The Influence of Fire on Important Range Grasses of East Africa

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THE PROBLEM

GRASSLAND burning has long been recognized as a major factor in maintaining balance in bush–grass vegetation patterns throughout East and Central Africa (Busse, 1908; Phillips, 1930). Recently, due to increased livestock grazing and fewer fires, bush encroachment has become a primary problem in the maintenance of the grassland resource of East Africa (Bently, 1963; Ivens, 1965; Naveh, 1966a; Skovlin, 1970; van Rensburg, 1969). In Kenya alone bush is a serious problem on at least 25 million acres (Heady, 1960). Moreover, it has been amply demonstrated that a large part of the present grassland "savanna" ecosystem is capable of becoming bushland (Glover, 1966).

In reviewing the need for coordinating regional range research, Naveh (1966b) said, "Bush encroachment is without doubt the most

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serious threat to the productivity of East African ranges, and should receive therefore the highest priority in any research programme."

LITERATURE REVIEW

Other reviewers have presented evidence showing that fire, when controlled, is a very useful, economical means of suppressing undesirable woody plants in grassland (Daubenmire, 1968; Langlands, 1967; Phillips, 1965; West, 1965).

In East Africa there is a lack of information on long term fire research from which to evaluate burning response. In Central Africa, Trapnell (1959) reported on woody species susceptibility from trials begun in 1935. From similar work in that region, prescriptions for burning and grazing have long been developed for various rangeland habitats (Kennan, et al., 1955).

Edwards (1942), working near Nairobi in perhaps the first East African burning and grazing study, showed that fire could favor certain desirable grasses at the expense of woody plants; protection from fire, and sometimes from grazing, often suppressed the desirable grasses. Observations elsewhere in Kenya (Bogdan, 1954), Tanzania (van Rensburg, 1952), and Uganda (Masefield, 1948) have largely substantiated his findings.

More recently, Thomas and Pratt (1967) proposed a burning regime for restoring certain acacia thickets for grazing and emphasized that woody plant susceptibility depended as much on season and frequency of fire as on general tolerance of species. They also suggested that at least one ton of dry grass fuel per acre was required to suppress most species.

Locally, most of the debate on the merits of fire is based only on limited experience or hearsay because facts on the effects of fire on species survival and growth are lacking. Heady (1960) suggested, "Experiments on the effects of burning in East Africa are lacking and must be carried out before definite burning practices can be either recommended or condemned." Unfortunately, much of the recent burning research has been either chance observation of wildfire or planned studies conducted under very unpredictable conditions of "controlled" burning (Ivens, 1970). Apart from the lack of long term studies, most of the knowledge gap stems from an inability to properly isolate burning conditions in order to assess the effects of fire.

THE STUDY

Recently, simulated approaches to the study of fire and related burning problems have been developed (Jameson, 1961; Owensby, et al., 1970; Stinson and Wright, 1969; Wright and Klemmedson, 1965). These techniques hold promise in providing quick answers to land management problems in emerging countries where time and money for research and development are in short supply.

The present study employed controlled experimental burning to individual plants in situ so that responses could be accurately measured.

Marked plants were burned at (1) two temperature levels and (2) two periods in the dry season. During the post-burn growing season, plants were observed for (A) mortality or (B) phenology and (C) vigor.

The purpose for studying level of fire was to duplicate the extremes of heat normally encountered in controlled burning. Low level temperature represented one season's accumulated dry grass fuel for periodically checking steady bush encroachment. High level burning temperature represented fire conditions under an added season's fuel for controlling bush on more heavily infested rangelands (Thomas and Pratt, 1967).

One of the purposes for assessing season of fire was to offer alternatives for suppressing types of bush having different growth habits. For example, deciduous bush often begins growing in the late dry season before the rains; however, evergreen bush is more active in the early dry season. Timing of fire for killing bush should be determined by the phenology of the species to control (Glover, 1967). When the purpose of burning is only for improving rank forage or attracting game, cool fire provided by early burning is usually preferred (Lemon, 1968).

