Ecology and management of bush encroachment – a paradigm shift

Tjelele, TJ[1,3]; Pule, HT[1]; Muller, FL[1]; Monegi, P[1]; Phoko, M[1]; Letsoalo, NL[1]; Manganyi, F[1]; Cupido, C[2]; Jacobs, TJ[2]; Samuels, MI[2]

[1]Agricultural Research Council, Animal Production- Range and Forage Sciences, Pretoria, South Africa

[2]Agricultural Research Council, Animal Production- Range and Forage Sciences, Cape Town, South Africa

[3]Department of Agriculture and Animal Health, College of Agriculture and Environmental Sciences, University of South Africa, Florida Campus, Roodepoort 1709, South Africa

Key words: animal performance; rangeland ecology; rangeland management; woody plant encroachment

Abstract

Tree and shrub densities have increased by approximately 30-50% in many areas of southern Africa, which increase the amount of bare soil surfaces and consequently declines in soil functions, which hinders the recovery of herbaceous plants. Additionally, encroaching woody plants such as *Vachellia species*, *Seriphium plumosum* and *Senegalia caffra* may alter ecosystem services such as forage production for livestock; and thereby increase associated costs of livestock management. The expansion of woody plants in communal and commercial systems is attributed to local and global driver including but not limited to overgrazing, elevated atmospheric CO_2, erratic rainfall. In an attempt to understand the underlying causes of woody plant encroachment, and develop management interventions the following objectives were explored the 1) effect of season, burning, slope position, and their interaction on *Seriphium plumosum* L. crude protein, neutral detergent fibre, total phenolics and condensed tannins concentrations, 2) optimal tree density that will maximize forage production, 3) the use of woody encroaching species as a measure of control of endoparasites in cattle, and 4) use of encroaching woody species as fodder and their effect on animal performance, methane emission and meat quality. Crude protein concentration was higher during the wet season in post-fire treatment sites than in no fire treatment sites, which were also higher than CP concentrations during dry season at no fire treatment sites and post-fire treatment sites. The results showed that mechanical- and chemical -control, as well as fire application influences the structure and functioning of savannas by creating gaps that promote grass production. *Senegalia caffra* resulted in nearly 100 % mortality of internal parasites in cattle after just 2 hours of application. Lastly, the encroaching woody plants showed the potential for use as fodder for livestock without adversely affecting animal performance, improve carcass characteristics and reduce methane emission.

Introduction

Woody plant encroachment has increased by approximately 30-50% in many areas of southern Africa, which hinders the recovery of herbaceous plants (Kraaij and Ward 2006). Given the widespread spread of woody plants into grasslands and savannas in southern Africa and worldwide (Archer et al. 2017), there is a considerable decline in the agricultural potential of rangelands (Börner et al. 2007). For instance, the increasing rate and extent of *Vachellia karroo*, *Senegalia caffra* and *Seriphium plumosum* in South Africa will compromise ecosystem services such as forage production to support a large population of grazers, with negative impacts on the pastoral economy (Pule 2018). In contrast, tannin-rich plants such as *Vachellia and Senegalia* species do not only aid in the reduction of enteric methane emissions in cattle (Piñeiro-Vázquez *et al*., 2015) but they are also beneficial to herbivore' health and well-being by minimizing parasitism in ruminants (Mbatha et al. 2002). The expansion of woody plants in communal and commercial systems is attributed to local and global driver including but not limited to overgrazing, elevated atmospheric CO_2, erratic rainfall. In an attempt to understand the underlying causes of woody plant encroachment, and develop management interventions the following objectives were explored the 1) effect of season and burning and their interaction on *Seriphium plumosum* L. forage quality; 2) optimal tree density that will maximize forage production, 3) the use of woody encroaching species as a measure of control of endoparasites in cattle, and 4) use of encroaching woody species as fodder and their effect on animal performance, methane emission and meat quality.

