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The Effects of Chemical and Mechanical Control of Woody Plants on Resprouting and Seedling Production in Communal Rangelands

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The effects of chemical and mechanical control of woody plants on resprouting and seedling production in communal rangelands

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Key words: Picloram; savanna; stem diameter; weed wrench; woody plant encroachment.

Abstract
In many African countries, communal rangelands are threatened by woody plant encroachment. We sought to explore potential solutions for communal ranchers that would be cost-effective. We conducted two field experiments to determine (1) the effects of various tree removal treatments (10%, 20%, 50%, 75% and 100%), and herbicide application on resprouting ability and vigour of several woody plant species; and (2) the effectiveness of Tree Poppers® (a weed wrench) as a low-cost mechanical control tool to physically uproot seedlings and saplings of woody species. In the first experiment, we examined 12 plant species from 20 plots (30 m x 30 m) each subjected to tree removal, followed by herbicide application on half of the stumps for each plot. In the second experiment, eight dominant tree species were grouped into three height classes (0-49 cm, 50-99 cm, 100-150 cm) of ten seedlings and saplings per species per height class. All the tree species in this study resprouted six months after cutting. Herbicide application significantly reduced the resprouting ability of *Dichrostachys cinerea* (L.) Wight & Arn, *Ehretia rigida* (Thunb.) Druce, *Vachellia robusta* (Burch.) Kyalangalilwa & Boatwright and *Ziziphus mucronata* Willd. Tree removal positively influenced the resprouting ability and vigour of only *Euclea crispa* (Thunb.) Gürke. The diameter of stumps was an important factor in determining resprouting ability, with shoot production decreasing with increasing stump diameter. We found no significant differences in the number of seedlings and saplings uprooted by Tree Poppers® among the different size classes. There were significant differences in the number of juveniles uprooted using a weed wrench with only a few individuals of *Vachellia* species uprooted. Woody plants are more likely to resprout and survive as juveniles than as adults after cutting. Communal ranchers may mechanically control shallow-rooted tree seedlings with a weed wrench but not deep-rooted ones, such as *Vachellia* species.

Introduction
Effective rangeland management can be achieved by developing appropriate strategies that can help increase or maintain grass production adequate for livestock- and game-ranching (Smit 2005; Harmse et al. 2016). One strategy for optimizing the availability of grass and maintaining the ecological benefits conferred by woody plants is by reducing the tree density (also termed *tree thinning*), which involves a reduction in the number of trees in areas where woody plant encroachment has occurred (Smit 2005). Tree density reduction has been shown to have positive benefits in savannas such as an increase in grass production and reducing soil erosion (Ndhlovu et al. 2016). Globally, brush management techniques may include mechanical control methods such as shredding or roller chopping to remove most of the woody layer (Archer 2010; Eldridge and Ding 2020). These methods are widely used in developed countries such as the United States of America and Australia (Eldridge and Ding 2020). In southern Africa, resource-constrained communal ranchers cannot normally afford to implement these methods. Given that the problem of woody plant encroachment is particularly acute in communal rangelands (Mograbi et al. 2015), alternative low-cost strategies that are effective, less complex and that can control the growth and survival of young trees in small-scale rangeland systems are needed. Mechanical tools such as Tree Poppers® may help control young trees in communal rangelands (see https://treepopper.co.za). Tree Poppers® are hand-held mechanical tools that are designed to physically uproot tree seedlings. Tree Poppers® work in a similar way to weed wrenches that are normally used in North America by nature conservation groups and land management agencies to control young trees (see e.g., https://www.theuprooter.com). The use of Tree Poppers® in savanna rangelands for mechanical woody-plant control has not previously been recorded in southern Africa.