Four stations across southcentral and eastern Kenya were chosen to represent different habitat types (Fig. 1). These stations represented a transect about 300 miles (480 km) in length and a change

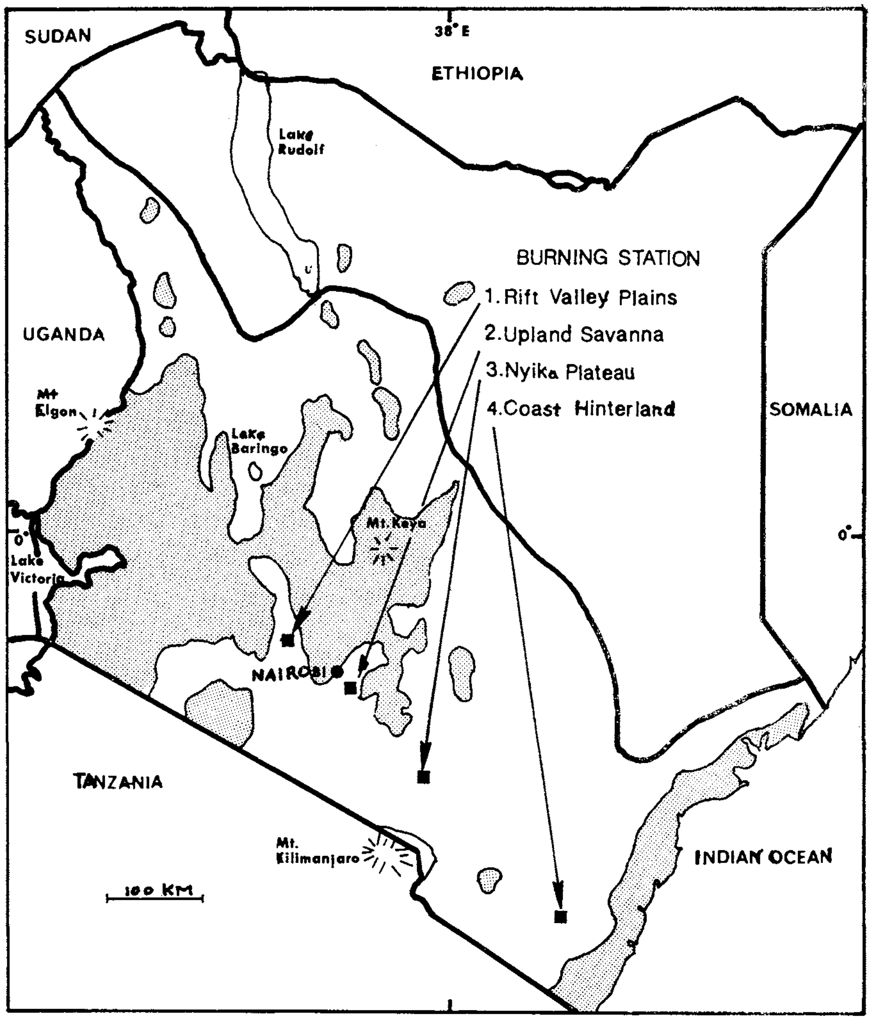

FIG. 1. A map of Kenya showing the location of four burning study areas. Shaded parts portray high-potential regions in contrast to the remainder which is principally rangeland. Most of the arid northeast territory is not suitable for burning.

in elevation of about 5,000 feet (1,525 m). This transect, beginning high in the Rift Valley and descending nearly to the tropical coastline, displayed a gradient from semi-arid to sub-humid. Habitat features are shown for each station (Table 1).

TABLE 1. FOUR STUDY AREA STATIONS AND THEIR SITE CHARACTERISTICS.

