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Research Note

Recovery and Germination of *Dichrostachys cinerea* Seeds Fed to Goats (*Capra hircus*)

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Abstract

Goats can act as dispersal agents by consuming seed pods of woody plants and dispersing the seeds in feces. Concerns that goats might thereby promote encroachment by woody plant species such as *Dichrostachys cinerea* (sickle bush) have not been addressed. The objective of this study was to determine the recovery rate and germination of *D. cinerea* seeds that pass through the digestive tract of goats. We hypothesized that 1) *D. cinerea* seeds will remain intact and viable after passage through the digestive tract of goats and that 2) *D. cinerea* seeds will be scarified by such passage, resulting in improved germination percentages. The first trial measured the recovery rate of 1 500 *D. cinerea* seeds that were consumed by indigenous goats, either voluntarily after mixing them with feed pellets (mixed) or by force-feeding (gavaged). Seed recovery for the gavaged treatment (32.7%) was significantly higher than for the mixed treatment (9.9%; $P < 0.001$). The second trial determined germination percentages of *D. cinerea* seeds recovered from the feces of animals in the two treatments of the first trial as well as scarified and control (untreated) seeds. The germination percentage of mechanically scarified seeds (53.0%) was significantly higher than that of seeds that passed through the digestive system in the mixed (35.5%) or gavaged (31.2%) treatments or were untreated (19.0%; $P < 0.001$). Seeds that passed through the digestive tract (mixed and gavaged treatments) had a significantly higher germination percentage than untreated seeds ($P < 0.001$). A nonnegligible proportion of *D. cinerea* seeds remained intact after ingestive chewing and passage through the digestive system, and their germination percentage was even elevated. This suggests that goats have a potential to facilitate woody plant encroachment through dispersal of viable and scarified seeds.

Resumen

Las cabras pueden actuar como agentes dispersores de semillas de plantas leñosas al consumir las vainas de estas. No se ha discutido la preocupación de que las cabras de este modo podrían propiciar la invasión de plantas leñosas tales como *Dichrostachys cinerea* (arbusto hoz). El objetivo de este estudio fue determinar la tasa de recuperación y germinación de semillas de *D. cinérea* que pasan a través del tracto digestivo de las cabras. Planteamos la hipótesis de 1) Las semillas de *D. cinerea* permanecerán intactas y viables después de haber pasado por el tracto digestivo de las cabras, y 2) Las semillas de *D. cinérea* serán escarificadas por tal pasaje resultando, en el mejoramiento de el porcentaje de germinación. El primer experimento se midió la tasa de recuperación de 1 500 semillas de D. cinérea que fueron consumidas por cabras criollas ya sea de manera voluntaria o después de mezclarlas con bolas de alimento o por alimentación forzada. La recuperación de semillas por medio del tratamiento de alimentación forzada (32.7%) fue significativamente mayor que la del tratamiento de la mezcla (9.9%; $P < 0.001$). El segundo experimento determino el porcentaje de germinación de las semillas de *D. cinerea* recuperadas por de las heces de los animales en los dos tratamientos del primer experimento, asi como semillas escarificadas y sin tratar. El porcentaje de germinación de las semillas mecánicamente escarificadas (53.0%) fue significativamente mayor que el de las semillas que pasaron por el tracto digestivo en los tratamiento de mezcla (35.5%) o alimentación forzada (31.2%) o sin tratar (19.0%; $P < 0.001$). Las semillas que pasaron a través del tracto digestivo (tratamientos de mezcla y alimentación forzada) tuvieron porcentaje de germinación significativamente mayor que las semillas no tratadas ($P < 0.001$). Una proporción importante de semillas de *D. cinérea* permanecieron intactas después de haber sido masticadas y pasadas por el sistema digestivo y su porcentaje de germinación también fue elevado. Esto sugiere que las cabras tienen el potencial de facilitar la invasión de plantas leñosas a través de la dispersión de semillas viables y escarificadas.

