# Effect of fire burning interval on species composition, herbage yield and bush control in the savanna of eastern Botswana

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## ABSTRACT

The purposes of this study were to examine the effects of various fire burning intervals on the dynamics of woodland structure and the resultant herb layer in the savanna vegetation of eastern Botswana. Plots of 1.2 ha were burnt at the interval of 0, 1, 2, 3, 4, and 5 years, using head fires from 1958 to 2003 in an *Acacia nigrescens/Combretum apiculatum* tree vegetation. In 1982 and 2003 the first and second evaluations, were assessed for bush density, grass basal cover, grass yield, composition and for soil properties when all burning treatments coincided for the first and second time, respectively. The data were analyzed using ANOVA procedure in Statistical Analysis System and means were separated using the Fisher's test. Annual burning revealed an increase in the vigour and abundance of *Eragrostis regidior and Bracharia nigropedata* while *Digitaria eriantha a*nd litter accumulation increased with less burning frequency. Total grass basal cover was increased although not significantly (p>0.05) from 2.43±2.25% in 1982 to 3.08±0.52% in 2003. Fire was successful in opening up woodland structure by shifting large trees to smaller size classes. Total woody plant density declined although not significantly in 2003 (1498±154 plants per ha) compared to 1982 (1623±285 pants per ha). The changes in soil properties resulting from low frequency of burning were small to account for any differences in vegetation composition. In the semi-arid savanna, once fire is used to control bush, it should not be a one time activity, but should be continued in order to control the re-growth of recruited seedlings and preventing their recruitment to adulthood.

**Keywords:** Botswana, Bush encroachment, fire, grass frequency, woody plant density

## INTRODUCTION

Bush encroachment is one of the major problems in the savanna areas of Botswana threatening the viability of livestock farming. The reduction in grass growth due to bush encroachment and the responses of bush clearing in terms of increased grass dry matter yield and basal cover are well documented elsewhere (Anon, 1978; Pratchatt 1978; Staurt-Hill, 1987; Lonsdale and Braithwaite, 1991; Smit and Rethman, 2000). Aucamp *et al.* (1984) indicated that at densities of 1000, 1500 and 2000 trees per hectare, grazing capacity of the range can be estimated to be 90, 67 and 32 percent of its potential, respectively. In Southern Africa's grazing systems, overstocking of cattle is held responsible for opening up the herbaceous layer resulting in bare soil patches, with increased amount of moisture penetrating to depth and serving to promote the growth and establishment of certain woody plant species (bush encroachers) (Van Vegten; 1981 & 1983; Skarpe, 1992, Moleele, 1998). Other hypotheses that account for bush encroachment include lack of fire due to insufficient fuel load, inadequate browser animals to suppress woody plants growth and soil nutrient concentration. The normal prevailing ecological equilibrium between woody plant species and herbaceous layer is disturbed in favour of woody species (Walker, 1964; Anon, 1975; Abel *et al.*, 1984; and Scholes and Walker 1993).

Considerable research efforts have been expended on both chemical and mechanical methods of bush control in Botswana (Anon, 1978; Pratchatt 1978), in South Africa (Donaldsn, 1970), in Zimbabgwe (Kelly, 1977) and elsewhere. A combination of the effects of fire and browser animals as management tools for bush encroachment have been explored (Sweet and Mphinyane, 1986; Trollope and Dondofema, 2003). In the latter study, on average, completely cleared pastures produced an average of approximately 20% more yield of grass than areas not cleared for all years. However, this improvement is considered not economic in the semi-arid environments of Botswana due to the cost associated with clearing high density of bushes. Furthermore, clearing fails to increase the potential grazing capacities to any significant value (Anon, 1978). There is therefore need for low cost means of bush control in such environments.

In an analysis of woody plant cover using a mosaic of images comprised of forty Landsat Thematic Mapper in south eastern Botswana, Moleele *et al.* (2002) indicated that the average of woody cover of all types is around 16%. There appeared by then to be a potential extent of 37 000 km$^2$ of bush encroached/potential browse areas. These occur extensively throughout the country but appear to predominate the south eastern parts of the Kalahari (Moleele *et al.*, 2002).

