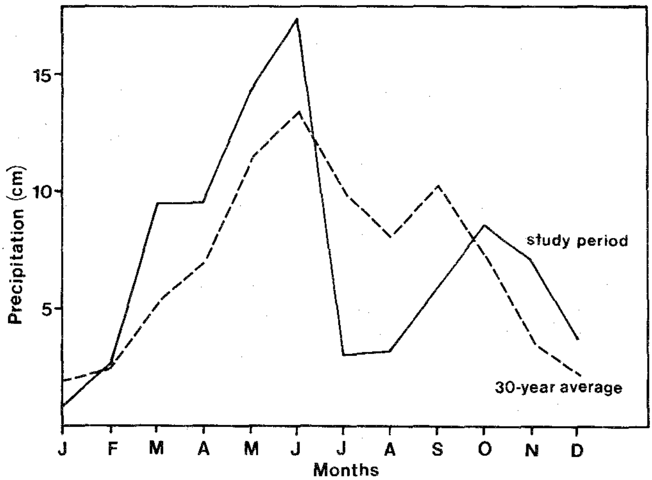

FIG. 1—Mean monthly precipitation at Konza Prairie Research Natural Area for 1951-1980 (dashed lines) and for the study period (solid lines).

and measured throughfall approximately 3 cm above the soil/litter surface. Six troughs were sufficient for standard errors to be less than 15% of mean throughfall amounts.

Collections were made after each precipitation event greater than 4 mm. Percent canopy interception was calculated by subtracting mean throughfall volume from bulk precipitation volume, dividing the difference by bulk volume, and multiplying the quotient by 100. Interception on the annually burned watershed was assumed to be 0% immediately following fire because burning completely removed the grass canopy.

Aboveground biomass was sampled at two-week intervals throughout the 1983 and 1984 growing seasons. Sampling sites were located on similar lowland soils in burned and unburned prairie. Oven-dried (60°C, 48 hrs) estimates of aboveground biomass were made by clipping at ground level all plant material within 20 0.1-m^2 quadrats systematically located along random transects. Statistical analyses of biomass and throughfall data were accomplished with standard t, paired-sample t, and correlation procedures. Percent interception data were arcsine-transformed prior to analysis.

RESULTS AND DISCUSSION—Throughfall amounts in both annually burned and unburned prairie correlated significantly with precipitation (Fig. 2). Of the approximately 82 cm/yr that fell during the study period, 51 and 64 cm were deposited as throughfall in unburned and burned prairie, respectively.

Canopy interception values are given only for May through November of each year because winter and early spring months had appreciable snow (Fig. 3). This caused unrealistic negative interception values because drifting resulted in snow accumulations on grass canopies in excess of that collected as bulk precipitation. Each monthly interception value is the volume-weighted mean of all precipitation events in that month. Weighting of means was necessary because the size of an event can influence greatly the degree of canopy interception (i.e., small events tend to result in high interception).

Seasonal patterns of canopy interception in burned and unburned prairie differed markedly (Fig. 3). Interception was generally lowest in spring in both watersheds and increased during the growing season to a maximum

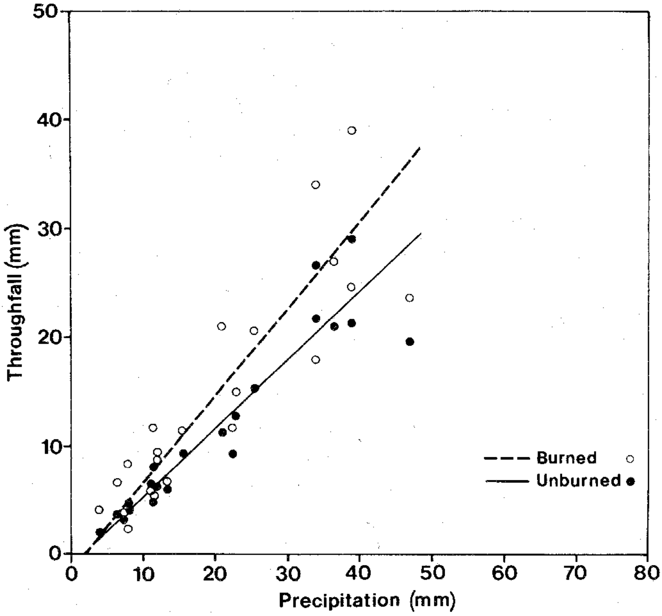

FIG. 2—Relationships of throughfall in burned (open symbols) and unburned prairie (closed symbols) to precipitation for individual storm events. Equation for burned prairie (dashed line) is: $y = -1.24+0.80x$; $r=0.90$; $P<0.001$. Equation for unburned prairie (solid line) is: $y = -1.15+0.63x$; $r=0.95$; $P<0.001$; where y is throughfall and x is precipitation.

