Short-term influence of fire in a semi-arid grassland on (8): two less palatable grass species (*Cymbopogon plurinodis* and *Elionurus muticus*)

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Introduction

The problem of selective grazing in semi-arid grassland areas, especially as the season's progress, is well known to South African farmers (Danckwerts and Teague 1989; Tainton and Mentis 1984; Tainton *et al.* 1993). In these areas characterized by a moderately high rainfall, moderate summer temperatures and cool winters, the various dominant grass species mature rapidly during the growing season and progressively decline in palatability and nutritive value with advancing maturity (Booysen and Tainton 1984). *Cymbopogon plurinodis* and *Elionurus muticus* are the two species causing more selective grazing problems in these areas than any other species, their unpalatability being due to volatile oils apparently (Opperman *et al.* 1974; Snyman 1999; Danckwerts and Teague 1989). Consequently, undesirable practices such as extensive burning in winter followed by intensive grazing and/or overstocking are adopted in an attempt to utilize these problem species (Booysen and Tainton 1984; Everson 1999). This invariably leads to severe defoliation of palatable species and an eventual deterioration both of the vigour and botanical composition of the grassland (Mentis and Tainton 1984). The same problem occurs with accidental or run-away fires where the above two species are actually rescued from either overgrowth or smothering due to fire and therefore compete more strongly the following season for water and nutrients than the more palatable plants, which were defoliated the previous season and may have less growth reserves and poorer root systems (Snyman 1998). Therefore it was the objective of this study to quantify the short-term (three years) impact of an unplanned or accidental head fire on the dynamics of the unpalatable grass species (*C. plurinodis* and *E. muticus*) in an attempt to establish guidelines for its management.

Procedure

Research was conducted on the Witfontein farm, 16km outside the town of Zastron (30^{o} 15' S, 27^{o} 10' E, altitude 1 652m), which is situated in the semi-arid (summer mean average 629mm) region of South Africa. Rain falls almost exclusively during summer of which 65% occurs from November through March, with a peak (15% of the total) in March. The study area is situated in the moist, cool, Highveld grassland. The botanical composition of the study area was determined by Van der Westhuizen *et al.* (2001) and Van der Westhuizen (2003) from the 1986/87 to the 1999/00 seasons. The grassland was in good condition for commercial livestock production purposes and consisted of a dense sward of perennial grasses such as *Cymbopogon plurinodis*, *Themeda triandra*, *Digitaria eriantha* and *Elionurus muticus*. Perennial grass cover diminished with overgrazing in these areas. Species such as *Eragrostis chloromelas* and poor perennials like *Microchloa caffra* and *Aristida* species are more abundant. Soils in the study area are mostly fine sandy loams of the Estcourt form (Haarlem family – 2200). Clay content increases with soil depth from 11% in the A-horizon (0-300mm depth), to 19% in the E-horizon (300-400mm) and 39% in the B-horizon (400-600mm depth).

The burn treatment was a single accidental wind-driven head fire that occurred on the morning of 27 August 2000, generally a windy time of the year. Moreover, it was a wind-driven head fire (Trollope 1978). The soil and grass fuel were very dry at the time of burning as only 10mm of rain had fallen in the two months preceding the fire. Spring rains of 65mm fell one week after the burn, resulting in regrowth of the grass sward.

No information on fire behaviour could be gathered, as it was an unplanned grassland fire. Due to small temporary roads across the farm, the fire did not burn in a straight line across the farm, but in patches. The research was conducted on six plots of 30 x 30m^2 each, which were randomly set out on the same soil form; half of them on the burnt area and half on unburnt patches. The experimental layout was a fully randomized design with three replications for each treatment. Grazing history of all plots before the fire was assumed to be the same because the sites were set out in the same camp. Experimental layout is fully discussed in Snyman (2003a, 2004a). Grasses in the unburnt plots were cut at a height of 30mm 1 week after the fire. The burnt and unburnt grassland were studied from the 2000/01 to 2002/03 growing seasons (September to April). At the end of each season (April), every treatment was cut at a height of 30mm. This was to compare growth between burnt and unburnt plots. All plots were excluded from livestock grazing for the three-year trial period, with no further accidental fires occurring. Before the fire the grassland was grazed according to the recommended grazing capacity for this grassland type, namely 6ha LSU^{-1} (Van der Westhuizen 2003), during which it was grazed only twice during the growing season for a two-week period with merino sheep.