The use of fire as a management tool for controlling bush encroachment is an attractive option for rangeland managers, because it is a low cost technique, compared to chemical or mechanical bush control methods which involve relatively high costs (Anon, 1978; Pratchart, 1978; Vallentine, 1989). Trollope (1980) indicated that fire favours the development and maintenance of a predominantly grassland vegetation by destroying the juvenile trees and shrubs and preventing the development of more mature woody plants to a taller fire-resistant stage.

The main thrust of the investigation was based on the hypothesis that fire can control bush encroachment and maintain it at an available height to browser animals and improve the herb layer. The objectives of this study were to evaluate the effects of burning intervals on woody plant structure, herbaceous species composition, yield and basal cover in the savanna of the eastern hardveld of Botswana.

## METHODS AND MATERIALS

### Study Site

The trial was conducted at Morale ranch, 7 km south of Mahalapye in eastern Botswana at 23$^0$ S and 27$^0$ E. at an elevation of 998m. The vegetation consists of *Acacia nigrescens/Combretum apiculatum* tree savanna of the eastern hardveld (Weare and Yalala, 1971). Low growing shrubs include *Grewia species, Dichrostachys cinerea* and *A. erubescens.* Major Grass species are *Panicum maximum, Eragrostis rigidior, Digitaria eriantha, Urochloa species, Aristida congesta and* various species of forbs. The soil type is ferric or chromic luvisols/cambisols (Bawden and Stobbs, 1963; FAO, 1991). These soils are non-calcareous, coarse loamy and well-drained. Temperatures above 33$^0$ C are common in summer, and they sometime decline to 3$^0$ C in winter. Long-term average rainfall is 450mm per annum and occurs mostly between October and April (Bhalotra 1987).

### Procedure

In 1958 six plots of 1.2 ha were demarcated and protected by 6 m wide permanent fire-breaks, which have been burnt annually during the dry season in *Acacia nigrescens/Compretum apiculatum* vegetation in eastern Botswana. The plots were burnt at the interval of 0 (no burn), 1, 2, 3, 4, and 5 years, using head fires and it would be suspended during drought years due to insufficient fuel load. The burning treatments were assigned randomly to the six plots. The whole area was protected from grazing by fencing it with a goat and cattle proof fence. The burning programme was first evaluated in 1982 (Sweet, 1982) and again in 2003 (present reporting) when all burning treatments coincided for the second time, respectively, since 1958. Bush density and composition were determined by recording all rooted life trees in five height classes within 50 m by 10 m randomly located belt transects. The five height classes were < 0.5, 0.5 – 1.0, 1.0 – 2.0, 2.0 – 3.0 and >3 m. Grass basal cover was estimated using a modified point frame quadrat (Goodale, 1952) and grass species frequency was determined by one hundred rooted frequency measurements using a 50 cm by 50 cm quadrat with random sampling. The herbage production measure was included in 2003 and was considered an important variable and was determined through clipping randomized 1 $m^2$ quadrats from each plot. Samples from each quadrat were separated into individual grass species and, various forbs lumped together. Soil samples were collected from each plot and tested for pH, organic carbons, phosphorus, sodium, calcium magnesium and cation exchange capacity. Although baseline data was not available, assumptions were that the non-burn plot may provide the somehow data commensurate to that of the initial base data.

The data were analyzed and compared against the non-burn plot using the ANOVA procedure through the SAS package (SAS, 2003), and where differences occurred, means were separated using the Fisher's test.

## RESULTS

### Woody Plant density

The follow-up treatments had been maintained after the first evaluation of the experiment in 1982 and the long term effects of burning intervals on bush density (Table 1). Total number of woody plants in the burned plots increased as burning interval increased from one to five years. On the other hand total plant density in the non-burn plot was generally lower although not significantly (P>0.05) than the annually burned and the two years interval. There were more trees at burning intervals of 3, 4 and 5 years than at 1 and 2 years. Total plant density tended to be higher in 1982 at each treatment compared to 2003 but, however, both evaluations displayed the same pattern of trend (Table 1).