A problem that is widely understood is that mechanical-control methods are limited by the abilities of many trees to resprout after incomplete removal (Pausas and Keeley 2017). Many empirical studies have reported on the importance of resprouting as a persistence strategy across different habitats, from savannas (Shackleton 2000), forests (Poorter et al., 2010) and deserts (Nano and Clarke, 2011) to Mediterranean ecosystems (Keeley et al. 2012). Woody plants have been reported to regenerate from the cut or broken stem as well as through seedling recruitment (Bond and Midgley 2001; Shackleton 2001). Resprouting is a mechanism that allows individual plants to regenerate after the elimination of the above-ground biomass and persist in ecosystems with recurrent disturbances (Nzunda et al. 2014). The resprouting ability of various woody plants is supported by the non-structural carbohydrate reserves stored in a well-developed, deep-root system (Casals and Rios 2018). Regardless, shoots produced by the cut stumps are undesirable because they have the ability to regrow into mature trees with multiple stems that may have negative competitive effects for resources on grasses (Shackleton 2001; Nano and Clarke 2010). To prevent tree stumps from regenerating after tree cutting, the cut stumps are frequently treated with chemical herbicides (Enloe et al. 2018). However, poor communal ranchers may be unable to afford such herbicides, so we sought to determine whether they could use other, less-expensive means.

Here we examined the resprouting patterns of 12 dominant woody species at Roodeplaat ranch in Gauteng Province of South Africa. We applied mechanical tree removal and herbicides to determine which of these two factors were most important for controlling woody plant encroachment. We sought to determine the combined effects of tree species, removal treatments, stump diameter, and herbicide application on resprouting patterns of the study species. Further, we investigated the effectiveness of a Tree Popper® to mechanically uproot tree seedlings and saplings of eight dominant species in the study area. To achieve these aims, we conducted two field experiments and made the following predictions: (1) A higher density of trees in low-removal treatments will result in reduced resprouting ability and vigour due to stump shading by the remaining trees; (2) Herbicide application will result in reduced or no growth from cut stumps regardless of the species; (3) There will be a positive correlation between resprouting ability and stump diameter because larger trees should have greater storage of below-ground resources (Nzunda et al., 2008); (4) The effectiveness of a Tree Popper® is likely to be negatively affected by seedling height and be greater for shallow-rooted trees.

Methods and Study Site

The study was conducted at the Roodeplaat experimental ranch of the Agricultural Research Council (25º 56'S 28º 35'E) in Gauteng Province, South Africa. The study was conducted in two sites within the ranch. The first study site consisted of 20 plots of 30 m x 30 m each subjected to different intensities of tree removal. Trees were removed to the approximate equivalents of 10%, 20%, 50%, 75% and 100% total clearing of the tree biomass per plot, following Smit (2005). This experiment was a split-plot design, where half of the tree stumps were treated with a herbicide. The herbicide used contains picloram as its active ingredient (Teague and Killilea 1990). To determine the regrowth patterns for each resprouting stump the following variables were measured in each plot 6 months after tree felling during July 2019: (1) total number of resprouting shoots, (2) number of leaves on the leader (longest) shoot, (3) shoot length of the leader shoot and (4) shoot diameter of the leader shoot, measured at the base of the shoot.

In the second study site, we assessed the effectiveness of a Tree Popper® (Fig. 1) to mechanically uproot woody seedlings and saplings of eight dominant species (viz. *Dichrostachys cinerea*, *Euclea crispa*, *Ehretia rigida*, *Gymnosporia buxifolia*, *Vachellia karroo, V. nilotica, V. tortilis* and *Ziziphus mucronata*). We used plant height to differentiate between seedlings and saplings (i.e., trees taller than 1 m were considered saplings). The effectiveness of a Tree Popper® to control unwanted young plants was assessed during the wet season after a rainy event. Individual plants were grouped into three height classes (i.e., 0-49 cm; 50-99 cm; 100-150 cm) of 10 seedlings per species per height class. At the second site, there were no *D. cinerea* and *V. nilotica* saplings in the 100-150 cm height class. Juvenile plants that were uprooted by the Tree Popper® were recorded as successfully removed and those that were either not removed or broke at the bottom of the stem were recorded as *unsuccessful*. A single person of 70 kg body weight carried out the removal of seedlings.

We used multivariate analyses of covariance (MANCOVA) to test the effects of tree species, stump diameter, herbicide application and tree removal treatments on the resprouting ability and vigour of the trees. We used linear regression to determine the relationship between resprouting ability of the trees and stump diameter. A two-factor ANOVA was used to determine whether there were significant effects of tree species and tree height on the number of juvenile plants uprooted by the Tree Popper®.