Botanical composition was determined with a bridge-point apparatus, where 500 points (nearest plant and strikes) were recorded per plot at the end of each growing season. A benchmark site (Van der Westhuizen 2003) was used on the same soil form as the experimental layout, to compare the botanical composition of both the burnt and unburnt plots. Grassland condition was determined according to the method of Fourie and Du Toit (1983). When the species were classified, their desirability in terms of grazing value (dry matter production, palatability, nutritive value, whether perennial or annual and grazing resistance) as well as their ecological status (Decreaser and Increaser species), as defined by Foran *et al.* (1978), were considered. The classification of dry *Themeda*-*Cymbopogon* grassland into different ecological groups as described by Fourie and Visagie (1985) was used.

Plant density was determined by counting whole plants within 20 (0.5 x 0.5m) randomly placed quadrats per plot at the end (April) of each growing season. The quadrats were randomly distributed over every plot for each treatment.

At the end of each growing season, 20 tufts of each of the dominant grass species per plot were randomly selected to measure their basal area. This was accomplished by copying only the living parts of every grass tuft onto a transparency, after which the drawn areas were cut out and sprayed with paint to determine the area of each species, using a leaf area meter. To accurately determine the area, this was only done after the selected tufts were cut.

Herbage production or regrowth was determined for each plot at the end of each growing season (April), by clipping plants to a height of 30mm in 20 randomly selected quadrats of $1m^2$ each. The productions of the species *Cymbopogon plurinodis* and *Elionurus muticus* were separated from that of the rest of the species.

Results and discussion

Vegetation botanical composition

The species composition and mean grassland condition score of the experimental plots before the fire and four months thereafter, as well as that of a benchmark site, are presented in Table 1. The experi-

Table 1: Frequency (%) of species, ecological status and veld condition score for the grassland before and four months after burning, as well as that of a benchmark site. Percentages of a species within a row with different superscripts differ significantly (P≤0.01).

Ecological status	Species	Benchmark	Experimental site	
			Unburnt	Burnt
Decreaser	*Andropogon appendiculatum*	0.5[a]	0.5[a]	0.2[a]
	Brachiaria serrata	3.2[a]	0.2[b]	0.2[b]
	Digitaria eriantha	8.2[a]	6.4[b]	1.7[c]
	Harpachloa falx	0.4[a]	0.5[a]	0.4[a]
	Helictotrichon turgidulum	1.0[a]	0.6[b]	0.4[b]
	Panicum stapfianum	0.2[a]	0.1[a]	0.1[a]
	Themeda triandra	25.2[a]	22.4[a]	14.6[b]
Decreaser total		***38.7***	***30.7***	***17.6***
Increaser II(a)	*Cymbopogon plurinodis*	34.2[a]	27.2[b]	18.6[c]
	Eragrostis chloromelas	9.5[a]	11.1[a]	19.6[b]
	Eragrostis plana	0.6[a]	2.0[b]	4.1[c]
	Setaria spacelata var. *torta*	3.4[a]	8.4[b]	13.6[c]
Increaser II(a) Total		***47.7***	***48.7***	***55.9***
Increaser II(b)	*Elionurus muticus*	9.8[a]	18.2[b]	12.4[c]
	Aristida diffusa	0.4[a]	0.5[a]	0.6[a]
Increaser II(b) Total		***10.2***	***18.7***	***13.0***
Increaser II(c)	*Aristida congesta*	0.5[a]	0.5[a]	1.4[b]
	Cynodon hirsutus	0.2[a]	0.5[a]	1.7[b]
	Eragrostis nindensis	0.2[a]	0.1[a]	0.1[a]
	Microchloa caffra	2.3[a]	0.6[b]	8.4[c]
	Eragrostis gumniflua	0.2[a]	0.2[a]	1.9[b]
Increaser II(c) Total		***3.4***	***1.9***	***13.5***
Increaser II Total		**61.3**	**69.3**	**82.4**
Veld condition score LSD(0.01) = 54.1		**765.1**	**724.6**	**632.8**
Veld condition (%)		**100**	**94.7**	**82.7**

mental plots were in good condition before the fire with a grassland condition score of only 5.3% lower than that of the benchmark site (Snyman

Table 2: Mean plant density (plants/m) in unburnt (UB) and burnt (B) grassland as measured at the end of the 2000/01 to 2002/03 growing seasons. Data (n = 60) are