Station[1] and habitat[2] type	Location	Elevation	Rainfall[3]	Ecological zone[4]	Substratum
		Feet (*Meters*)	*Inches* (*mm*)		
1. Rift Valley Plains Kedong Ranch Bush Savanna	0°55′S 36°30′E	6,200 (1,890)	28.2 (716)	IV	Poorly structured pumicite over volcanics
2. Upland Savanna Athi Ranch Open Tree Savanna	1°21′S 37°04′E	5,100 (1,555)	23.4 (595)	V	Gray clay loam over basement system
3. Nyika Plateau Kiboko Range Bush & Woodland Steppe	2°17′S 37°42′E	3,300 (1,005)	22.8 (579)	V	Red sandy clay loam over basement system
4. Coast Hinterland Buchuma Range Coastal Woodland	3°42′S 38°57′E	1,200 (365)	27.8 (705)	V	Red sandy loam over basement system

[1] Stations 1 and 2 were experimental range areas maintained by the East African Agriculture and Forestry Research Organization, Muguga, Kenya, and Stations 3 and 4 were range research areas maintained by the Ministry of Agriculture, Nairobi, Kenya.

[2] Physiographic study area names are local terms, place names are vernacular for research areas, and physiognomic names are taken from Rattray (1960) representing his T–13, H–25, C–1, and PA–2 grassland mapping types, respectively.

[3] Rainfall averages are taken from the nearest long term meteorological stations at Mt. Margaret (1), Athi River (2), Makindu (3), and Mackinnon Road (4), with 45, 57, 49, and 48 years of observation respectively.

[4] Ecological zones are after Pratt, Greenway, and Gwynne (1966).

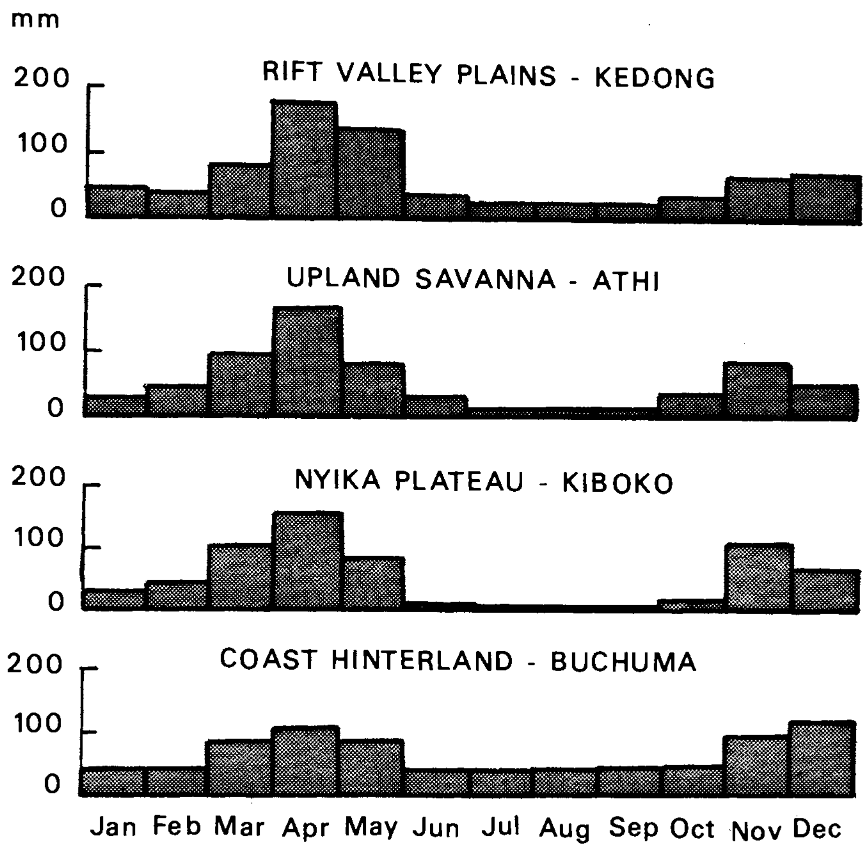

FIG. 2. Monthly rainfall averages near the four burning stations show patterns that are strongly bi-modal. Except in the Rift Valley, they produce two distinct growing seasons.