Table 1: Woody plant density (plants/ha) in plots burnt at different intervals for all plant species by height stratum in the savanna of the eastern hardveld of Botswana.

| | Burning interval (years) | | | | | | |
|---|---|---|---|---|---|---|---|
| Height class (m) | 1 | 2 | 3 | 4 | 5 | Control | |
| <0.5 | 405 | 418 | 734 | 800 | 792 | 412 | 593.5 |
| 0.5-1.0 | 530 | 600 | 690 | 820 | 981 | 331 | 648.2 |
| 1.0-2.0 | 78 | 32 | 188 | 117 | 175 | 300 | 148.3 |
| 2.0-3.0 | 60 | 0 | 12 | 20 | 5 | 45 | 23.7 |
| >3.0 | 120 | 40 | 0 | 20 | 25 | 110 | 52.5 |
| Total (2003) | 1093±405 | 1119±379 | 1822±324 | 1777±299 | 1978±480 | 1198±300 | 1498 ± 154 |
| Total (1982) | 1210±413 | 1240±383 | 1870±247 | 1960±337 | 2180±557 | 1280±343 | 1623 ± 285 |

Row values with different superscripts differ significantly at P<0.05

Plant density below the 0.5 m height class was almost twice greater at the 3, 4 and 5 year burning intervals than in the 1, 2 and the non- burning plot. There seemed to be more trees at the 0.5 m – 1.0 m height class than other classes (Table 1). Plant density declined starting at 1.0 m and above height classes. The height classes above 2.0 m had fewer plants, more pronounced at the 2 - 5 years burning intervals.

Table 2: Individual woody plant species composition (%) in plots burned at different intervals in the savanna of the eastern hardveld of Botswana.

| | Burning Interval (Years) | | | | | |
|---|---|---|---|---|---|---|
| Plant Species | 1 | 2 | 3 | 4 | 5 | Control |
| *Acacia nigrescens* | 16 | 15.1 | 21.3 | 3.4 | 7.7 | 6.9 |
| *Acacia tortilis* | 9 | 4.2 | 1.5 | 3.1 | 2.5 | 3.4 |
| *Acacia erubescens* | 5.4 | 8.2 | 8.9 | 8.2 | 6.5 | 10.3 |
| *Acacia spp* | | | 7.5 | 1.9 | 2.5 | |
| *Boscia albitrunca* | *1.7* | 1.3 | 1.9 | 2.5 | 3.4 | |
| *Combretum apiculatum* | 16.0 | 26.6 | 32.8 | 13.1 | 11.7 | 44.9 |
| *Combretum mollie* | *10.2* | 3.4 | 8.2 | 19.7 | 8.2 | 6.9 |
| *Dichrostachys cinerea* | 13.1 | 17.1 | 8.3 | 11.2 | 27 | 6.9 |
| *Grewia bicolar* | *19.4* | 13.4 | 9.9 | 24.4 | 26.4 | 10.4 |
| *Grewia Flava* | *6.7* | *8.7* | 11.2 | 2.5 | 3.5 | |
| *Albezia anthelmentica* | *1.9* | | 1.5 | 1.9 | 2.5 | |
| *Sclerocarya caffra* | *0.6* | 2.0 | 0.1 | | | 3.4 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |

The woody plants, which appeared as tall trees were dominated by *A. nigrescens* and *C. apiculatum*, while the lower bushes consisted of *D. cinerea* and *Grewia spp.* Generally, the proportions of *A. tortilis, A. nigrescens* and *D. cinerea* increased at frequently burned plots then declined at the subsequent burning intervals (Table 2).

There was no consistent trend in the composition of other species as burning interval increased from 1 to 5 years. *C. apiculatum* was higher in the non-burn plot and dominated all other plant species in all treatments (Table 2).

**Grass basal cover**

In general total basal cover of grasses significantly ($P<0.05$) decreased with increasing interval of burning (Table 3). Basal cover in the non-burn plot was however slightly higher than that of 4 and 5 years burning intervals. Total basal cover tended to be higher at each treatment in 2003 compared to that of 1982, but the two evaluations displayed the same pattern of trend except for the three-year burning interval of 1982, which was significantly higher. In the exception of 1982 at two year interval the frequently burnt plots (1 – 3 intervals) exhibited a high total basal cover of grass for both 2003 and 1982 while the 4 and 5 burning interval were lower from frequently burned plots probably implying changes in composition (Table 3).

Basal cover of *E. rigidior* and *B. nigropedata* generally increased with more frequent burning but that of *S.pappophoroides* remained somehow evenly distributed among the treatments. Basal cover of *D. eriantha* increased with increasing burning interval and it was the dominant grass across the treatments with its frequency being highest in the non-burn plot (Table 4).