Ecological status	Species	Season 2000/01	
		UB	B
Decreaser	*Andropogon appendiculatum*	1.42(±0.14)	
	Brachiaria serrata	1.23(±0.11)	
	Digitaria eriantha	4.16(±0.21)	
	Harpachloa falx	9.26(±0.21)	
	Helictotrichon turgudulum	3.11(±0.12)	
	Panicum stapfianum	1.11(±0.09)	
	Themeda triandra	22.21(±1.21)	11.91 (±1.12)
Decreaser total		***42.5[a]***	***11.91[b]***
Increaser IIa	*Cymbopogon plurinodis*	7.71(±0.61)	11.69 (±1.35)
	Eragrostis chloromelas	11.29(±1.11)	
	Eragrostis plana	1.22(±0.16)	5.55(±1.21)
	Setaria spacelata var. *torta*	25.25(±8.14)	
			6.67(±0.92)
Increaser IIa Total		***45.47[a]***	***23.91[b]***
Increaser IIb	*Elionurus muticus*	13.21(±1.31)	18.19 (±2.16)
	Aristida diffusa	1.29(±0.96)	
Increaser IIb Total		***14.50[a]***	***18.19[a]***
Increaser IIc	*Aristida congesta*		
	Cynodon hirsutus	1.91(±0.15)	
	Eragrostis nindensis	1.62(±0.19)	
	Microchloa caffra		3.33(±1.15)
	Eragrostis gumnuflua	2.22(±0.61)	2.92(±0.90)
Increaser IIc Total		***5.75[a]***	***6.25[a]***
Increaser II Total		**65.72[a]**	**48.35[b]**
Total		**108.22[a]**	**60.26[b]**

2000). Due to the fire the grassland condition score decreased (P≤0.01) with 12.7% four months after the fire.

Where the grassland contained a large percentage Decreaser species (30.7%) before the fire, it was dominated by Increaser II species (82.4%) after the fire. Especially the Increaser IIc species increased

means and standard errors. Numbers within a column with different super-scripts for each season, differ significantly (P<0.01)

Season			
2001/02		**2002/03**	
UB	**B**	**UB**	**B**
1.33(±0.09)		1.32(±0.09)	
1.33(±0.09)		1.35(±0.07)	
433(±0.09)		2.32(±0.92)	2.35(±0.15)
8.19(±0.96)	2.32(±1.11)	5.36(±0.95)	3.32(±0.65)
2.26(±0.91)	1.32(±0.61)	3.62(±1.21)	1.56(±0.50)
1.34(±0.09)		1.33(±0.07)	
26.27(±3.15)	12.92(±1.36)	25.19(±1.26)	13.13(±1.11)
45.05^{a}	***16.56***^{b}	***40.49***^{a}	***20.36***^{b}
6.31(±0.94)	13.15(±2.14)	6.31(±1.52)	14.52(±3.16)
9.23(±1.27)	6.23(±1.15)	7.36(±0.66)	5.55(±0.91)
1.33(±0.09)		2.36(±1.51)	2.32(±0.50)
21.21(±1.53)	7.72(±1.21`)	31.39(±3.15)	5.52(±0.36)
38.08^{a}	***27.10***^{b}	***47.42***^{a}	***27.91***^{b}
11.11(±0.32)	21.92(±1.06)	11.86(±1.52)	18.91(±1.11)
1.71(±0.92)		1.43(±0.07)	1.36(±0.09)
12.82^{a}	***21.92***^{b}	***13.29***^{a}	***20.27***^{b}
			1.36(±0.09)
		1.38(±0.06)	1.62(±0.06)
		1.52(±0.51)	1.63(±0.07)
	3.33(±1.52)		3.36(±0.96)
2.31(±0.34)	2.22(±2.51)	2.36(±0.61)	2.32(±0.66)
2.31^{a}	***5.55***^{b}	***5.26***^{a}	***10.29***^{b}
53.21^{a}	**54.57**^{a}	**65.97**^{a}	**58.47**^{a}
98.26^{a}	**71.13**^{b}	**106.46**^{a}	**78.83**^{b}

most due to the fire. The most conspicuous decrease (P≤0.01) in frequency due to fire was the species *Digitaria eriantha*, *Themeda triandra*, *Cymbopogon plurinodis* and *Elionurus muticus*. The species increasing (P≤0.01) with fire were *Eragrostis chloromelas*, *E. plana*, *Setaria sphacelata* var. *torta*, *Microchloa caffra*, *E. gummiflua*, *Aristida congesta* and *Cynodon hirsutus*. *Microchloa caffra* increased due to fire from only 0.6% of the total species composition to as much as 8.4%. It seems that grassland in excellent condition is dominated by *C. plurinodis*, while the relative abundance of *E. muticus* and *T. triandra* are also high.