In eastern Kenya, the monsoon periods produce a "long" rainy season beginning in March and a "short" rainy season beginning in November. Differences in annual rainfall among stations were not great (Fig. 2). However, seasonal distribution and other climatic factors such as evaporation caused some time variation in growing cycles.

Grasses observed were: *Chloris roxburghiana* Schult. (*C. myriostachya* Hochst.), *Digitaria milanjiana* (Rendle) Stapf. (var. *macroblephara*).[2]

[2] For varieties of *Digitaria milanjiana,* see Edwards and Bogdan (1951).

Hyparrhenia lintonii Stapf.,[3] *Panicum maximum* Jacq., *Pennisetum mezianum* Leeke., and *Themeda triandra* Forsk.[4] Only *T. triandra* was common to all stations. However, other species studied were usually represented on at least two stations.

Bush and trees, usually acacia and commiphora, were common on all but the upland savanna; however, none occurred on the burning sites.

METHODS AND MATERIALS

Field Technique

Mature plants were chosen at random within a belt transect. During establishment, litter, debris, and adjacent vegetation were cleared away by hand for about one-half meter around all observation plants. Calibration measurements on each plant were made prior to burning dates.

Ten individual plants of a species represented the minimum number of replications per burning treatment at each station; also each treatment had at least 10 unburned control plants. Extremely large or small plants were avoided during establishment, but a wide variety of intermediate sizes allowed for stratification to evaluate burning response according to large and small plants.

A standard amount of dry fuel, finely shredded woodwool excelsior from *Podocarpus* sp., was loosely positioned around assigned plants. A portable ignition barrel and a wind baffle were then placed over the prepared plant. The fuel was ignited with a gas torch and uniform levels of heat were generated near the plant crown.

Design

The first phase of study evaluated the effects of two levels of late dry-season burning. Burning treatments were accomplished just prior to the long rainy season of March and April, 1970. Because wildfire was common at all periods of applied burning, transect areas were protected by double-break fire lanes.

[3] "A revision of the genus *Hyparrhenia*," by Clayton (1969), Kew Series II, London, has suggested *H. lintonii* is not sufficiently different from *H. papillipes* (Hochst. *ex* A. Rich.) Anderss. *ex* Stapf. to merit separation.

[4] Except where indicated, plant names are taken from Bogdan (1958).

Levels of high or low burning employed 15 or 90 grams of fuel which produced temperatures of approximately 300 or 600 F (150 or 315 C) at the plant crown respectively. Preliminary thermocouple pyrometer tests showed that temperatures above the lethal limit of 150 F (65 C) (Byram, 1958; Hare, 1961) lasted for about two and four minutes for each volume of fuel. These characteristics of heat flux compared closely to low and high production (2,000 and 6,000 pounds/acre) of dry standing grass under natural burning conditions (Stinson, 1968).

Season of burning was the second phase of study. Here, early and late season burning were compared during the long dry season of 1970. Using a heat level intermediate between the low and the high (50 g of fuel) half the plants were burned during mid-August and the remaining half during mid-October. Season-of-burning treatments were superimposed on the earlier level of burning treatments in a compensating crossover technique.

Plant measurements prior to burning involved vigor and basal (plant crown) area. Vigor assessment consisted of height, number of seed stalks, and weight of herbage. Observations on post-burn growth were of mortality, flower stalk height, number of exerted or retarded flower stalks, and basal area. Final measurements and terminal harvest were accomplished in mid-January 1971 following growth after the short rainy season of 1970.

RESULTS AND DISCUSSION

Growth and Development

At upland stations there was little apparent difference in rates of growth between burned and unburned control plants. However, in the Coast Hinterland unburned plants showed earlier initiation and more rapid growth than burned plants (Table 2).

