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EFFECTS OF BURNING AND GRAZING ON PLANT SPECIES PERCENTAGE COVER AND HABITAT CONDITION IN THE HIGHLAND GRASSLAND OF MPUMALANGA PROVINCE, SOUTH AFRICA

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ABSTRACT

Fire and grazing have long been used as a grassland management tool in South Africa for livestock production. Despite the ecological importance of fire and grazing to the grassland ecosystem, the appropriate use of fire and grazing as a land use management tool has been questioned. The effects of different burning frequencies and stocking rates on species composition were studied between January and March 2008 using a Modified-Whittaker design in commercial farms, communal land and a nature reserve stocked with game herbivores in the highland grassland of Mpumalanga Province of South Africa. The results revealed that species assemblages of an annually burned site were completely dissimilar from a biennially burned site. The annually burned site was dominated by flora that is considered as fire-tolerant species. In contrast, the protection of some areas from burning in addition to regular burning of other areas ensured the presence of both fire-tolerant and fire-intolerant species and contributed to the high species composition of communal land. This study therefore suggests that biennial burning, or even longer intervals of burning of grazed land in addition to partial or mosaic burning should be employed to enhance the biodiversity conservation status of these montane grasslands.

Key words: fire, grazing, highland grassland, herbivores

INTRODUCTION

Fire and grazing has been used as a land use management tool in the Grassland Biome in South Africa by altering or manipulating the frequency of burn and stocking rates primarily to reinvigorate pastures for livestock production (Bond and Keeley, 2005; Mucina and Rutherford, 2006). Fire and grazing has been shown to have a detrimental effect on the biodiversity of Grassland Biome (Bond and Keeley, 2005). Fire, for instance, causes a reduction in species composition due to the large amount of biomass it consumes which consequently has an effect on the loss and degradation of biodiversity through the representation of fire-tolerant plants to the detriment of fire-intolerant plants (Bond *et al*. 2005, Bond and Keeley, 2005). The loss and degradation of biodiversity as a result of grazing occurs through processes such as selective grazing that facilitate the dominance of grazing tolerant species (Sternberg *et al*., 2000) and trampling by herbivores that reduces the attractiveness and acceptance of plant species to livestock (Owen-Smith, 1999). The grazing effects result in changing the vegetation community species composition usually with dominance of unpalatable plants in grasslands (Afzal *et al*., 2007, Arshadullah *et al*., 2009, Mushtaque *et al*., 2010). However, protection of grassland from fire and grazing can lead to succession from grassland species to woodland species and a change in species composition (Bond and Keeley, 2005). Currently, frequency of burning far exceeds what would have occurred naturally in the Grassland Biome as well as elevated stocking rates. When these thresholds are breeched, the ecosystem health of the Grassland Biome is compromised and these changes also take place quite slowly even when it is mismanaged due to the stable botanical composition and extremely low resilience of the Mesic Highveld Grassland (Rethman and Kotze, 1986). The appropriate use of fire and grazing as a land use management tool is critical since different fire regimes as well as grazing levels produce different landscapes as a result of its effect on the establishment of plant species. The aim of this study was to determine whether fire frequency and stocking rates have impacted negatively on plant species composition and cover of the Mesic Highland Grassland of Mpumalanga Province in South Africa.

MATERIALS AND METHODS

Study Area: The study was conducted in the Mesic Highveld Grassland (25^o 42′ 846″ S 30^o 09′ 818″ E) between the towns of Lydenburg and Belfast in the Mpumalanga Province, South Africa (Figure 1). The vegetation of the study area falls under the North-eastern Sandy Highveld classification of Acocks (1953). It occurs in the recently re-classified Mesic Highveld Grassland (Mucina and Rutherford, 2006) and specifically in the Lydenberg Montane Grassland vegetation unit and is dominated by sour grasses and classified as sourveld (Mucina and Rutherford, 2006). The region is characterized by high rainfall in summer (Bredenkamp *et al*., 1996; Mucina and Rutherford 2006) with a mean annual rainfall ranging between 660 – 1180 mm per annum (Mucina and Rutherford, 2006). Temperatures in the region vary from below 0^{o}C in winter to 39^{o}C in summer with an average of 15^{o}C per annum (Bredenkamp*et al*., 1996). The mean rainfall during the data collection period was 210 mm, 102 mm and 125 mm in January, February and March 2008 respectively. Temperature average was 17^{o}C for the months of January and February and 15^{o}C for the month of March with a high of 24^{o}C in January, 26^{o}C in February and 22^{o}C in March. The region is situated within an altitudinal range of 1260 – 2160 m above sea level with undulating plains, mountain peaks and slopes (Mucina and Rutherford, 2006). The dominant land use in the study area is livestock farming, primarily with cattle in the commercial farms and mixed herds of cattle, sheep and goats in the communal farms.