**Grass frequency**

The frequency of the herb layer was dominated by *D. eriantha, E. rigidior* and to a lesser extent *Schmidtia pappophoroides* and *B nigropedata* respectively (Table 4). *D. eriantha* was the most frequent grass in each treatment and it was more pronounced in the non-burn plot. The frequency of *E. rigidior* and *B nigropedata* exhibited an increase with increasing frequency of burning, suggesting that their vigour was enhanced by fire Grass species of *H. contortus and P. maximum* were not present or very low at one and two years of burning interval. *Schimidtia pappophoroides* was not responsive to burning treatment and somehow remained uniformly distributed across all plots (Table 4).

**Table 3**: Percentage basal cover of grasses in plots burned at different intervals from 1958–2003 2003 in the savanna of the eastern hardveld of Botswana

| | Burning Interval (Years) | | | | | | |
|---|---|---|---|---|---|---|---|
| Grass Species | 1 | 2 | 3 | 4 | 5 | Control | Mean |
| *Aristida congesta* | 0.01 | | | 0.01 | | | 0.003 |
| *Bracharia nigropedata* | 0.35 | 0.15 | | 0.10 | | | 0.10 |
| *Bothriochloa insulpta* | 0.12 | 0.21 | 0.30 | | 0.15 | 0.65 | 0.24 |
| *Digitaria eriantha* | 1.05 | 1.20 | 1.50 | 1.45 | 1.25 | 1.35 | 1.30 |
| Enneapogon cenchroides | | *0.01* | *0.25* | | | *0.15* | *0.07* |
| Enneapogon scorperus | | *0.02* | *0.1* | | | | *0.02* |
| Eragrostis denudate | *0.12* | *0.20* | *1.2* | *0.1* | | | *0.27* |
| Eragrostis rigidior | *1.04* | *0.75* | *0.60* | *0.24* | *0.65* | *0.20* | *0.58* |
| *Panicum coloratum* | 0.10 | | 0.1 | | 0.30 | | 0.08 |
| *Panicum maximum* | | 0.20 | | 0.05 | | 0.05 | 0.05 |
| Schmidtia pappophoroides | *0.31* | *0.20* | *0.30* | *0.20* | *0.25* | *0.20* | *0.24* |
| Tragus racemosus | | | | *0.25* | *0.15* | | *0.70* |
| *Urochloa mossambicensis* | | | | | *0.35* | | *0.06* |
| *Forbs* | *0.15* | *0.01* | | *0.10* | | | *0.04* |
| Total in 2003 | 3.34±0.08[a] | 3.23±0.05[a] | 3.24±0.09[a] | 2.85±0.11[b] | 2.80±0.12[b] | 3.07±0.09[ab] | 3.08 ± 0.52 |
| Total in 1982 | 3.20±0.05[a] | 1.95±0.41[b] | 3.75±0.12[c] | 1.75±071[b] | 1.50±0.65[d] | 2.40±0.31[b] | 2.43 ± 2.25 |

Row values with different superscripts differ significantly at P<0.05

**Table 4**: Herbaceous plant frequency (percent of quadrats in which each species is present) in plots burned at different intervals from 1958–2003 in the savanna of the eastern hardveld of Botswana.