Direct effects of burning often caused some reduction in living plant parts, whereas indirect effects were retardation in growth rate Fig. 3). One month after the onset of rains, unburned *Panicum maximum* plants at the Coast Hinterland had nearly half of their flower heads exerted, but none had yet emerged on burned plants. All flower heads of *Themeda triandra* had exerted on control

TABLE 2. THE INFLUENCE OF LATE SEASON BURNING ON SUBSEQUENT LEAF GROWTH OF TWO GRASSES AT THE COAST HINTERLAND STATION.[1]

Species	Burned	Control
	Centimeters	
Panicum maximum	22.6	27.1
Themeda triandra	9.5	10.8

[1] Averages are based on terminal leaf height of the 10 longest blades per plant using 20 plants per treatment.

plants, but only one in 10 of those on burned plants were showing.

These phenology findings differ from reports on temperate regions of Africa (Scott, 1934; Phillips, 1936). This is not unexpected because in temperate regions low soil temperature often limits post-burning shoot growth (Ehrenreich, 1959).

FIG. 3. During the growing season, burned plants (center) produced shorter leaves and later-appearing flower stalks than their counterpart control plants (foreground).

TABLE 3. AVERAGE SURVIVAL OF SIX RANGE GRASSES IN SOUTHCENTRAL AND EASTERN KENYA FOLLOWING ONE, TWO, OR THREE SEASONS OF BURNING.[1]

Species	Number of Seasons One	Two	Three
		Percent	
Chloris roxburghiana	100	90	—
Digitaria milanjiana	100	98	—
Hyparrhenia lintonii	100	—	—
Panicum maximum	100	100	98
Pennisetum mezianum	100	100	—
Themeda triandra	100	99	97

[1] Weighted average of burned plants only for combined stations.

MORTALITY AND SURVIVAL

In general, all six grasses were very tolerant of burning (Table 3). No plants died as a result of the first late dry season high or low burning treatment. Five of the six species were subsequently burned early or late under diminishing and below normal rainfall. Still, only one species (*Chloris roxburghiana*) showed any appreciable mortality.

Only two species (*P. maximum* and *T. triandra*) of the original six were burned for three successive seasons. Again, with subnormal rainfall compounded, neither species was unduly stressed.

Generally, mortality was higher on species burned at the coastal station than the same species burned at upland stations.

EFFECTS ON VIGOR

The effect of burning on plant vigor must also be determined because the recovery period after burning is a critical phase in grazing management (Heady, 1960; Pratt, 1967).

Generally, species showing greatest mortality were also those most affected in vigor (Table 4). *Chloris roxburghiana* area and herbage on burned plants averaged about half that of unburned plants. Seed stalk production of *Digitaria milanjiana* was diminished by well over half as a result of burning. The number of stolons, however, appeared to be slightly increased in a compensating manner. *Hyparrhenia lintonii*, although not replicated, seemed to be slightly improved by burning.

Area and herbage of *Panicum maximum* was not much affected by fire, but seed stalk numbers were greatly reduced. All plant

TABLE 4. AVERAGE HERBAGE AND SEED STALK PRODUCTION FROM BURNED AND UNBURNED PLANTS OF SIX SPECIES; TREATMENTS AND STATIONS COMBINED

Species	Number	Area		Herbage[1]		Seed Stalks	
	Burned	Burned	Un-burned	Burned	Un-burned	Burned	Un-burned
		Centimeters[2]		Grams		Number	
Chloris roxburghiana	80	55	102	3	6	6	9
Digitaria milanjiana[2]	100	54	89	5	9	2	7
Hyparrhenia lintonii	20	204	157	67	68	83	73
Panicum maximum	120	220	222	32	34	5	9
Pennisetum mezianum	60	111	117	8	11	3	4
Themeda triandra	240	99	125	24	27	19	20

[1] Production is adjusted to an air-dry basis.
[2] *Digitaria milanjiana* var. *macroblephara* also produces stolons. In this study, only stolons contacting the soil were counted.

characteristics of *Pennisetum mezianum* were somewhat retarded by fire. *Themeda triandra* showed slightly reduced area and herbage output, but little if any reduction in seed stalks.

Despite rather large average differences in some species, the analysis showed variation among stations which masked strong treatment expression.