Methods

The studies were conducted in 1) Bronkhorstspruit (25.76907°S, 28.67918°E), Gauteng Province, South Africa; 2) & 3) Roodeplaat experimental ranch of the Agricultural Research Council (25º 56'S, 28º 35'E) in Gauteng Province, South Africa; and 4) Agricultural Research Council - Animal Production farm (25° 53'S, 28° 11'E), Gauteng province, South Africa. Objective one: a combination of *S. plumosum*'s fine leaves and twigs from previously burned and unburned (n = 116) areas were sampled from randomly selected plants during the wet (n = 58) and dry (n = 58) seasons, respectively. The 58 samples were from burned (n = 29) and unburned (n = 29) treatment areas. *Seriphium plumosum* samples were collected in (2015) wet/growing season on previously burned areas, while on unburnt areas, samples were from previous (2014) wet/growing season. The minimum distance between sampled *S. plumosum* plants at each sampling site was approximately 10 m. Objective two: a tree-thinning study was conducted in two savanna sites that differ in soil texture and woody species. Trees were thinned to the approximate equivalents of 0% (control-no removal), 10, 20, 50, 75 and 100% (complete removal of trees), followed by herbicide application on half of the stumps for each plot. Tree stumps were treated with herbicide within 15 min after felling during the growing season (Teague and Killilea, 1990; Burch and Zedaker 2003). Objective 3: grass biomass was assessed using five randomly placed 50 cm × 50 cm quadrats in each plot, with all of the grass samples within the quadrats harvested regardless of species. Objective 3: seedlings (< 1m) and adult trees (> 1.5m) of seven woody encroaching species (namely *Vachellia nilotica*, *Vachellia tortilis*, *Senegalia caffra*, *Ziziphus mucronata*, *Vachellia karroo*, *Searsia lancea and Euclea crispa*) were sampled in addition to *Opuntia ficus-indicathat* that was used as a control. Leaf-based ethanol extract: a 20% ethanol solution was prepared in order to extract the dried-ground plant material by adding 1500 µl of ethanol 96% to 0.1 g of ground leaves from each encroacher species (i.e. *V. nilotica*, *V. tortilis*, *S. caffra*, *Z. mucronata*, *V. karroo*, *S. lancea and E. crispa*) into an eppendorf tube (McIntire, 2005-2008). Objective 4: edible *S. plumosum* (i.e. leaves and twigs) were harvested using a tractor slasher and sun-dried for three days before bailing. *Seriphium plumosum* forage material was used for chemical analysis (i.e. dry matter, crude protein, neutral detergent fibre, metabolizable energy, acid detergent fibre and condensed tannin and feed formulation. Twenty-eight Nguni steers aged 22 months with a mean body weight of 300 ± 10kg were randomly assigned

to one of four treatment diets containing *S. plumosum* meal levels at 0, 10, 20 or 30 % as replacements for Lucerne hay.

Results

Seriphium plumosum forage quality

There was a significant interaction effect of season x fire on NDF and CP ($P < 0.05$), but not on CTs and TPs concentrations ($P > 0.05$). The interaction effects of season x fire on *S. plumosum* crude protein (Fig. 1) and neutral detergent fibre. The effect of dry season × fire (5.34 % g−1 DW ± 0.18 SE), as well as dry season × no fire (5.09 % g−1 DW ± 0.18), on CP percentage were insignificantly different. However, the wet season post-burning had significantly higher CP (7.33% g−1 DW ± 0.31) than the wet season on unburned treatment (6.08% g−1 DW ± 0.20; Fig. 2a).