| | Burning Interval (Years) | | | | | |
|---|---|---|---|---|---|---|
| Grass Species | 1 | 2 | 3 | 4 | 5 | Control |
| *Aristida congesta* | *1.0* | *1.0* | *2.0* | *1.0* | *1.0* | |
| *Bracharia nigropedata* | *15.0* | *6.0* | *9.0* | *8.0* | *8.0* | *8.0* |
| *Bothriochloa insulpta* | *1.0* | *2.0* | *3.0* | *1.0* | *2.0* | |
| *Digitaria eriantha* | *41.0* | *47.0* | *40.0* | *44.0* | *45.0* | *55.0* |
| Enneapogon cenchroides | 2.0 | | 1.0 | 1.0 | 2.0 | |
| Enneapogon scorperus | | | 3.0 | 1.0 | | 1.0 |
| Eragrostis denudata | 1.0 | 2.0 | | 3.0 | 1.0 | 3.0 |
| Eragrostis rigidior | 28.0 | 21.0 | 19.0 | 15.0 | 15.0 | 6.0 |
| *Heteropogon contotus* | | *1.0* | *3.0* | *4.0* | *1.0* | *3.0* |
| *Panicum maximum* | | | *1.0* | *2.0* | | *4.0* |
| *Panicum coloratum* | | *1.0* | | *2.0* | *5.0* | *3.0* |
| Schmidtia pappophoroides | 5.0 | 8.0 | 12.0 | 9.0 | 8.0 | 6.0 |
| *Setaria pallide-fusca* | | *2.0* | *1.0* | *2.0* | *5.0* | *2.0* |
| *Tragus racemosus* | *1.0* | *2.0* | | *2.0* | *1.0* | |
| *Urochloa mossambicensis* | *2.0* | *1.0* | *1.0* | *1.0* | *2.0* | *3.0* |
| *Forbs* | *3.0* | *6.0* | *5.0* | *4.0* | *6.0* | *4.0* |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |

### Herbage yield

Although not significantly different, total herbage yield was highest and lowest in the non-burn plot and annually burn plot, respectively (Table 5). Herbage yield increased at 2 and 3 years burned plots, but declined at 4 and 5 years burning intervals, but still remained above the annually burned plot. Herbage yield in the site was dominated by *D. eriantha*, *B. insulpta* and *S. pappophoroides* (Table 5).

Yield of *D. eriantha* and litter accumulation increased with the increasing burning intervals, while that of *E. rigidior* decreased with increasing burning intervals. There was more litter accumulation in the non-burn plot compared to the frequently burned plots, which had no litter. Though *E. scorperus* had a reasonable grass yield, it was poorly distributed among the plots.

### Soil properties

Soil pH ranged from 4.67 to 5.79 across the treatments (Table 6). The annual and non-burn plots had low soil pH compared to other burning treatments. There was however, a trend of increasing pH with decreasing burning frequency. Both the non-burning and annually burnt plots had a reduced level of all soil nutrient status compared to other treatments. Both calcium and potassium levels were high and increased with increasing frequency of burning intervals, the exception occurred in the annually burned and non-burned plots (Table 6).

Phosphorus content increased starting from 4.78 ppm at the non-burn plot up to 13.9 ppm at the two year burning interval. Phosphorus was very low at the non-burn plot. Most soil nutrients were somehow higher and consistent between 2 and 5 year burning intervals as compare to the non-burn and annual burn plots. The soil content of organic carbon and cation exchange capacity declined with annual burning applications.

Table 5: Herbage yield (kg/ha) of grasses in plots burned at different intervals from 1958 to 2003 in the savanna of the eastern hardveld of Botswana.

| | Burning Interval (Years) | | | | | |
|---|---|---|---|---|---|---|
| Grass Species | 1 | 2 | 3 | 4 | 5 | Control |
| *Aristida congesta* | | | | *20.5* | | |
| *Bracharia nigropedata* | 11.8 | | 14 | | | |
| *Bothriochloa insulpta* | 51.8 | 405.8 | 109.5 | 170.5 | 63.5 | 269.8 |
| *Digitaria eriantha* | 132.0 | 183.8 | 204.8 | 175.3 | 249.8 | 242.5 |
| Enneapogon cenchroides | *61.5* | *16.5* | | | | |
| Enneapogon scorperu | | | *471.8* | | *378.0* | |
| Eragrostis denudata | | | *9.5* | *10.5* | *127.8* | *21.5* |
| Eragrostis rigidior | *113.8* | *103.5* | *165.5* | *47.8* | *47.5* | *60.0* |
| *Panicum coloratum* | 78.8 | | 27.8 | 229.0 | 15.3 | |
| Schmidtia pappophoroides | *121.5* | *180.3* | *99.8* | *88.8* | *62.0* | *129.5* |
| Urochloa mossambicensis | *13* | *28.8* | *28.0* | *20.0* | *14.0* | *46.3* |
| *Forbs* | 50.3 | 25.0 | | 43.0 | 54.3 | |
| Litter | | | 137.0 | 83.5 | 166.3 | 269.3 |
| Total (2003) | 634±299 | 953.2±19.7 | 1131.7±198 | 730±303 | 957±25 | 1194.9±261 |
| Total (1982) | n/a | n/a | n/a | n/a | n/a | n/a |