Experimental Design: Five study sites were selected which reflected the common farming practices in the study area. Table 1 details the characteristics of study sites that include the stock of herbivores on study sites, burning frequency and grazing intensity. The annually burned farm (Site 1) was the only study site that was completely burned in spring 2007 while the communal land (Site 3) was partially burned due to lack of proper burning management. Sites 2, 4 and 5 however were not burned in spring 2007 but were burned in spring 2006. Each study site had four replicates of 25 hectares (ha) in size with at least 500 m between replicates to avoid pseudo-replication. Relative grazing intensity was defined as the amount of hectares of grazing land available per large animal unit (ha/LAU). One large animal unit was estimated to be equivalent to one cow or five sheep or goats and represents the metabolic equivalent of a 454 kg cow (Owen-Smith and Danckwerts, 1997). Heavy, moderate and low grazing intensity were assumed to be a stocking rate of 1 LAU on 3 ha or less, 1 LAU on 4 - 10 ha and 1 LAU on 11 - 25 ha respectively.

Vegetation composition and abundance sampling: A Modified-Whittaker sampling design was established in all four replicates of each study site to measure plant species composition and percentage cover. The Modified-Whittaker plot design has been found by Stohlgren *et al*. (1995) to sample the heterogeneity of plant communities with a higher level of accuracy than either true random sampling or the original Whittaker plot design. Only plant species cover was measured with the Modified-Whittaker design and species presence. Plant species composition recordings for each Modified Whittaker plot were conducted in January 2008. Plant species cover was measured within 1 m^2 (10 replicates), 10 m^2 (two replicates) and one 100 m^2 subplots for each replicate of study site. Within each subplot, plant species cover was visually estimated using a cover class as this has been suggested as the most suitable percentage cover estimate as it removes extremes (McCune and Mefford, 1999). This cover class and midpoint were used as follows 1: 2.5%, 2: 7.5%, 3: 15%, 4: 25%, 5: 35%, 6: 45%, 7: 55%, 8: 65%, 9: 75%, and 10: 90%. Plants species that were not found in the subplots but were in the 1 000 m^2 plot were noted without assigning a percentage cover. Plant species identification was undertaken at the South African National Biodiversity Institute herbarium located in Pretoria. The names of forbs and their families follow Germishuizen and Meyer (2003). The grazing value and status of grasses were based on van Oudtshoorn (2006).

Data analysis: The Bray-Curtis similarity index (Bray and Curtis, 1957) was used to assess similarity between sites based on presence and abundance of plant species using PC-ORD software program (McCune and Mefford 1999) and the results are presented as a cluster analyses.