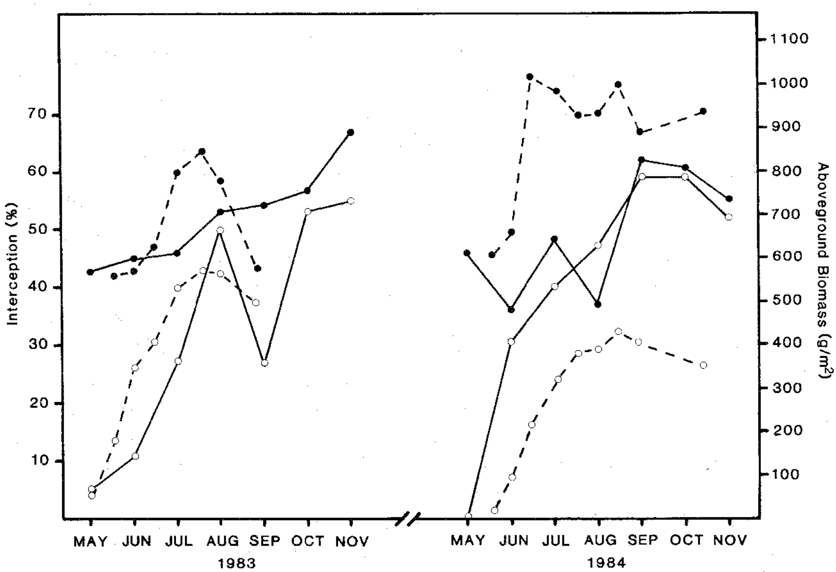

FIG. 3—Mean monthly canopy interception (solid lines) and biweekly aboveground biomass (dashed lines) in unburned (closed symbols) and annually burned (open symbols) tallgrass prairie.

in middle to late autumn. For the two years of the study, maximum interception for unburned paririe was 67% in November 1983 and 59% for burned prairie in September-October 1984. For the entire study period, mean annual interception was 38.3% and 19.4% for unburned and burned prairie, respectively, reflecting slope differences of throughfall/precipitation relationships in Fig. 2. Interception means differed significantly using a paired-sample t test ($P < 0.001$).

Patterns of aboveground biomass through the growing seasons in burned and unburned prairie are shown in Fig. 3. Burns administered during the study were typical of prairie fires, removing virtually all aboveground biomass. Rapid regrowth in burned prairie contrasted to smaller seasonal fluctuations in total canopy biomass in unburned prairie, dominated by the previous year's dead biomass.

Variations in seasonal interception patterns in the two treatments arose from differences in canopy characteristics. When compared on the basis of mean monthly values for the two years, interception was significantly correlated with total aboveground biomass ($r=0.93$) in burned prairie, whereas no significant correlation was found in unburned prairie. There appeared to be a critical range of canopy biomass with respect to canopy interception between 500-600 g/m^2. Below this range, interception was linearly related to biomass; above this range, changes in canopy biomass resulted in small, sometimes inconsistent, changes in interception.

A major role of fire in tallgrass prairie ecosystems is the removal of standing dead biomass. This removal increases the availability of light energy (Knapp, 1984) and nitrogen (Seastedt, 1985). Our results show that the amount of water reaching the soil also is enhanced greatly by fire, particularly early in the growing season when climatic conditions are optimal for growth. For example, of the 24 and 29 cm of total precipitation that fell from May through July in 1983 and 1984, respectively, 22 and 21 cm reached as throughfall the burned prairie soil, whereas only 13 and 17 cm reached unburned prairie soil. Furthermore, the burned prairie received annually a 30% higher volume of throughfall than unburned prairie.

The amount of water moving directly down plant tillers (stemflow), not measured with our collectors, remains unresolved. Clark (1940) concluded that the amount of water reaching the soil via stemflow in tallgrass prairie was small. Seastedt (1985), however, demonstrated that stemflow contributed significantly to the amount of water available to burned and unburned prairie, increasing the amount by as much as 50%. He also demonstrated that stemflow amounts increased with increasing grass tiller density. Hulbert (1969) showed that spring burning increased tiller density in tallgrass prairie (911 and 342 stems/m^2 for burned and unburned prairie, respectively); hence, the amount of stemflow on burned sites may be equal to or greater than that on unburned sites. Furthermore, litter interception, which occurred beneath our collectors, would be greater on unburned sites because annual litterfall rates of unburned prairie are more than twice those of burned prairie (Gilliam, unpubl. data) and because virtually all burned prairie litter is removed by fire.

This study has demonstrated that canopy development can alter greatly the amount of water reaching prairie soil. The effect of canopy development on throughfall functions as a feedback mechanism, which is positive with fire and negative without fire.

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