Plant density

As the grassland of the whole trial area was in uniformly good condition before the fire, it seems reasonable to assume that the plant density was statistically (P≤0.01) decreased by the fire (Table 2) for the full three seasons following the fire. The plant density of the burnt grassland was still 26% lower than that of unburnt grassland for the three years following the fire. Although the density of Decreaser species declined enormously (P≤0.01) the first growing season due to the fire, it still did not return to that of unburnt grassland three growing seasons after the fire. Since the second growing season following the fire, the density of Increaser species had started to differ statistically non-significantly (P >0.05) from that of unburnt grassland.

Cymbopogon plurinodis and *Elionurus muticus* were the two species increasing the most (P≤0.01) in density over the three year trial period due to the fire. Three year after the fire the density of *C. plurinodis* was 14.52 plants/m versus the average for the species over the three years of only 6.78 plants/m. Especially notable was that during the third year after the fire, the larger *C. plurinodis* tufts did not allow other plants in their immediate vicinity to successfully establish and develop due to competition. Large conspicuous open spaces started appearing around *C. plurinodis*. The density of *Eragrostis* species remained relatively constant over the three growing seasons regardless of fire. The species only occurring in burnt grassland were *Microchloa caffra* and *Aristida congesta*. Except for those species with a low occurrence and only found in the unburnt grassland, *Setaria sphacelata* and *Themeda triandra* were the two species decreasing most in density over the three years due to fire.

Tuft basal area

Among all species the tuft basal area of *C. plurinodis* was the highest and varied between 10.15 and 77.11cm^2 (Table 3). Taking unburnt grassland as reference, the tuft basal area of this species was stimulated most by fire, increasing 252% over the three year trial period. The large tufts formed by especially *C. plurinodis* and *Themeda triandra*, generated much combustible material, therefore leading to the significant (P≤0.01) decrease in basal cover due to die-back, the first year after the fire. The tuft basal areas of *Digitaria eriantha*, *Harpochloa falx* and *T. triandra* decreased significantly (P≤0.01) over the three years. The fire did not

Table 3: Mean tuft basal area/cm of only living parts, for the unburnt (UB) and burnt (B) grassland as measured at the end of the 2000/01 to 2002/03 growing seasons. Data (n = 60) are means and range in brackets. Numbers within a column with different superscripts for each year, differ significantly (P≤0.01).

Species	Season					
	2000/01		2001/02		2002/03	
	UB	B	UB	B	UB	B
Cymbopogon plurinodis	17.15 (16.13-17.28)	11.27^{b} (10.15-14.16)	19.46^{a} (16.24-22.16)	49.22^{b} (28.28-51.62)	19.25^{a} (16.25-21.25)	67.74 (47.21-77.11)
Digitaria eriantha	9.15 (8.15-10.22)	7.16^{b} (6.15-9.15)	9.14^{a} (6.22-11.15)	6.15^{b} (5.22-8.15)	9.16^{a} (7.22-10.15)	7.13^{b} (6.11-9.15)
Eragrostis chloromelas	5.15 (4.11-6.55)	5.24 (4.01-6.22)	5.61 (4.15-7.22)	5.18 (5.00-7.22)	5.01 (4.62-7.11)	5.21 (4.02-7.15)
E. gumniflua	6.17 (5.21-7.82)	6.14 (5.22-6.99)	6.42 (5.21-7.32)	6.22 (5.21-7.14)	6.16 (5.01-7.11)	5.15 (4.15-6.22)
Elionurus muticus	6.86 (5.66-7.81)	6.98 (5.91-7.15)	7.00 (4.16-8.15)	7.17 (5.21-8.16)	7.10 (5.21-8.15)	7.12 (5.22-8.44)
Harpachloa falx	5.14^{a} (5.01-6.10)	3.12^{b} (3.00-3.15)	5.22^{a} (5.01-5.36)	3.61^{b} (3.21-3.77)	5.10^{a} (5.00-5.31)	3.81b (3.71-3.92)
Helictorichon turgidulum	5.24 (5.02-5.71)	4.14 (4.02-4.66)	5.51 (5.41-5.61)	4.31 (4.11-4.53)	5.26 (4.89-5.41)	4.71 (4.61-4.89)
Setaria spacelata var. *torta*	2.15 (1.89-2.61)	2.14 (2.01-2.21)	2.32 (2.11-2.42)	2.21 (2.03-2.29)	2.22 (2.11-2.33)	2.31 (2.10-2.42)
Themeda triandra	11.36^{a} (10.15-12.01)	7.15^{b} (6.88-7.36)	12.01^{a} (11.55-12.66)	7.21^{b} (6.98-7.82)	11.89^{a} (11.21-12.22)	7.25^{b} (6.88-7.86)