RESULTS AND DISCUSSION

A total of 111 species were recorded in the five sites. Of the total number of species found in the sites, 20 were from the grass family (Poaceae) (Table 2). In terms of grass species composition, six grasses (*Aristida junciformis, Eragrostis capensis, Eragrostis curvula, Sporobolus pectinatus, Trachypogon spicatus* and *Tristachya leucothrix*) were present in all five sites. The remaining 91 species were from 32 families with the family Asteraceae having the highest prevalence in terms of species composition (25 species) while Cyperaceae and Fabaceae families both had seven species respectively which was observed to be the second highest species composition by a plant family (Table 3). Five species: *Helichrysum acutatum, Helichrysum pilosellum, Tolpis capensis, Acalypha punctata* and *Hypoxis rigidula* were found in all the sites (Table 3). There was strong variation in taxonomic composition between study sites as shown in the cluster analysis (Figure 2) that indicated a clear response to the frequency of burning, selective grazing, stocking rate, and mixed proportion of herds. Across all sampling sites, Site 1 was the most dissimilar from all other sampling sites. Site 1 contained different assemblages of plant species to those sites under biennial burning as observed in the hierarchical cluster analysis results. This result is consistent with a study by Uys*et et al*. (2004). They observed frequently burned sites to contain different species assemblages from unburned sites in South African grasslands. The result of this study suggests that the flora of Site 1 represents a pool of fire-tolerant species. For instance, the adaptation of the genus *Acalypha* to disturbance prone environments such as fire may have accounted for the high percentage cover of *Acalypha punctata* on Site 1 since it was burned in spring 2007. The genus *Acalypha* spp. is known to have the capacity to resprout from a rootstock with numerous new shoots developing after burning (Pywell *et al*., 2003). Pywell *et al*. (2003) consider heavy allocation to vegetative reproduction (*e.g*. ease of germination, short-life cycles, early flowering, and heavy allocation to reproduction) after burning as a trait associated with plants that tend to be good colonizers after disturbances and may explain the high percentage cover of *Acalypha* on Site 1 (Table 3). The dissimilarity in species assemblages as observed in the hierarchical cluster analysis results found on the annually burned Site 1 from biennially burned sites (Sites 2 & 3) can also be attributed to the immediate grazing following burning in that this may have affected the phenological stages such as plant establishment, seed set and dispersal due to the sensitivity of some plants to grazing. Changes in vegetation species composition can be related to the phenological status of vegetation during grazing (O'Connor *et al*., 2004) which may have affected the species composition of Site 1 due to the immediate introduction of livestock following fire. Selective grazing from mixed herds due to their differences in dietary preferences may have accounted for the differences in grass species composition and percentage cover. Hardy *et al*. (1999) found selective grazing to cause an increase in the abundance of "wire" grasses such as *A. junciformis*, particularly in the Mesic Highveld grassland. The dominance of *A. junciformis* in Site 5 can therefore be attributed to the complementary feeding behavior from mixed game herbivores that grazed within Site 5 which may have promoted selective grazing. This in turn may have resulted in the observed high percentage cover of low value grazing grasses such as *A. junciformis* in Site 5 (Table 2). The low cover class of *T. triandra* in Site 3 (Table 2) which was grazed by livestock can be attributed to the effect of different herds of livestock, particularly by sheep and cattle. Selective grazing by sheep, in addition to the ability to graze close to the ground, results in the shortening of grass tuft leaving the edges of tillers shorter and reducing their chances of survival compared to cattle that tend to graze less on grass tufts (Kirkman, 2002). This reduces the successful establishment of tufted grasses such as *T. triandra* (Kirkman, 2002) which may account for the low percentage cover of *T. triandra* within Site 3 that was grazed by both cattle and sheep compared to Sites 1 and 2 which were only grazed by cattle.

Ecological status has often been used as a veld condition assessment tool in the Grassland Biome by determining the reaction of each grass species to different levels of disturbance, particularly from grazing. Sites that are dominated by decreaser grasses are often classified as well managed veld. The use of ecological status as a veld condition assessment tool can however, be regarded as overly simplistic based on the results of this study. Site 1 was observed to have a high percentage cover of decreaser grasses (Table 2) although it was found to be the worst form of management practice based on the outcome of the hierarchical cluster analysis results (Figure 2). Hubbert *et al*. (2006) found areas in grazed land such as vleis and marshes, to be avoided by livestock during grazing and are also rarely consumed by fire. The Mesic Highveld Grassland has also been described as heterogeneous, characterized by differences in elevation and slope (Hardy *et al*., 1999; Mucina and Rutherford, 2006) which has resulted in a variation in floristic composition and pattern of growth and subsequent variation in utilization by livestock (Hardy *et al*., 1999). Hardy's view is supported by Jansen *et al*. (2001) who also found plant percentage cover in the Mesic Highveld Grassland to positively correlate with microhabitat, irrespective of grazing intensity, which is an indication that livestock avoid utilizing certain areas within the landscape. The variation in plant utilization by livestock and consumption by fire may have accounted for the high percentage cover of decreaser grasses in Site 1 since the landscape was observed to be dominated by wet and rocky areas that may have been avoided by livestock during grazing as well as fire during the spring 2007 burn. The dominance of *Helictotrichon turgidulum* and the high abundance of *Setaria sphacelata* var. *sericea*, both of which are decrease grasses on Site 1, (Table 2) may therefore attest to this view since both species prefer damp habitats such as vleis and marshes (van Oudtshoorn, 2006). In addition to habitat preference by grass species, grazing management may have also influenced the ecological status of grasses. Everson (1999) found continuous grazing following burning to favor the establishment of increaser II grasses which may explain the frequent occurrence of increaser II species in all the sites (Table 2) as stock was introduced immediately following burning in all the sites. The use of ecological status as a method for veld condition assessment should be critically examined in order to ensure poor grassland management practices are not promoted based on our simplistic mode of assessment. The observed inconsistencies in the responses of grass species to this rigid ecological status classification of species based on their grazing response calls for a caution against the uncritical designation of species into groups. This study will therefore suggest that, grassland condition assessment take into consideration the niche preference of each species during assessment in addition to the grazing level that is currently in use. This will help in ensuring that accurate grazing capacity is compiled for the proper management of grasslands.