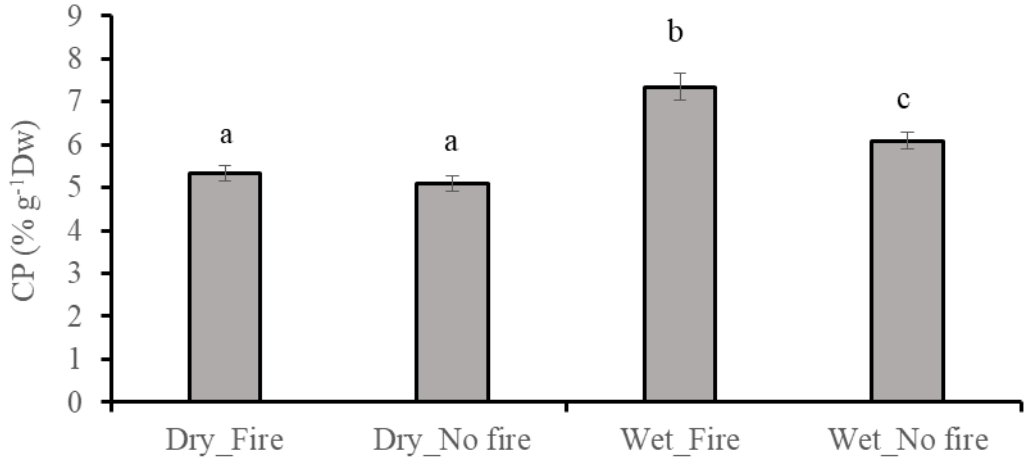

Fig. 1. *Seriphium plumosum* mean crude protein (CP) concentrations during the dry season in burned (fire) and unburned (no fire) areas and during the wet season in burned (fire) and unburned (no fire) areas.

Tree thinning on biomass production

The study revealed that the control plots (0 %) had a higher recorded grass biomass than at 75% and 100% (complete removal) removal treatments. In site 1, the control plots (0 %) had a higher recorded grass biomass than at 75% and 100% (complete removal) removal treatments. At site 2, tree removal significantly increased grass-biomass at the end of the first and second growing seasons i.e. grass biomass increased in the plots totally cleared of trees in the first growing season at site. Grass biomass increased in the plots totally cleared of trees in the first growing season at site 2. Towards the end of the second growing-season, grass biomass was greater than the previous season across all treatments, with substantial increases at 50%, 75% and 100% removal.

