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Relating weather and fine fuel conditions during fires to mesquite topkill

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Introduction

Weather conditions and fine fuel loads during fires have a profound effect on fire behavior and subsequent response of mesquite to fire. Knowledge of how weather conditions affect mesquite response to fire may be beneficial to resource managers who wish to manipulate growth form of mesquite to meet different management goals. Our objective was to determine effects of weather (air temperature, relative humidity) at the time of burning and fine fuel amount and quality on fire behavior and mesquite topkill response. This paper is a summary of results found in Ansley et al. 1998.

Methods

Research was conducted on 2 sites in the northern Rolling Plains of Texas: Ninemile Pasture on the Waggoner Ranch south of Vernon, and Strip and River Pastures on the Y Experimental Ranch (YER) west of Crowell. The Ninemile site has an equal mixture of cool and warm-season grasses, while warm-season grasses dominate the Y Ranch site. Soils on both sites are clay loams.

Twenty fires were conducted from late-January to early March, 1991 to 1995, on small plots (ranging 3 to 15 acres in size). Most mesquite trees were 2-4 m (8-13 ft.) tall and multi-stemmed with a few smaller plants scattered throughout each plot. Herbaceous understory fuel ranged from 1037 to 5759 kg/ha (923 - 5125 lbs/ac) and wind speed during the fires ranged from 5.6 to 25.7 kmph (3.5-16 mph). Mesquite were evaluated along permanently marked transects the growing season following each fire. Percent topkill per stand, foliage remaining of non-topkilled (NTK) trees, and percent mortality (i.e., rootkill) were quantified.

Results

Peak fire temperature, measured with thermocouples at various heights above ground, usually occurred at 10 to 30 cm (4 to 12 in.) above ground and ranged from 600 to 900 ^{o}C (1,100 to 1,650 ^{o}F) in higher intensity fires, and 750 to 1,300 ^{o}F in lower intensity fires. Differences in fire temperature between high and low intensity fires increased with increasing height above ground. At 1 to 3 m (3 to10 ft.) above ground, temperatures of high intensity fires were often 3-4 times greater than those in low intensity fires.

Air temperature had an equal or greater influence on mesquite canopy response to fire (r^2 = 0.73) than did fuel amount or fuel moisture content (Table 1). Higher air temperatures and fuel amounts produced more intense fires and increased mesquite topkill (Figure 1). Greatest variability in mesquite response occurred when air temperatures were between 17 and 22 ^{o}C (62 to 68 ^{o}F). As fine fuel moisture content increased, percent topkill by fire decreased.

Topkill increased when fires were conducted under lower RH, but this relationship was found only on the Y Ranch and not the Waggoner plots (Table 1 and Figure 1). While fuel moisture was linked to mesquite response to fire at both sites,

Table 1. Regressions between weather and fine fuel during the fires and mesquite topkill. Values are r^2 of linear regressions. Based on plot means (n= 18-20).

Independent Variable	r^2
Fine Fuel Amount (kg/ha)	0.52**
Fine Fuel Moisture (%)	0.63**
Air Temperature ^{o}C	0.73**
Relative Humidity (%)	0.47**
RH at Ninemile only	0.17
RH at Y Ranch Only	0.92**
Wind Speed (kph)	0.03

* = significant at p<0.01; ** = significant at p<0.001.

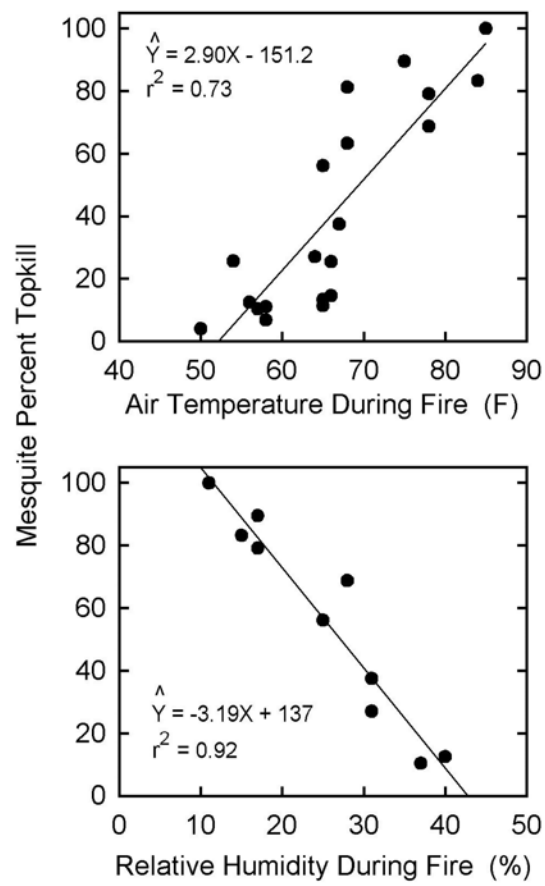

Figure 1. Relationships between air temperature and relative humidity just prior to a fire and percent of mesquite topkilled by the fire. Each point represents a separate fire. Top: data from Waggoner and Y Ranch. Bottom: data from Y Ranch only.