Key Words: gavaging, rumen digestion, scarification, seed germination, seed survival, sickle bush, woody plant encroachment

INTRODUCTION

Woody plant encroachment has been reported throughout the savannas of southern Africa (van Vegten 1983; Skarpe 1986; Smit 2004). It is a phenomenon whereby trees and shrubs invade grassland and/or increase in density in an already wooded area, resulting in lower yields of herbaceous plants and a reduction in the carrying capacity of rangelands (Richter et al. 2001; Ward 2005). It is not only the extent of woody plant encroachment but also the rate at which it occurs that is a major concern (Kraaij and Ward 2006). The question of what causes woody plant encroachment still remains unanswered (Ward 2005; Wiegand et al. 2006), and this inhibits development of effective management.

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Herbivores browsing certain woody plants may consume fruits and/or seed pods and disperse seeds through their dung (Janzen 1984; Fuhlendorf 1999; Tews et al. 2004). Seeds dispersed by animals may contribute to an increase in bush encroachment alone or, in combination with other factors such as global climate change, heavy grazing and reduced fire frequency (O'Connor 1996; Schupp et al. 1997; Bond et al. 2003; Ward 2005).

In savannas, fire and goats have been used as tools to manage woody plant encroachment (Trollope 1980; El Aich and Waterhouse 1999). Yet the role of goats in the dispersal of *Dichrostachys cinerea* (sickle bush) seeds and the germination percentages of seeds dispersed by goats remains unknown and a major concern for land users.

D. cinerea is a thorny tree that is one of the common encroachers of South African savannas. The crown-like umbrella structure and its relatively impenetrable canopy constrain browsing by large mammalian herbivores. *D. cinerea* suppresses the herbaceous layer and reduces rangeland carrying capacity and livestock production (Richter et al. 2001).

The main objective of this study was to determine the recovery and germination of *D. cinerea* seeds that passed through the digestive tract of goats. We hypothesized that 1) *D. cinerea* seeds will remain intact and viable after passage through the digestive tract of goats and that 2) passage of *D. cinerea* seeds through the digestive tract of goats will facilitate scarification of the seed coat and improve germination percentages.

MATERIALS AND METHODS

Seed Collection

Dry mature pods of *D. cinerea* were collected from trees and under trees at Kwa-Mhlanga, Mpumalanga province (lat 28°30′E, long 25°15′S), approximately 95 km north of Pretoria, where this species occurs abundantly. Five different *D. cinerea* trees were used to collect pods. Undamaged seeds were removed from the pods and immersed in water, and floating seeds were discarded. Cleaned seeds were stored in paper bags at room temperature (20–23°C; Lacey et al. 1992). Sorting on the basis of density was done before storage to exclude seeds that were infected or not fully ripened. Three replicates of 1 000 seeds were weighed to obtain an average seed weight, and the lengths and widths of 100 seeds were measured using a caliper. Mean seed weight was 27.56 mg (SE ± 0.23), while the mean length and width were 5.06 mm (SE ± 0.04) and 2.22 mm (SE ± 0.02), respectively.

Animals and Feeding

A total of 20 female indigenous goats (South African unimproved veld goats) were used for the study, with an average weight of 20.4 kg (SE ± 0.71). The study was conducted at the Agricultural Research Council (ARC) Irene Experimental Farm in Pretoria, Gauteng province. Goats were placed individually in 2 × 1 m pens and were fed ram-lamb and ewe pellets (Epol [Pty] Ltd, Pretoria) ad libitum for 24 d prior to the experiment to allow them to acclimate to experimental conditions and clean any possible seeds from the digestive tract as well as during the experiment. The pellets contained 13% protein, 14% crude fiber, 1.5% calcium, and 0.2% phosphorus on a dry-matter basis and were 14.80 mm (SE ± 0.75) long and 4.89 mm (SE ± 0.03) wide. Fresh drinking water and salt blocks were also provided ad libitum.

Seed Recovery Trial

Seed recovery was investigated using two methods of feeding goats—voluntary feeding of seeds mixed with diet and force-feeding—in order to separate the effects of ingestive chewing from those of digestion (including rumination chewing). In the first method, 10 goats were fed 1 500 *D. cinerea* seeds mixed with a basal diet of ram-lamb and ewe pellets (mixed). Goats were allowed to consume seeds within 24 h, after which the refusals were collected and unconsumed seeds were sorted and counted. In the second method, 10 goats were force-fed (gavaged) with 1 500 *D. cinerea* seeds. Gavaging seeds directly into the stomach ensured that a known quantity of seeds is ingested (Barrow and Havstad 1992). The amount of seeds fed to goats in this experiment was based on the level used by Lacey et al. (1992).