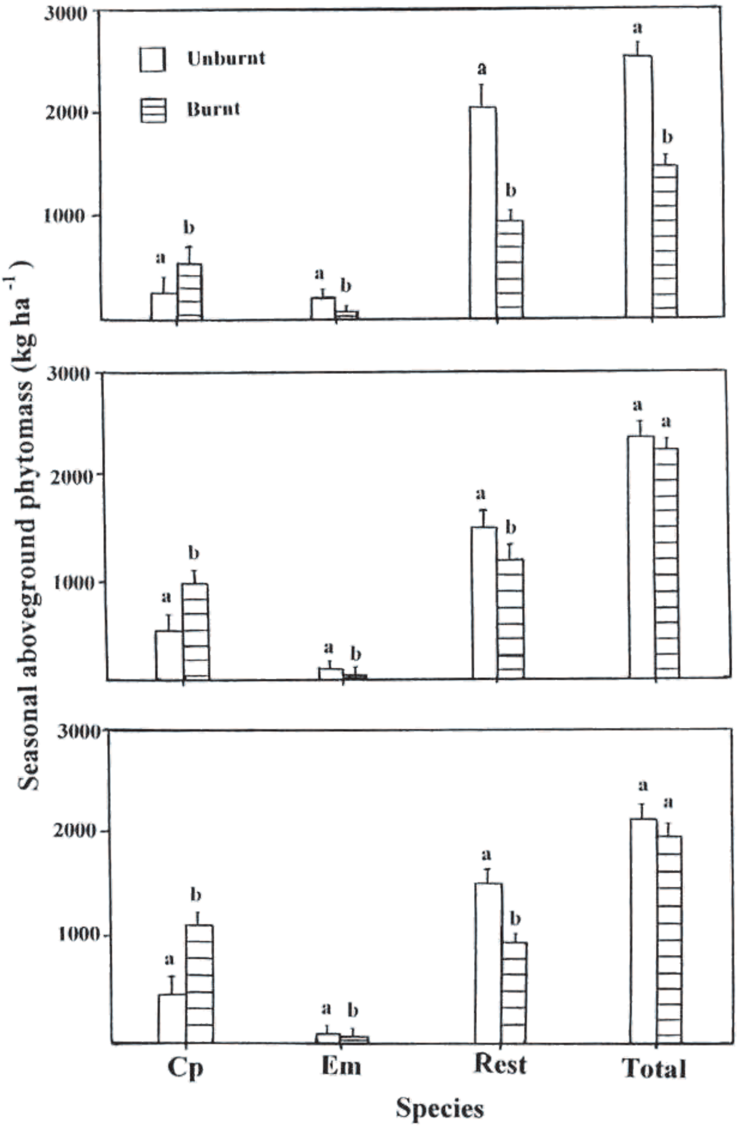

Figure 1: Mean (±SE) seasonal aboveground phytomass production (kg/ha) for *Cymbopogon plurinodis (Cp), Elionurus muticus (Em),* rest of species and total for all species. The unburnt and burnt grassland were measured over the 2000/01 (A), 2001/02 (B) and 2002/03 (C) growing seasons. Numbers within a species with different superscripts, differ significantly (P≤0.01).

significantly ($P \leq 0.01$) influence the tuft basal areas of the rest of the species.

Aboveground phytomass production

The rainfall for the 2000/01, 2001/02 and 2002/03 growing seasons (1 August to 30 April) were 686, 620 and 592mm respectively and did not differ much from the long-term average of 629mm for the study area. The production or regrowth of *Cymbopogon plurinodis* was significantly ($P \leq 0.01$) increased by fire for all three seasons (Figure 1). In contrast, the production of *Elionurus muticus* and the rest of the grass species were decreased ($P \leq 0.01$) by the fire over the three seasons studied. Throughout the three seasons, *Elionurus muticus* had a low production due to the fire, even dropping as low as 82% the first season after the fire. The production of *Cymbopogon plurinodis* notably increased during the second and third growing seasons following the fire compared to the rest of the grass species. At the end of the second season following the fire, the production of burnt *C. plurinodis* was only 29% lower than that of the rest of the grass species in total. Three years after the fire, the production of *C. plurinodis* was 18% higher than the total production of the rest of the species that also burnt.