factors that affected fuel moisture differed between sites

Air temperature and relative humidity affected fuel moisture at the Y Ranch site because it was dominated by warm-season grasses (tobosagrass, buffalograss) which were dormant and had abundant standing dead tissue at the time of burning. In contrast, cool season grasses (Texas wintergrass, Japanese brome) at the Ninemile sites were often green at the time of burning and less affected by changes in relative humidity. At this site, air temperature and relative humidity did not affect mesquite response to fire because they had little effect on fine fuel moisture content

Mesquite responses to fire temperature variables were more related to fire temperature at 1-3 m than at lower heights (Table 2). There was a strong positive relationship between fire temperature duration in seconds over 100 ^{o}C (i.e., FTD100) at 1-3 m height and mesquite topkill (r^2=0.74). Mesquite topkill for the stand exceeded 50% if fire temperature at 1-3 m above ground was greater than 100 ^{o}C for more than 25 sec. Relation between topkill and FTD100 at other heights (ground level and 10-30 cm) was not as strong as between FTD100 at 1-3 m and topkill.

Table 2. Regressions between fire temperature duration (FTD) in Seconds Over 100 ^{o}C at various heights above ground during fires and mesquite percent topkill. Values are r^2 of linear regressions. Regressions are based on plot means (n= 18-20).

Independent Variable	r^2
FTD; Seconds >100 ^{o}C (0 cm)	.19
FTD; Seconds >100 ^{o}C (10-30 cm)	.39*
FTD; Seconds >100 ^{o}C (1-3 m)	.74**

* = significant at p<0.01; ** = significant at p<0.001.

Discussion

Variability of mesquite response to fire may enhance opportunities to manipulate growth form and provide alternative management strategies for this species (Ansley et al. 1998). Knowledge of relations between climate, fuel, fire temperature and mesquite response is critical to forming a predictive platform for manipulating mesquite growth form with fire. This has particular significance if the management goal is not to topkill mesquite but merely to reduce some foliage and preserve a growth form which facilitates savanna development (Ansley et al. 1997a, 1997b). Results from this study suggest that fire behavior and mesquite canopy responses to fire can be manipulated to meet a variety of management goals by burning at selected times when weather and fuel conditions are appropriate At study initiation we hypothesized that fire interrupts a physiological mechanism in mesquite by destroying phloem at stem bases. In this process, fire girdles the stem bases and the above-ground portions of mesquite are physiologically separated from roots. Our data suggest that this is not the case and that the topkill mechanism is related more to fire temperature within aerial portions of the canopy than at stem bases. The “topkill mechanism” appears to involve convective heat enveloping aerial portions of mesquite rather than destroying stem bases. We hypothesize that fire temperatures at upper heights caused the differences in mesquite topkill response to fire.

If mesquite topkill is dependent on fire temperature at higher positions above ground (1-3 m), factors that influence fire temperature at these heights, like air temperature and relative humidity, are as important as understory fine fuel in affecting topkill. This study suggests fire temperature at these upper heights are affected more by air temperature and relative humidity than by fine fuel amount or fuel moisture content. The implications are that under adequate understory herbaceous fine fuel amounts to carry a fire, degree of honey mesquite topkill or partial defoliation of non-topkilled plants is largely a function of the air temperature and relative humidity under which the fire is conducted.

References

Ansley, R.J., J.A. Huddle, B.A. Kramp and T. Tunnell. 1997a. Using fire to sculpt brush. Pages 99-108 In: D. Rollins, D.N. Ueckert and C.G. Brown (eds). Proceedings: Brush Sculptors Symposium, Uvalde, August 21-22 and Abilene, Sept. 17-18, 1997, TAEX Misc. Pub., TAES-San Angelo. 150 pp.

Ansley, R.J., B.A. Kramp, and T.L. Moore. 1997b. Development and management of mesquite savanna using low intensity prescribed fires. Pages 155-161 In: J.M. Greenlee (ed). Proceedings: Fire Effects on Threatened and Endangered Species and Habitats Conference, 13-15 Nov. 1995, Coeur d'Alene, ID. International Association of Wildland Fire.

Ansley, R.J., D.L. Jones, T.R. Tunnell, B.A. Kramp and P.W. Jacoby. 1998. Honey mesquite canopy responses to single winter fires: relation to fine fuel, weather and fire temperature. International Journal of Wildland Fire 8: 241-252.

Ansley, R.J, and P.W. Jacoby. 1998. Manipulation of fire intensity to achieve mesquite management goals in north Texas. Pages 195-204 In: T.L. Pruden and L.A. Brennan (eds). Fire in Ecosystem Management: Shifting the Paradigm from Suppression to Prescription. Tall Timbers Fire Ecology Conference No. 20. Tall Timbers Research Station, Tallahassee, FL.