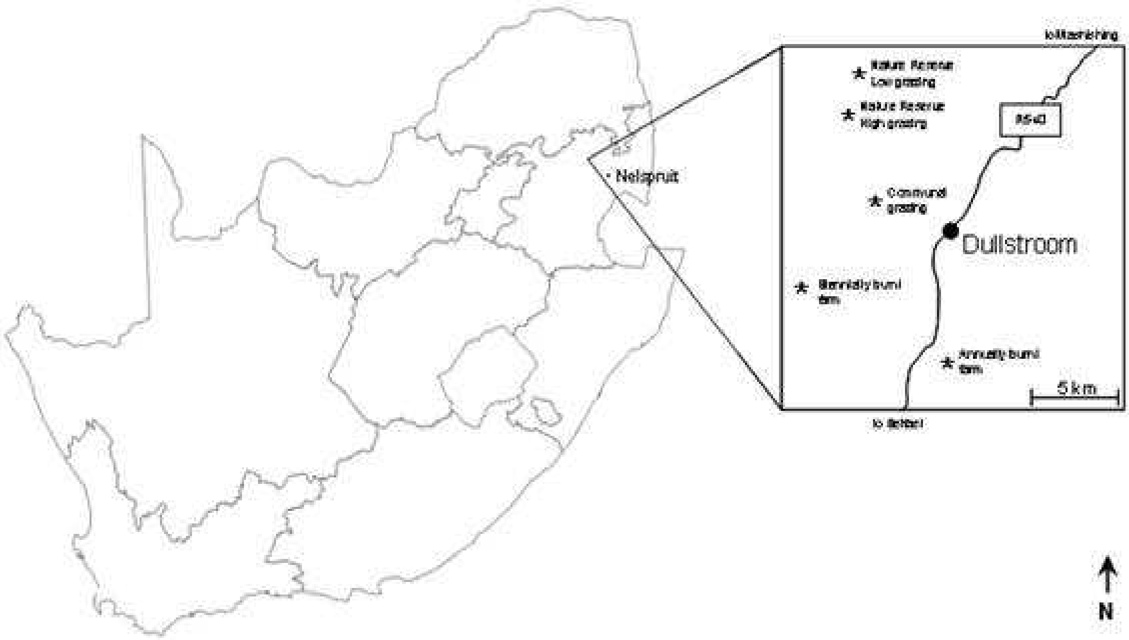

Figure 1: Map of study area showing sampling sites

Figure 2: Hierarchical cluster analysis linking similar sites closer together based on plant species presence. Linkage method: nearest neighbor, distance measure: Sorensen (Bray-Curtis)

Table 1. Characteristics of study sites based on burning frequency and grazing intensity

Study site	Stock	Frequency of burning	Grazing intensity
1	Herbivores (Cattle)	Annual	Heavy
2	Herbivores (Cattle)	Biennial	Heavy
3	Herbivores (mixed proportion of cattle, goats and sheep)	No strict burning management regime	Heavy
4	Indigenous herbivores (Blesbok)	Biennial	Low
5	Indigenous herbivores (mixed proportion of Blesbok, Black wildebeest, Zebra, Oribi, Grey redbuck and Reedbuck	Biennial	Moderate

Table 2. Grass species and their grazing value and ecological status for the different study sites.

