Short-term influence of fire in a semi-arid grassland on (3): litter production, root and litter turnover

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Introduction

Unplanned fires, which are a normal phenomenon in the semi-arid areas, could have a drastic effect on the functioning of the grassland ecosystem, ranging from the reduction or elimination of aboveground biomass (Snyman 2003a, 2004a) to impacts on belowground physical, chemical and microbial mediated processes (Neary *et al*. 1999; Snyman 2003b). Depending on several fire severity measures, changes in belowground components can be either beneficial or deleterious to the entire ecosystem (Snyman 2005b). Vegetation cover and litter, through limiting runoff and promoting infiltration (Snyman 1999; Ekaya and Kinyamario 2001), is an important control on the amount and efficiency of plant production which could also negatively influenced by fire, especially in the more arid areas (Van de Vijver 1999; Snyman 2003a). Litter tends to stabilise soil water and soil temperature (Willms *et al*. 1993), thus improving conditions for germination, and often the presence of litter alters the botanical composition of a plant community through the effects on soil nutrient status (Ekaya and Kinyamario 2001). Although litter is an important functional compartment of grassland ecosystems in terms of nutrient recycling, little work has been carried out to investigate the patterns of litter turnover (above- and belowground dead material) (Wolfson and Tainton 1999; Ekaya *et al*. 2001). The objective was therefore to quantify the short-term (two years) impact of a fire on the soil characteristics and turnover of litter and roots.

Procedure

The research was conducted in Bloemfontein (28°50'S; 26°15'E, altitude 1350m), which is situated in the semi-arid (summer annual average 560mm) region of South Africa. The study area is situated in the Dry Sandy Highveld Grassland (Grassland Biome) with a slope of 3.5%. At the start of this study the veld was in good condition (veld condition score was 92% of that of the benchmark site) and dominated by the climax species *Themeda triandra* with *Eragrostis chloromelas* and *Elionurus muticus* also occurring relatively abundantly. Soils in the study area are mostly fine sandy loams of the Bloemdal Form (Roodepoort family 3 200). Clay content increases with soil depth from 10% in the A-horizon (0 to 300mm) to

24% in the B1-horizon (300 to 600mm) and 42% in the B2-horizon (600 to 1200mm).

The research was conducted on 18 plots of 10 x 10m each, with an edge effect of 5m around each plot. The three treatments included fire burning against the wind (back fire), with the wind (head fire) (Trollope 1978), and a control with no burning. The experimental layout was a fully randomized design with three replications for each treatment The application of the different treatments on 30 August 2000 and on 23 August 2001 as well as the fire behaviour are fully discussed in the previous volumes of Grassroots (Snyman 2005a, b).

The aboveground litter (dead plant material separated from mother plant) for all treatments were determined every second month at the end of October, December, February and April of the 2001/02 growing season. The August 2000 burn treatments were therefore defoliated the first time in 2001, after resting for a full growing season. As the burn treatments of the two separate years were defoliated the first time the same year, variation of climate on phytomass productions was largely excluded. Eight 0.5m^2 quadrats were randomly placed in each plot, in

Table 1: Cumulative litter production (kg/ha) for the unburnt and burnt (first [A] and second [B] seasons after burning) grassland measured every second month. Least significant difference (LSD) is calculated at the 1% level. Data are means and standard errors.

Months	Unburnt	Burnt			
		Head fire		Back fire	
		A	B	A	B
August LSD = 19.61	130.00 ±16.15	17.0 ±1.66	76.2 ±9.14	15.0 ±2.12	75.6 ±15.14
October LSD = 16.22	104.2 ±12.12	9.5 ±0.12	42.5 ±8.17	8.9 ±2.00	43.1 ±18.15
December LSD = 10.60	70.0 ±10.15	10.4 ±0.22	42.5 ±9.14	9.1 ±2.14	43.9 ±19.14
February LSD = 14.21	122.6 ±16.82	12.2 ±0.30	67.4 ±15.16	11.5 ±3.16	64.1 ±22.14
April LSD = 11.11	129.7 ±19.14	15.9 ±0.45	70.3 16.14	14.2 ±3.55	66.5 ±6.15
June LSD = 13.66	136.2 ±21.65	17.1 ±1.01	77.3 ±9.15	15.9 ±6.65	76.2 ±8.14
Average	115.45	13.68	62.70	12.43	61.58

which the litter was hand-picked after which the grasses were defoliated to a height of 30mm. In the laboratory, the litter was washed with running water over a two mm sieve to get rid of attached soil particles. All plant material was then oven-dried at 80°C. Care was taken that the bi-monthly defoliations and litter collection within the growing season were not from the same site, by marking the previously used quadrats.

Results and discussion

Aboveground litter production

The aboveground surface litter production was decreased ($P \leq 0.01$) by the fire in all months for one and two seasons following the fire (Table 1). This trend is expected as fire not only lowers basal cover (Snyman 2004b), but also aboveground production (Snyman 2005a). Two seasons following the fire, litter was still lower ($P \leq 0.01$) (47% - average for head and back fires) than that of unburnt grassland. The litter production differed non-significantly ($P > 0.05$) between head and back fires over the two growing seasons. The small difference in aboveground phytomass production between the two types of fires (Snyman 2005a) is the most important reason for this. Various researchers also reported a considerable decrease in litter with a fire treatment (Emmerich and Cox 1992; Blank *et al*. 1994) which could decrease productivity (Willms *et al*. 1993; Holm *et al*. 2002; Snyman 2003a, 2004a).