Only during the first season the total production of all species significantly ($P \leq 0.01$) decreased with 42% due to fire. At the end of the second and third seasons after the fire, the production of burnt grassland was only 4.6% and 2.5% lower ($P>5$) than the unburnt grassland.

Conclusions

This study makes a useful contribution towards understanding the dynamics of the grass species *C. plurinodis* and *E. muticus* and their reaction to burning. As these species dominate grassland in large parts of the semi-arid grassland, its correct management, whether burnt or not, is essential for sustainable utilization of this grassland ecosystem. With grassland degradation due to selective grazing in the study area *E. muticus* can increase drastically at the expense of species such as *C. plurinodis*, *T. triandra* and *E. chloromelas* (Danckwerts and Teague 1989; Van der Westhuizen 2003). With degradation due to overgrazing *E. chloromelas*, *C. hirsutus* and *E. plana* will increase at the expense of species such as *C. plurinodis*, *E. muticus*, *T. triandra*, *H. falx* and *H. contortus* (Van der Westhuizen 2003). Probably the most significant changes in grassland condition in this grassland type are due to selective grazing. According to Opperman *et al.* (1974) the unpalatable *E. muticus* causes more selective grazing problems in South Africa than any other single species. If the grassland is also subjected to burning, it will further complicate management as clearly shown in this study.

This study conclusively showed that there is no need for burning in this grassland type and that burning only further complicates its management. The grassland should be utilized efficiently without burning (Snyman 2003b, 2004b). The burning of grassland in semi-arid areas can create a situation where the old materials of previous seasons of more sour grasses like *C. plurinodis* and *E. muticus*, which are more poorly utilized than the more palatable grasses, are removed and the sour grasses rejuvenated in this way. The sour grasses have a built-in survival mechanism in that they get the opportunity to complete their annual life cycle due to their unpalatability (Opperman *et al.* 1974; Roberts and Opperman 1966; Opperman *et al.* 1970). They seeded and build-up growth reserves. By burning such grassland the sour grasses are rejuvenated in spring by rescuing them from old material which would have lead to smothering of the tuft (Snyman 1989), leading to increase in tuft size of *C. plurinodis* and *E. muticus* as observed in this study. This is supported by Shackleton (1989) who argued that tiller population of *C. plurinodis*, whose tillers survive a maximum of two years, are eventually eliminated by complete protection from grazing, because tiller mortality is marginally increased and tiller recruitment is suppressed (Shackleton 1989). However, they increase under annual or biennial burning or annual harvesting, because the increased production of secondary tillers compensates for the increased mortality of harvested or burnt tillers (Shackleton 1989). In contrast, according to most researchers, *E. muticus* can't successfully be "grazed out" nor "rested out" in the short-term (Opperman *et al.* 1974), while the tufts of *C. plurinodis* do not readily become moribund and die under controlled selective grazing for the higher rainfall areas (Danckwerts and Teague 1989).

It can further be speculated that the grassland in this study investigation would probably not have been accompanied by the very dominating large *C. plurinodis* tufts, three years following the fire if it was utilized in the spring of the first year after the fire, at a high stocking rate. According to Lűtge (1995) and Morris (2002) early grazing after a spring burn will minimize patch grazing. Ring *et al.* (1985) similarly noted that patches were least distinct under early intensive stocking. Where grassland has become severely encroached, fire followed by non-selective grazing with cattle, has resulted in a marked decrease of *C. plurinodis* and an increase in *T. triandra* in the Eastern Cape (Danckwerts and Teague 1989). In contrast, *E. muticus* cannot be controlled by non-selective grazing (Danckwerts and Teague 1989). The following of further pressure grazing periods in well-spaced successive spring periods with sufficient rest between may also give rise to a more stable botanical composition of the study area. There may be a further danger that the grazing capacity of the burnt grassland may be totally overestimated due to the large component unpalatable plants, which are poorly utilized. This study should therefore be followed by an investigation into the ideal utilization of burnt grassland in this semi-arid grassveld area for sustainable utilization of the grassland ecosystem.

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