Feces collection in both treatments commenced 24 h after feeding and continued for 11 d, by which time no seeds were found in the feces. All feces excreted by each goat were collected twice daily from the concrete floor. Feces were immersed in cold water until soft and then washed with tap water through a wire strainer until the water was clear. A light cabinet was used to separate seeds from fecal remains. Undamaged (intact) seeds that were recovered from the feces for each goat for that day were counted and stored in brown paper bags in a cool dry place until the end of the trial.

Germination Trial

Germination potential was determined for seeds subjected to four treatments: 1) mixed seed, 2) gavaged seed, 3) mechanically scarified seeds, and 4) control (untreated seeds). Each treatment consisted of four replicates of 50 seeds per replicate. Seeds for the mixed and gavaged treatments were drawn randomly from the pooled collection of seeds that were recovered from the feces of goats that had been allocated to these treatments in the seed recovery trial. The scarified seed treatment used seeds that had been mechanically scarified using sandpaper (Baes et al. 2002).

Germination tests were conducted at the ARC Roodeplaat Farm Forage Genebank according to the standards of the International Seed Testing Association (1985). The germination tests used 12-mm square plastic dishes containing one disc of germination paper and 5 ml of distilled water and were run in a germination chamber kept at a temperature of 20–30°C with a 16-h dark period and an 8-h light period. Each plastic dish contained 50 seeds. The germination trial was monitored for a period of up to 16 d, and all germinated seeds were recorded and removed. All seeds that did not germinate were counted, and the percentage germination was calculated as the number of seeds germinated divided by the total number of seeds placed in a Petri dish × 100 (Armke and Scott 1999).

Statistical Analysis

In the seed recovery trial, the effect of two seed feeding methods (gavaged seed and mixed seed) on seed recovery was

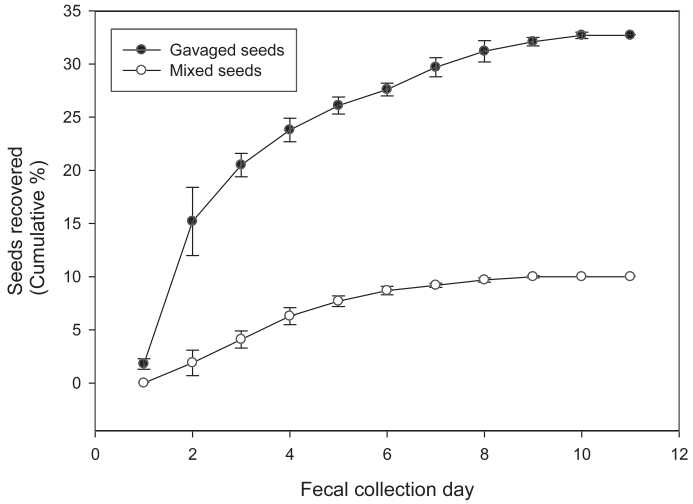

Figure 1. Cumulative recovery (as % of seed consumed) of *D. cinerea* seeds from goats fed using two methods (mixed seed and gavaged seed).

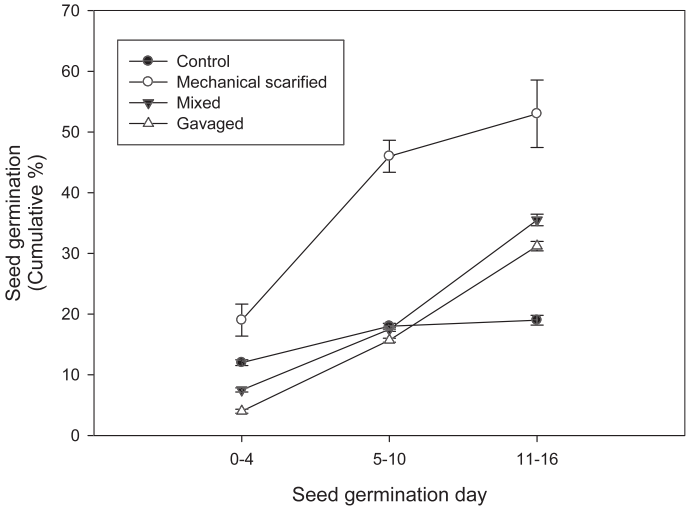

Figure 2. Cumulative seed germination percentage among four treatments: mixed seed, gavaged seed, mechanically scarified seed, and control (untreated) seeds over three periods (days 0–4, 5–10, and 11–16).