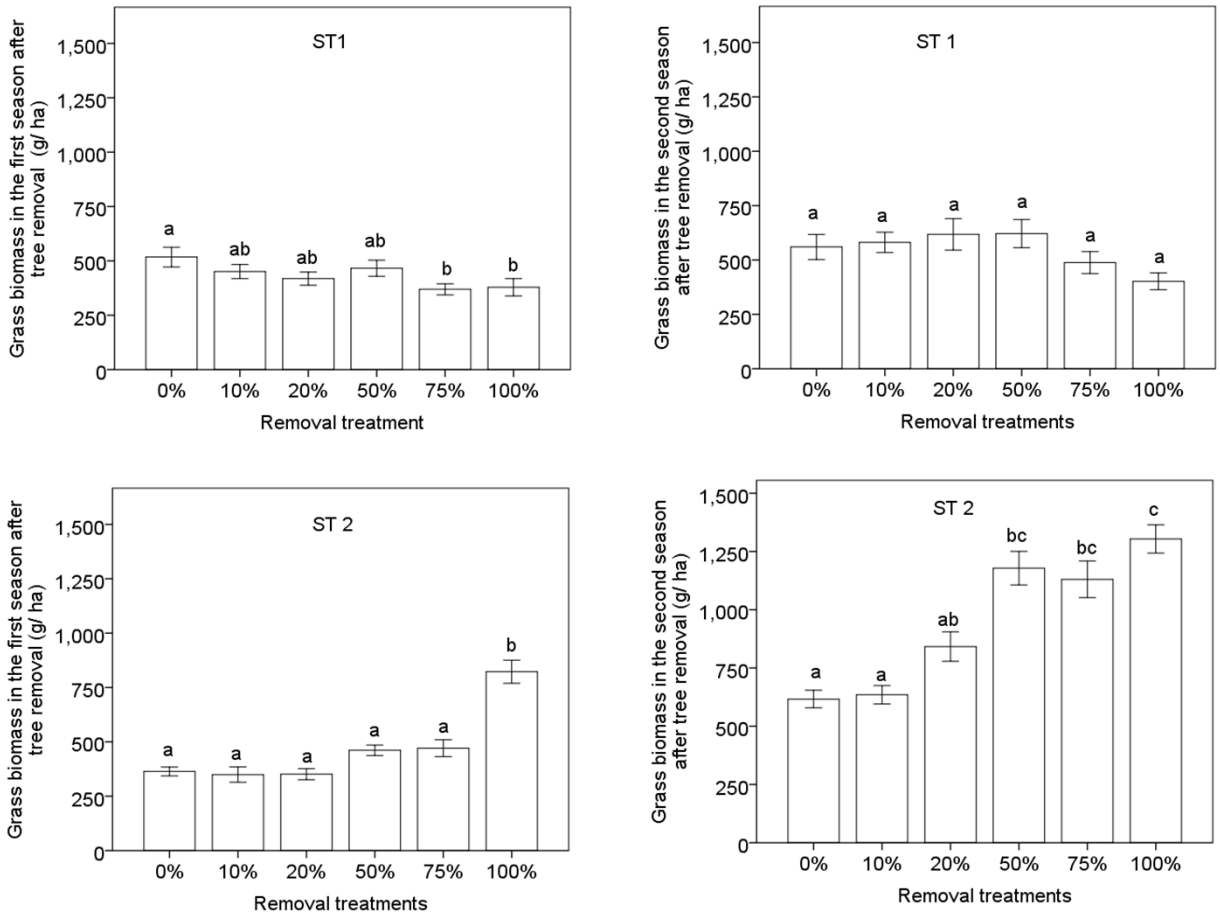

Fig. 2. Grass biomass production after tree removal in study sites 1 (ST1) and 2 (ST2). Treatments range from 0% = no removal (control) to 100 % removal = complete tree removal.

Encroaching woody plants: implications for internal parasites

Opuntia ficus-indica yielded the highest inhibition at 43.88% after 4 hours of application followed by *Vachellia karroo* at 42.26%. At species evaluated except for *Vachellia tortilis* parasitic larvae mortality was noted after 1 hour averaging 52.40% mortality at four hours. *Senegalia caffra* resulted in nearly 100 % mortality after just 2 hours of application.

Encroaching woody plants as fodder for ruminants

Seriphium plumosum meal inclusion in the diets at 0, 10, 20 or 30% did not affect live weight, feed conversion ratio and body condition score values of Nguni steers. Notably, Nguni steers fed a diet with 30 % of *S. plumusom* meal had lower significantly lower ($P<0.05$) CH_4 emission values than those fed diets having 10 or 20 % of *S. plumosum* meal. No significant difference was observed ($P > 0.05$) on tenderness, warmer blazer shear force, cooking loss %, beef aroma and bloody flavour of Nguni steers fed varying levels of *S. plumosum* meal.

Implications

The study has demonstrated that strategic use of fire may contribute to improve *S. plumosum* CP concentrations, especially in the wet season. This may result in improved preference and intake of *S. plumosum* by browser, thus contributing to control its encroachment on semi-arid grassland communities

and livestock production. Additionally, encroaching woody plants can be used as fodder for livestock without adversely affecting animal performance, improve carcass characteristics and reduce methane emission. While tree removal may increase standing grass biomass in multi-tree-species systems on healthy soils, it may not be effective in monospecific stands especially on eroded clay soils. Thus the recovery of key ecosystem services such as an increased forage production may not be realised, regardless of investment in woody species control.

Acknowledgements

The Agricultural Research Council, National Research Foundation, Red Meat Research & Development South Africa (RMRD-SA) and the University of South Africa is appreciated for funding the studies.

References

Archer SR, Andersen EM, Predick KI, Schwinning S, Steidl RJ, Woods SR (2017) Woody plant encroachment: Causes and consequences. (Eds Briske DD Rangeland Systems: Processes, Management and Challenges). (Springer, New York). pp. 25-84.

Börner J, Higgins SI, Kantelhardt J, Scheiter S (2007) Rainfall or price variability: what determines rangeland management decisions? A simulation optimization approach to South African savannas. *Agricultural Economics* 37: 189-200.

Burch PL, Zedaker SM. 2003. Removing the invasive tree *Ailanthus altissima* and restoring natural cover. *Journal of Arboriculture* 29: 18-24.

Kraaij T, Ward D (2006) Effects of rain, nitrogen, fire and grazing on tree recruitment and early survival in bush-encroached savanna. *South Africa. Plant Ecology* 186, 235-246.

Teague WR, Killilea DM. 1990. The application of various picloram formulations to stumps of *Brachystegia spiciformis* Benth., *Julbernardia globiflora* (Benth). Troupin, *Terminalia sericea* Burch. ex DC. and *Acacia karroo* Hayne trees. *Journal of the Grassland Society of Southern Africa* 7: 125-132. https://doi.org/10.1080/02566702.1990.9648218