Row values with different superscripts differ significantly at P<0.05. n/a = data on herbage yield was not measured

Table 6: Soil nutrient status in plots burned at different intervals from 1958 to 2003 in the savanna of the eastern hardveld of Botswana.

| Burning Interval | pH ($CaCl_2$) | P (ppm) | OC (%) | CEC Cc mo+/kg) | Exchangeable Cations (c mo+/kg) Mg | K | Ca | Na |
|---|---|---|---|---|---|---|---|---|
| 1 | 4.67 | 6.98 | 0.57 | 5.37 | 1.09 | 0.59 | 2.49 | 0.04 |
| 2 | 5.48 | 13.89 | 0.68 | 6.4 | 1.44 | 0.85 | 6.07 | 0.06 |
| 3 | 4.84 | 7.98 | 0.72 | 6.64 | 1.21 | 0.68 | 3.82 | 0.04 |
| 4 | 5.1 | 6.30 | 0.76 | 6.18 | 1.29 | 0.71 | 3.42 | 0.03 |
| 5 | 5.79 | 5.83 | 0.74 | 6.39 | 1.07 | 0.65 | 3.41 | 0.02 |
| Non-burning | 4.78 | 2.89 | 0.72 | 5.46 | 1.10 | 0.57 | 2.61 | 0.02 |

## DISCUSSION

Fire had a marked effect on woodland structure and induced a shift from the larger to smaller size classes. The shift to smaller size classes was particularly observed amongst individuals below 0.5 and 1.0 m size range and resulted in a major increase in the number of individuals below 1.0 m. These results concur with those from O'Reagain and Bushell (2003) who reported similar findings on their investigation on effect of fire on mortality and regrowth in different savanna communities in Australia. William *et al.* (1999) also observed a decline in large size classes and attributed this reduced survival to approaching senescence. However, in the present study, at least some of the larger trees succumbed to the intense heat generated by burning logs lying adjacent to the trunk, rather than the effects of the fire front per se. These data confirm the expectations of the ability of fire to suppress the development of seedlings and juveniles up to a height of two meters (Trollope, 1980; Sweet, 1982; O'Reagain and Bushell, 2003; William *et al.*, 1999). Suppression of these plants prevented development of 2.0 m – 3.0 m height classes. Sweet (1982) postulated that the presence of the upper stratum (>3.0m) might have developed from trees that were already beyond susceptibility to the earlier burns.

In the height classes below 1.0 m, there was an obvious trend of increasing bush density with less burning intervals from 1 to 5 years, indicating an increasing number of seedlings progressing into these height strata. The fire stimulated recruitment of new individuals into the class below 1.0 m. The seedling recruitment probably resulted from post-fire release of seed from capsules held in the canopy together with the creation of miro-sites such as ash beds. It is likely that fire scarifies the hard seeded woody plants of *D. cinerea* and *Acacia* species, and encourages germination and recruitment. Seeds scarification by fire could explain this trend. This implies that once fire is used to control bush, it should not be a one time activity, but should be continued in order to control the re-growth of recruited seedlings. Hoffmann and Solbring (2003) indicated that recurrent burning enhances mortality by killing young succulent seedlings. In this study, probably the fuel load was not enough to build up high temperatures to kill the seeds and high density of individuals of seedlings below 1.0 m size classes. Subsequent establishment and growth of seedlings would also have been favoured by the above average rainfall received in the wet seasons immediately following fire. The low number of woody plants below 1 m in the non-burn plot could have been attributed by the exclusion of fire in the absence of grazing which also restricted progression of seedlings into a taller phase through suppression by grass cover.

Although total plant density for the two evaluation periods displayed similar pattern of trend, the lower total density for 2003 could have been attributed to the drought condition that occurred starting in 1982/83 season through 1986/87 and repeating itself during the early 1990's which probably resulted in the mortality of woody plants as shown in 2003 evaluation. Even in stable vegetation communities, there continue to be cyclic succession changes on a very local scale (Barbour *et al.*, 1998). These changes occur because the life span over-story is infinite, and their disappearance from the canopy may open the site to an invasion by new species.