LEVEL OF BURNING

Comparisons of burning levels show that response between species is different and that for a given species response may vary by area (Table 5). For example, at the Nyika station only, *T. triandra* reacted more vigorously to high burning than low burning. What is more, high burning of *T. triandra* here resulted in more vigorous production than even the unburned control plants. Burning of other species at this station retarded vigor over control plants; however, in nearly all other species high burning was superior to low burning.

Generally, differences between high and low late season burning were not significant.[5] However, the combined difference for high and low burning compared with unburned control plants was often real.

[5] Significant and highly significant differences mean differences at the 95 and 99 percent probability levels, respectively.

TABLE 5. THE EFFECTS OF BURNING LEVEL ON HERBAGE AND SEED STALK PRODUCTION OF SIX GRASSES AT FOUR STATIONS

Stations and species	Herbage High	Herbage Low	Herbage Control	Seed stalks High	Seed stalks Low	Seed stalks Control
	Grams			Number		
1. Rift Valley (Kedong)						
Hyparrhenia lintonii	64	70	68	76.1	90.1	72.7
Themeda triandra	19	22	21	28.1	35.1	30.6
2. Upland Savanna (Athi)						
Digitaria milanjiana	5	8	9	0.6	1.6	3.0
Pennisetum mezianum	9	12	13	4.2	5.4	4.8
Themeda triandra	8	8	14	6.8	4.8	9.7
3. Nyika Plateau (Kiboko)						
Chloris roxburghiana	2	2	4	1.0	1.7	2.6
Digitaria milanjiana	8	8	15	0.4	0.2	1.5
Panicum maximum	26	23	31	15.1	16.5	18.5
Pennisetum mezianum	8	7	8	1.0	0.3	0.2
Themeda triandra A	20	14	12	9.7	5.8	6.2
Themeda triandra B	28	23	19	13.9	10.0	9.1
4. Coast Hinterland (Buchuma)						
Chloris roxburghiana	7	8	16	14.4	12.3	22.4
Digitaria milanjiana	8	10	12	2.4	3.3	13.2
Panicum maximum	31	27	32	5.3	6.1	12.4
Themeda triandra	26	32	36	3.8	3.9	5.6

[1] Late season burning treatments were done during March 5–15, 1970; long rains began during March 25–30.

In *Chloris roxburghiana,* which occurred at the Nyika and coastal stations, differences in herbage and seed stalk production due to burning were not significant. However, the difference in plant area for high and low burning combined, 80 cm^2, compared with that for control plants, 111 cm^2, was highly significant.

Digitaria milanjiana, occurring at three of the four stations, showed seed stalk and area differences between burned plants and control plants that were significant; also, differences for herbage weight were significant at the 90 percent level of probability. *P. maximum,* although only occurring at two stations, displayed differences in seed stalks and area that were of the same magnitude as those for *D. milanjiana. T. triandra,* which occurred at all stations, showed meaningful differences in herbage weight between burned and control plants but only at the 90 percent level of probability.

Differences displayed by species of *Hyparrhenia* and *Pennisetum* were not significant. However, *H. lintonii* was the only species studied that showed net increases from burning over control plants in all three vigor attributes.

Season of Burning

Results from early or late season burning were available only from two locations, the Nyika and Coast Hinterland Stations. The Upland Savanna Station had been treated but at the time of writing no meaningful rainfall had occurred for 11 months. For both the Nyika and coastal stations, current growing season rainfall was slightly below half of the normal amount; the previous season's rainfall was slightly above half of normal.

Herbage at these two stations was generally less than half the amount produced during the previous season, yet seed stalk numbers were only slightly reduced. Although most species were more vigorous at the coastal station than at Nyika after the first burning, only *C. roxburghiana* was decidedly better after the second burning (Table 6).

Direct comparison between early or late burned plants and unburned control plants is not appropriate. This is because the seasonally burned plants had a previous burning but control plants did not. Apart from this feature, a comparison does show differences resulting from two seasons of burning as opposed to two seasons without burning for control plants.