Names of grass species	Grazing value	Ecological status	Grass species cover				
			Site 1	Site 2	Site 3	Site 4	Site 5
Agrostis eriantha	Low	Increaser II grass	2		4		
Alloteropsis semialata	Average	Increaser I grass	5				
Andropogon appendiculatus	High	Decreaser grass		3	1		
Andropogon schirensis	Average	Increaser I grass		1	1	2	
Aristida junciformis	Low	Increaser III grass	4	5	3	4	6
Digitaria monodactyla	Average	Increaser II grass		3	4		
Elionurus muticus	Low	Increaser III grass				1	
Eragrostis capensis	Average	Increaser II grass	2	2	2	1	2
Eragrostis curvula	High	Increaser II grass	3	6	3	3	3
Eragrostis racemosa	Average	Increaser II grass		2	3	2	2
Helictotrichon turgidulum	Average	Decreaser grass	5				
Harpochlo afalx	Average	Increaser I grass		1	1		
Koeleria capensis	Low	Increaser II grass		1	1	2	1
Loudetia simplex	Average	Increaser I/II grass*		5	4	4	5
Panicum natalensis	Low	Decreaser grass		3	3		
Setaria sphacelata	High	Decreaser grass	3				
Sporobolus pectinatus	Average	Increser II grass	3	4	2	2	1
Themeda triandra	High	Decreaser grass	3	4	2	6	
Trachypogon spicatus	Low	Increaser I grass	2	4	3	4	2
Tristachya leucothrix	Average	Increaser I grass	2	1	2	2	1

* Grouping for each site was based on the level of utilization or management practice of the site. * Grouped as Increaser II in sites 1, 2 and 3 but as Increaser I in Sites 4 and 5.

Table 3: Forb species recorded at different sites together with family names. Names of forbs and their families follow Germishuizen and Meyer (2003).

Monocotyledonous plants							
			Forb species cover				
Family name	Names of forb species	Growth form	Site 1	Site 2	Site 3	Site 4	Site 5
Anthericaceae	*Chlorophytum fasciculatum*	Herb		1			1
	Chlorophytum transvaalensis	Herb	2	1			1
Asphodelaceae	*Chortolirion angolensis*	Geophyte		1	1		1
Colchicaceae	*Commelina africana*	Herb	1	2	3		1
Commelinaceae	*Cyanotis lapidosa*	Herb				1	
	Cyanotis speciosa	Herb		1	1	1	1
Cyperaceae	*Bulbostylis collina*	Herb		2	2	1	1
	Bulbostylis humilis	Herb		2			2
	Cyperus flavissimus	Herb			1		
	Cyperus longus	Herb			4		
	Schoenoxiphium spartum	Herb	2				
	Scleria dieterlenii	Herb	2				1
	Scleria woodii	Herb	2		4		
Eriospermaceae	*Eriospernum flagelliforme*	Geophyte					1
Hyacinthaceae	*Dipcadi gracillimum*	Geophyte				1	
	Eucomis autumnalis	Geophyte	1			1	
Hypoxidaceae	*Hypoxis hemerocallidea*	Geophyte	1			1	
	Hypoxis rigidula	Geophyte	1	1	1	1	2
Iridaceae	*Crocosmia paniculata*	Herb	3				1
	Dierama insigne	Herb		1	1		
	Lapeirousia masukuensis	Herb	1	1			1
	Moraea stricta	Herb			1		
	Wastonia pulchra	Herb			1	1	