Results

We found a significant effect of tree removal on resprouting patterns of the tree species (Wilks' $\lambda = 0.971$; $F = 1.705$; $P < 0.039$). There was a significant effect of stump diameter on resprouting patterns of 10 of the 12 tree species (Wilks' $\lambda = 0.885$; $F = 29.383$; $P < 0.001$). Furthermore, we observed a significant negative relationship between stump diameter and shoot production on the trees. We found a significant effect of herbicide application on the resprouting patterns of five of the 12 tree species (Wilks' $\lambda = 0.819$; $F = 50.798$; $P < 0.001$).

We found significant differences in the number of juveniles removed using the Tree Popper® ($P < 0.05$) among species, with a higher number of juveniles removed for *E. crispa*, *E. rigida*, *G. buxifolia* and *Z. mucronata* than for *D. cinerea*, *V. karroo*, *V. nilotica* and *V. tortilis*.

Discussion

All the tree species in this study resprouted following cutting, demonstrating their ability to regenerate from the damaged tissues. Our results are consistent with findings of similar studies demonstrating abilities of woody plants to resprout after disturbances (Shackleton 2001; Bond and Midgley 2001).

The various intensities of tree-removal applied in this study were not important determinants of resprouting ability (shoot production) and vigour (shoot length and shoot diameter) of 11 of the 12 species examined. This may be attributed to the distribution pattern of woody plants in savanna rangelands (Mureva and Ward 2016) where competition for resources (particularly soil moisture) among savanna trees usually results in reduced tree densities and sizes, and leads to a more regular pattern of tree distribution (Pillay and Ward 2012).

We predicted that larger stumps would show a greater resprouting ability than smaller stumps. However, we found that shoot production decreased with increasing stump diameter of the study plants, except for *Ehretia rigida*. Similar studies have demonstrated that the effectiveness of resprouting differs according to tree age, which is usually measured by stem diameter at the time of disturbance (Sands and Abrams 2009).

Herbicide application significantly reduced the resprouting abilities of *D. cinerea*, *E. rigida*, *V. robusta*, and *Z. mucronata*. Although herbicide application significantly reduced shoot length and leaf production of *V. tortilis*, it did not affect the resprouting ability (i.e. shoot production) and diameter of the leader shoot of this species. Furthermore, herbicide application had no significant effect on the resprouting ability of seven species tested (*E. crispa*, *G. buxifolia*, *P. capensis*, *S. lancea*, *V. caffra*, *V. karroo, V. nilotica*), inconsistent with our prediction that herbicide application will significantly reduce the resprouting ability of all cut stumps regardless of species. A possible reason for the inconsistency of the effects of herbicide application across species may be attributed to the amount of picloram applied to the cut stumps and time of application for each plant species.

Our prediction that weed wrenches such as Tree Popper® may be an effective mechanical tool to control woody plant seedlings and saplings was partially supported by our results. We also predicted that the effectiveness of the Tree Popper® would differ among tree species due to differences in rooting systems. The majority of *Vachellia* trees, regardless of species, were either not successfully uprooted or broke at the bottom of the seedling stem. This may be because many *Vachellia* species have a long taproot to access ground water (Kambatuku et al. 2013). This kind of root system makes it difficult to uproot seedlings of these species.

In conclusion, our findings provide evidence that woody species in this study area are capable of resprouting after cutting. However, tree removal was not a major determinant of resprouting success in this study. The effects of herbicides to prevent tree stumps from resprouting are species-specific, and are unlikely to be affordable to communal ranchers. We found that stump diameter was the most important factor affecting resprouting capabilities of woody plants. Woody plants are more likely to resprout and survive disturbances as juveniles than as adults. Although the Tree Popper® was not effective in controlling the *Vachellia* species that are responsible for much of the woody plant encroachment in southern Africa (Hoffman and Ashwell 2001), it was adequate for control of *D. cinerea*, another major encroacher in the region. The results provided a scientific basis for deciding whether a Tree Popper® is a viable rehabilitation tools for managing tree seedlings in communal rangelands. Further development of hand-held tools may revolutionize mechanical bush-control measures, particularly in developing countries with limited economic resources. This information can be used to inform land managers and communal ranchers regarding more effective approaches for controlling density of young trees in savannas.

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