Seasonal responses to burning were not consistent. In general, no species showed a clear-cut advantage from early burning. However,

Table 6. Effects of Burning Season on Herbage and Seed Stalk Production of Four Grasses at Two Stations[1]

Station and species	Herbage production[2]			Seed stalks		
	Early	Late	Control	Early	Late	Control
	Grams			Number		
Nyika Plateau (Kiboko)						
Chloris roxburghiana	0.2	0.3	1.3	0.2	0.1	1.1
Digitaria milanjiana	3.5	4.0	6.5	4.5	3.2	7.2
Panicum maximum	[3]	[3]	[3]	0.3	0.6	2.8
Themeda triandra	14.3	10.4	15.1	27.2	15.0	27.4
Coast Hinterland (Buchuma)						
Chloris roxburghiana	2.0	0.9	3.4	5.6	4.5	11.2
Digitaria milanjiana	1.8	1.9	3.3	4.3	1.7	10.5
Panicum maximum	7.2	9.0	15.0	0.0	0.1	1.7
Themeda triandra	5.4	4.5	9.5	0.1	0.5	1.1

[1] Each entry represents the average measurement from 10 or more plants.
[2] Production is adjusted to an air-dry base.
[3] Herbage of *Panicum maximum* at Kiboko was defoliated by a local infestation of army worm several weeks before measurement.

there were trends showing that some species did benefit more from late burning.

D. milanjiana produced larger plant crown areas under late burning than under early burning, a difference that was significant. Late burning also resulted in larger average herbage and stolon production than early burning. On the other hand, seed stalk numbers showed opposite trends.

Despite rather large average differences in production of *T. triandra* between early and late burning, they were not significant. There was essentially no difference in average crown areas of burned plants due to season fire.

Inspection of results from separate stations showed that *T. triandra* was especially favored by early burning at the Nyika site. Also, *C. roxburghiana* was probably favored by early burning at the coastal station.

Unreplicated information on *Pennisetum mezianum* at Nyika station showed higher production under late burning than early burning, differences that were significant in all three measured responses.

SUMMARY

Preliminary results from levels and seasons of burning six forage grasses at four different locations throughout southcentral and eastern Kenya showed that species often react differently to similar fire conditions. Also, plants of a species in one location may react differently than plants of the same species at another location under the same burning conditions.

Burning retarded development of all species studied at one location as compared with controls; however, burning did not measurably affect development of the same species at other locations.

Plant survival, even under conditions of repeated burning and moisture stress, was generally high. Apart from *Chloris roxburghiana*, which suffered 10 percent mortality following the second burning season, all species maintained at least 95 percent survival.

Burning usually had the effect of reducing the crown area, herbage weight, and seed stalk numbers of nearly all species studied. *Chloris*

roxburghiana, Digitaria milanjiana, and *Panicum maximum* were particularly affected. *Pennisetum mezianum* and *Themeda triandra* were little affected by burning. *T. triandra* showed a wide tolerance for burning. *Hyparrhenia lintonii,* the exception, appeared to be improved by burning.

Generally, low temperature burning in the late dry season had less harmful effects on vigor than highlevel late season burning. However, there were exceptions. At the Nyika Plateau Station, high burning did not adversely affect any species and actually improved some species compared to low burning. Here, high burning on *Themeda triandra* plants even outproduced counterpart unburned control plants. In the case of *Hyparrhenia lintonii* at the Rift Valley Station, low burning provided slightly better average production than controls.

Season of burning produced some varied responses among species. In general, there was little difference between early dry season and late dry season burning. However, where differences did occur, late season burning seemed to be less harmful to herbage production than early burning. *Digitaria milanjiana* and apparently *Pennisetum mezianum* were favored more by late dry season burning.

Results show that response of grasses to burning varies among species. Also, species response to levels or seasons of burning can vary considerably between habitat systems.

This study highlights the need for intensified burning research. Although local field application of many findings are appropriate, long term applied burning studies with controlled grazing are needed.

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