The average litterfall of 116 kg/ha from the unburnt grassland in this study is lower than the 750 kg/ha from semi-arid *Astrebla pectinata* grassland in Australia (Ingram 2003). Monthly litter production in the semi-arid Rift Valley province of Kenya, ranged from 314 kg/ha in August to 1304 kg/ha in December, with a mean monthly litter yield of 925 kg/ha (Ekaya and Kinyamario 2001). The difference between highest and lowest bi-monthly litter production is greater in unburnt grassland than that of burnt grassland. Therefore it can be concluded that litter turnover or decomposition should be much faster in unburnt than in burnt grassland. This must also be seen against the background of litter turnover being very slow in most arid and semi-arid grasslands (Whitford *et al*. 1988).

Expressed as a proportion of annual phytomass production (Snyman 2005a), litterfall was 5.88% and 1.13% (average for head and back fires), for the first season following the fire and for the second season after burning respectively; and 5.74% and 3.65% (average for head and back fires) for unburnt and burnt grasslands respectively. These values are much lower than reported values from other semi-arid rangelands of 16% (*Astrebla pectinata* grassland, Ingram 2003), 11% (*Themeda triandra* grassland, Ingram 2003) and 9% (*Eragrostis xerophila* grassland, Ingram 2003). Patterns of litter accumulation may also reflect drought (West 1984), prevailing wind conditions (West 1984) and the extent to which material remains attached to the plant after senescence (Danckwerts and Aucamp 1985). Litter plays a crucial role in nutrient cycling and soil organic matter build-up in grassland ecosystems. It increases soil-water through the effects on infiltration (Emmerich 1999), evaporation (Thurow *et al*. 1988), and runoff (Wright *et al*. 1982; Emmerich and Cox 1992; Snyman 1999). It tends to stabilise soil-water and soil temperature (Du Preez and Snyman 2003), and often the presence of litter alters the botanical composition of a plant community through the effects on soil nutrient status (Ekaya and Kinyamario 2001).

Root and litter turnover

Despite the many sampling problems that could occur in determining root turnover (Shackleton *et al*. 1988), the ratio of annual increment to peak root phytomass was used in this study (Dahlman and Kucera 1965). The root mass as determined by Snyman (2005b) on the same plots was used in this calculation. The annual increment was taken as the difference between the maximum and minimum root phytomass production recorded during any one year. Turnover times calculated for this study were calculated using the annual increments over the first and second seasons after burning (Snyman 2005). The same approach as used for root turnover was also applied to the estimation of litter turnover. The root and litter turnover rates were also applied to the estimation of litter turnover. The root and litter turnover rates, as well as the calculated times for decomposition, are presented in Table 2 for both unburnt and burnt grassland (first and second season after burning).

The turnover rates for both roots and litter are lower with burning. Burning lengthened the replacement of the total root system by about a year, with decomposition of litter taking three months longer (Table 2).

If the ratios are calculated from the average root phytomass or litter production (Sims and Singh 1971), instead of peak values (Dahlman and Kucera 1965), the turnover times were on average only 5.3 to 7.6 months shorter in all treatments. The same shortened turnover rate was calculated

Table 2: Calculated root and litter turnover rates/year and time for decomposition (months) for the unburnt and burnt (first [A] and second [B] season after burning) grassland.

	Turnover rate (per year)		Replacement roots (months)	Decomposition aboveground (months)
	Roots	Litter		
Unburnt	0.61	0.49	19.67	24.49
Burnt (A)				
Head fire	0.36	0.44	33.33	27.27
Back fire	0.35	0.43	34.29	27.91
Burnt (B)				
Head fire	0.59	0.47	20.34	25.53
Back fire	0.58	0.46	20.69	26.09

by various researchers (Shackleton *et al*. 1988). Obviously certain portions of the root system are more active than others (the fine root system, for instance) and therefore turnover times will not be uniform for the whole system (Shackleton *et al*. 1988). In general belowground material consistently decomposed faster than aboveground material (Ekaya and Kinyamario 2001). In most arid and semi-arid rangelands litter and root turnover is very slow (Whitford *et al*. 1988). In warm, high rainfall areas, breakdown of grass litter is rapid (could be 50% to 52% of mass in three months), but the rate depends on moisture availability and species (West 1984; Mott *et al*. 1992; Shackleton *et al*. 1988; Ingram 2003). The turnover rates for roots of 0.61 obtained in this study for unburnt grassland compares well with that obtained in other grassland areas of the world. Turnover times are generally higher in grazed sites (Sims and Singh 1971; Shackleton *et al*. 1988). Root turnover results obtained in Africa, North America, India and Marion Island varied for grazed grassland between 0.19 and 0.68 and for ungrazed areas between 0.22 and 0.77 (Dahlman and Kucera 1965). Grassland and savanna are the most fire-adapted ecosystems, with 83-85% of their C belowground (Neary *et al*. 1999).

Conclusions

Fire is often blamed for having caused grassland degradation in southern Africa. However, it could be an extremely useful and in many situations an indispensable management tool if used correctly. It would seem likely though, that it has contributed to degradation when it has been associated with over-stocking, poor grazing practices and the grazing of sheep, in particular, during the post-fire recovery period (Tainton *et al*. 1993; Trollope 1999). The post-fire management is therefore believed to have caused most of the degradation associated with the use of fire, rather than fire *per se*. Though the above is perhaps more applicable in the higher rainfall areas, this study clearly showed that fire and the management of grassland after a fire must be handled more circumspectly in the arid and semi-arid areas. In these areas, where small changes may have long-lasting consequences, increased research must be focused on belowground sustainability, particularly primary productivity and the impacts of land management practices such as fire on ecosystem functioning.

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