		Dicotyledonous plants					
Apiaceae	*Peucedanum magalismontanum*	Herb	1				
Apocynaceae	*Asclepias albens*	Geophyte	2				1
Asteraceae	*Aster bakeranus*	Herb			1	1	
	Aster harveyanus	Herb				1	
	Aster perfoliatus	Herb			1	1	
	Berkheya setifera	Herb	3	2		1	
	Conyza bonariensis	Herb				1	
	Dicoma anomala	Herb		2	1	1	2
	Euryops transvalensis subsp.setilobus	Herb		2		2	
	Gerbera piloselloides	Herb	1			1	
	Haplocarpha scaposa	Herb		3			
	Helichrysum acutatum	Herb	2	2	3	1	5
	Helichrysum aureonitens	Herb	3	2			3
	Helichrysum candolleanum	Herb			1		1
	Helichrysum cephaloideum	Herb			3		
	Helichrysum nodifolum	Herb	3	1	1	1	
	Helichrysum pilosellum	Herb	3	2	4	3	3
	Helichrysum rugulosum	Herb			2	1	
	Nolletia rarifolia	Suffrutex		1			
	Schistostephium crataegefilium	Herb	2				
	Senecio anomalochrous	Herb			2		
	Senecio conrathii	Herb			1	2	3
	Senecio serratuloides	Herb		2	1	2	2
	Seriphium vulgaris	Herb			3		
	Tolpis capensis	Herb	1	1	2	1	1
	Vernonia monocephala	Herb	4		1		
	Vernonia natalensis	Herb	1	1	2		
Campanulaceae	*Craterocapsa tarsodes*	Herb		1		1	1
	Wahlenbergia squamifolia	Herb				1	1
Caryophyllaceae	*Silene burchellii*	Herb			1		
Crassulaceae	*Crassula lanceolata subsp.transvaalensis*	Herb	1		1	1	
	Crassula obovata	Dwarf shrub		1	1	1	
	Crassula vaginata	Herb			1		1
Euphorbiaceae	*Acalypha punctata*	Herb	4	1	3	1	3
	Euphorbia striata	Dwarf shrub			1	1	1
Fabaceae	*Chameacrista absus*	Herb		2	2	2	
	Eriosema ellipticofolium	Herb				1	
	Eriosema simulens	Herb	3		2		2
	Indigofera hedyantha	Herb		2	2		3
	Indigofera hilaris	Herb	1		1		
	Lotononis foliosa	Herb		1			
	Rhynchosia monophylla	Herb			4	2	3
Geraniaceae	*Mansonia attenuata*	Herb			1	1	1
	Pelargonium luridum	Geophyte	1		1		
Lamiaceae	*Stachys natalensis*	Herb				1	
Lobeliaceae	*Lobelia erinus*	Herb			3		1
Malvaceae	*Hibiscus aethiopicus*	Herb	1				
Molluginaceae	*Psammotropha breviscapa*	Herb				1	
Myriceae	*Myrica brevifolia*	Shrub		2			
Plantaginaceae	*Plantego lanceolata*	Herb			1		
	Plantago myosuros	Herb	1		1		
Polygalaceae	*Polygala ohlendorfiana*	Herb		1			
	Rumex acetosella subsp. angiocarpus	Herb		2	2	1	1
Portulaceae	*Talinum caffra*	Dwarf shrub		1	3	1	1
Proteaceae	*Protea parvula*	Dwarf Shrub				4	

Rosaceae	*Cliffortia strobilefera*	Shrub				2	1
Rubiaceae	*Anthospenum pumilum*	Dwarf shrub		1	1	1	
	Kohautia amatymbica	Herb		1		1	1
	Pygmaeothamnus chamaedendrum	Dwarf shrub		2			
	Richardia humistrata	Herb			4		
Scrophulariaceae	*Selago acutibrachea*	Herb				1	
	Selago witbergensis	Dwarf shrub		1	1		
	Sutera neglecta	Herb			2	1	1
Solanaceae	*Solanum lichtensteinii*	Shrub	1				
Thymelaeaceae	*Gnidia canoargentea*	Dwarf shrub		1			
	Gnidia gymnostachya	Dwarf shrub		1	2	2	1
	Gnidia kraussiana	Shrub	1		1		
	Gnidia splendens	Dwarf shrub				2	

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Conclusion: This study revealed that species assemblage on an annually burned site was completely dissimilar from biennially burned sites and was dominated by flora that is considered as fire-tolerant species. In contrast, the lack of fire or degree of rockiness or kloofs in some areas from burning in addition to regular burning of other areas contributed to the high species composition of communal land which was partially burned and ensured the presence of both fire-tolerant and fire-intolerant species. The study therefore suggests the partial burning or mosaic style of burning on grazed habitats as a mean of improving species composition. In addition, the effect of different game herbivores on species composition should be investigated due to the dissimilarity in species assemblage between mix proportion of herds and single herd grazed game sites. The use of ecological status as a method for grassland condition assessment should be critically re-examined.

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