analyzed using a *t* test. The total seed recovery from goats was the dependent variable. Each goat was considered an experimental unit ($n = 20$). The data were log transformed for normal distribution. In the germination trial, analysis of variance was used to evaluate significant differences in germination percentages among the four seed treatments (gavaged seed, mixed seed, mechanically scarified, and control). The total germination percentage was the dependent variable. Differences between means were considered significant at the $\alpha = 5\%$ level. SAS software (SAS Institute 2002) was used for data analysis.

RESULTS AND DISCUSSION

Goats consumed fewer seeds (1 298 [SE ± 9.58] seeds · goat^{-1}) when allowed to voluntarily feed on seeds mixed in a ration than when the seeds were gavaged (1 500 seeds · goat^{-1}). Seed recovery for the gavaged seed treatment was significantly higher than for the mixed feed treatment ($P < 0.001$; Fig. 1). A sharp increase in seed recovery for gavaged compared to mixed seed treatments may be due to the rate at which seeds entered the digestive system: as a single massive pulse for gavaged seeds versus a slow trickle for the mixed seed treatment. The morphology of *D. cinerea* seeds (small hard seeds) may explain the generally rapid initial rate of passage for both treatments (Whitacre and Call 2006). Seeds that are < 2.5 mm in width usually have higher recovery during the first few days after consumption than later in the period because they more readily separate from fibrous digesta in the rumen (Gardener et al. 1993; Whitacre and Call 2006). Although seed recovery from the two seed feeding methods followed the same trend (a larger percentage being recovered earlier), cumulative percentage seed recovery for the gavaged seed treatment was higher (32.7%), compared to 9.9% for the mixed seed treatment (Fig. 1), suggesting some damaging effects of ingestive chewing. This study, therefore, partially supported the hypothesis that *D. cinerea* seeds pass through the rumen of goats intact and viable.

The germination percentage of mechanically scarified seeds was higher (53.0%) compared to gavaged (31.2%), mixed (35.5%), and control (19.0%) seed treatments ($P < 0.001$). Rumen-treated seeds (gavaged and mixed seed) had a higher germination percentage than control seeds ($P < 0.001$). The hypothesis that *D. cinerea* seeds that pass through the digestive tract of goats will have higher seed germination percentages compared to untreated seeds was supported. The hard coat of *D. cinerea* seeds together with the faster passage rates may explain the viability of the recovered seeds and the improved germination due to adequate scarification without substantial damage to some of the seeds (Brown and Archer 1987; Miller 1995).

The germination percentages of mechanically scarified and the control treatment increased rapidly during the first 10 d compared to days 11–16 (Fig. 2). The seed germination percentages obtained from gavaged and mixed seed treatments suggest that passage of seeds through the digestive tract of goats improves seed germination compared to seed germinated from untreated (control) seeds. However, many factors influence germination percentages, including the quality of diet, animal species, plant species, and seed characteristics (Simao Neto et al. 1987; Whitacre and Call 2006). All these factors need to be investigated collectively to determine the extent to which herbivores contribute to spreading of viable seeds via the dung and how this may subsequently lead to woody plant encroachment.

MANAGEMENT IMPLICATIONS

Results from the current study showed that although there was a lower percentage of seeds that passed intact through the digestive tract of goats, those seeds remained viable and had substantial germination potential. Although the relative viability of seeds that passed through the rumen was lower than mechanically scarified, it was nearly double compared to that of untreated seeds. The small relative loss in viability of ingested seeds is a good trade-off for the likelihood of these seeds being dispersed by animals away from the tree. We conclude that goats have a potential to facilitate woody plant

encroachment through dispersal of viable and partially scarified seeds that have potential to germinate. Understanding other factors that influence seed viability and germination following ingestion by herbivores and the evolutionary seed dispersal strategies of encroaching tree species may aid attempts to manage woody plant encroachment.

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