Frequency of grass species provides a useful measure of botanical composition of the sward although it is not an absolute measure as basal cover. Trollope (1980) indicated that where an even spatial distribution is reasonable, correlation is expected between basal cover and plant frequency. Intensive sampling by frequency method enabled more of the less dominant species to be detected, but in this study the lack of detection of *P. maximum* by this method suggest that this species was not evenly distributed. It is associated with trees of large canopy size than small trees and does not occur on the open area. Annual burning resulted in a reduced frequency of *D. eriantha* but increased the abundance of *E. rigidior* and *B. nigropedata.*

Total grass basal cover at each treatment was low in 1982 compared to that of 2003, but however, the two evaluations displayed the same pattern of trend except at the three-year burning interval of 1982, which was higher. These findings could be attributed to higher (above average) rainfall amount received during the early 2000's. Grasses are more sensitive to drought than woody plants because of their rooting system. The rate of recovery of basal cover of grass is usually fast. Annual burn plot showed more basal cover probably due to robust tuft species such as *B. nigropedata* and *E. rigidior*, which were favoured by frequent burning compared to other treatments. Basal cover of *D. eriantha* declined with frequent burning suggesting that it is sensitive to frequent burning. However, the lower basal cover of *D. eriantha* did not affect its forage yield.

The burning frequency evaluation revealed that annual burning had negative impact on herbage production, while less frequently burned plots increased their herbage yield but declined as bush density increased. The non-burn plot and the three-year burning interval plots yielded more herbage compared to the annually burnt plot, which had the least. *E. rigidior* and *B. nigropedata* responded by increasing their dry matter yield with increasing fire frequency while *D. eriantha* and litter accumulation increased with less burning frequency suggesting their sensitivity to frequent burning. Herbage yield of the area was dominated by *D. eriantha, B. insulpta, E. rigidior* and to a lesser extent, *S. pappophoroides*. Frequent burning promoted high basal cover, and which is regarded by the rangeland managers as important against soil erosion. Sweet (1982) indicated that in the context of range management, where the rangeland is being grazed by livestock, it is unlikely that in semi-arid environment enough grass cover can be maintained to suppress the development of bush seedlings. Prescribed burning in which grass fuel load is allowed to accumulate may offer a low cost means of bush control, but since the present study did not incorporate the grazing factor, it would seem more practical to include grazing animals as to permit estimation of a suitable burning interval under grazing conditions.

The soil nutrient status results reveal a generally low pH content, which may be attributed to the acid igneous parent material. There was a tendency of pH to increase with increasing burning interval owing to the accumulation of the exchangeable bases from the ashes, notably calcium and magnesium. Organic carbon was considered to be depleted by frequent burning and however, some of the low frequently burn plots showed more organic carbon than the control, probably due to the possibility of the accumulation of charcoal in the burning treatments. Low levels of soil nutrient content in the non-burn plot usually result from locked nutrients in the dry matter content of the standing crop whereas in the burned plots nutrients had been released into the soil through the ashes. Changes in soil properties and botanical composition resulting from low frequency of burning are likely to be small.

## CONCLUSSIONS

Fire was successful in opening up woodland structure by shifting to smaller size classes to a somewhat desired browse-line for the browser-animals. This suggests that in the semi-arid savanna, regular fire could be a successful tool in controlling both woodland structure and density by suppressing small to moderate size classes and preventing their recruitment to adulthood and also by causing slow attrition of plants in the large size class through fire induced mortality. Once fire is used to control bush, it should not be a one time activity, but should be continued in order to control the re-growth of recruited seedlings. Annual burning resulted in a reduced frequency of *D. eriantha* but increased the abundance of *E. rigidior and B. nigropedata*. *E. rigidior* and *B. nigropedata* responded by increasing their dry matter yield and basal cover with increasing fire frequency while *D. eriantha* and litter accumulation increased with less burning frequency suggesting their sensitivity to frequent burning. Prescribed burning in which grass fuel load is allowed to accumulate may offer a low cost means of bush control since in practice, where the rangeland is being grazed by livestock, it is unlikely that in semi-arid environment enough grass cover can be maintained to suppress the development of bush seedlings, but since the present study did not incorporate the grazing factor, it would also seem more practical to include grazing animals as to permit estimation of a suitable burning interval under grazing conditions.

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