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Analysis of three techniques for controlling invasive *Lantana camara* in Swaziland

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In this study, we investigated three different treatment options for controlling infestations of the aggressive Invasive Alien Plant Species (IAPS) *Lantana camara* at the Emantini Game Reserve in Swaziland. Treatment options included cut stump treatment, foliar spraying with herbicide and hand pulling using a manual plant puller. Results from this study indicated that foliar spraying significantly reduces new growth compared to other treatment options investigated. Associations between the various treatments and regrowth were not significant. Comparisons of the various treatments using a contribution index (CI) showed that foliar spraying is the most effective overall treatment for controlling *L. camara* at our study site. Foliar spraying worked best on plants less than 1.5 m high, but cut stump treatment was most effective for thickets where plants needed to be cut before being treated. To improve the effectiveness of foliar spraying, we suggest that this treatment option be used in combination with cut stump treatments. Findings from this study provide valuable information for the control of *L. camara* in different growth stages and levels of infestation. Recommendations for the control of this IAPS can be used in similar environments to effectively control infestations.

Key words: Invasive alien plant control, invasive alien plant species (IAPS), *Lantana camara*, Swaziland.

INTRODUCTION

Lantana camara is an aggressive Invasive Alien Plant Species (IAPS) occurring throughout the southern African sub region including Swaziland. The plant originates from Tropical America and was first recorded in South Africa in 1858 (Bromilow, 2010). It is considered one of the world's top 10 worst weeds (Bromilow, 2010). Toxins in *L. camara* originate from a chemical produced within the plants leaves called Leptodine, which causes photosensitivity of mucous membranes and kidney failure in livestock (Cilliers and Neser, 1991). Due to the extensive invasion of *L. camara* in the sub region and the impact it is having on indigenous plant species, it is important to know which control technique or combination of techniques is best for its removal and the cost implications involved.

Habitat preferences for *L. camara* are tropical, temperate climates with a minimum temperature of 5℃. The plant typically forms dense impenetrable thickets, replacing indigenous plants and increasing erosion (Bromilow, 2010). Water (rivers, streams, and canals), birds and primates are the main dispersal agents for *L. camara*. Grassesand forbs do not grow under *L. camara* thickets, making management by fire difficult due to insufficient fuel loads. Emantini has a history of annual

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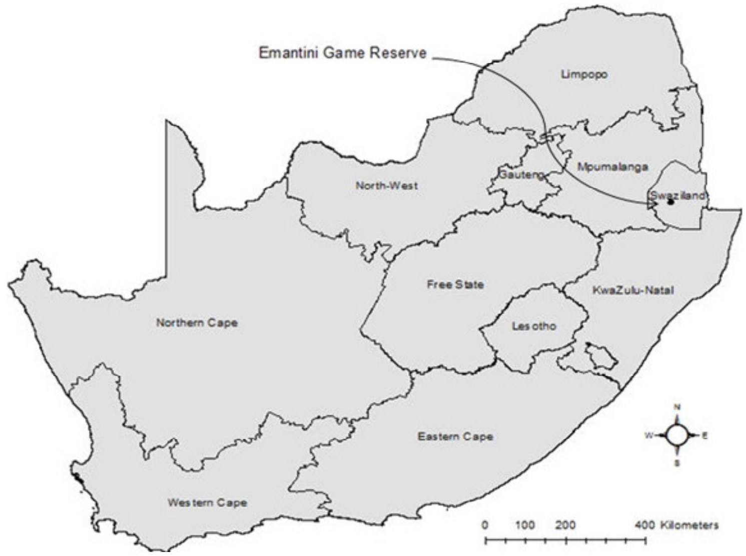

Figure 1. Location of Emantini Game Reserve.

fires and severe over grazing. According to Masacha et al. (2011), alien plant species richness increases significantly as the interval between fires becomes shorter. Frequent fires may inhibit competitive dominance, creating windows of opportunity for alien forbs to establish (Alpert, 2006). The presence of dense *L. camara* thickets prevents seedling recruitment of indigenous tree species, leading to declines in the presence of these species (Sharma and Raghubanshi, 2007). Only older trees that are over 2 m tall survive the encroachment of this aggressively growing IAPS.

L. camara covers a large percentage of Emantini, killing all indigenous plant species within its vicinity through competition for sunlight, moisture and nutrients. Due to its strong allelopathic properties, *L. camara* interrupts the regeneration processes of other plant species by decreasing their germination rates, reducing early growth rates and selectively increasing mortality rates, ultimately reducing species diversity and overall biodiversity. *L. camara* thickets also have a negative effect on soil water regimes (Dye and Bosch, 1999; Van et al., 2001).

In this study, we look at three treatment options for controlling *L. camara* infestations, including cut stump, foliar spraying and hand pulling. We focus on treatment efficacy, costs, time taken to apply the treatments, number of stems treated, regrowth, new growth and plants missed during treatments. Our objectives are to find the most efficient and cost effective treatment or combination of treatments to control *L. camara*, with particular emphasis on regrowth and new growth.

MATERIALS AND METHODS

Study site

The study took place on the Emantini Reserve in Swaziland (Figure 1). Emantini is situated in the mountains to the North West of Manzini. The predominant rock type in the area is Quartz, resulting in the reserve having mostly sandy soils in low-lying areas and exposed rocky outcrops in higher lying areas. Two permanent rivers flow through the reserve, the Mzinene River in the west and the Ngwempitsi River in the south. These rivers mark the western and southern boundaries of the reserve, separating the reserve from surrounding local communities. Seven ephemeral streams originate in the reserve. Two man-made canals flow through the property, one originating from the Mzinene River and the other from the Ngwempitsi River. Both canals run in a south easterly direction from their respective sources. The reserves vegetation is classified as Mountain and Escarpment grasslands (Bothma and du Toit, 2010). The reserve is in a summer rainfall region and receives on average 1200 mm of rain per annum. Temperatures range from 28 to 44°C in summer and 5 to 30°C in winter. Over the past 30 years the reserve has been used extensively for cattle ranching, resulting in severe overgrazing of the grass layer and extensive bush encroachment by *L. camara.*

Plot selection and treatment options

We randomly selected fourteen sample points infested with *L. camara* in the study area. At each sample point, we put out a 10 ×10 m sample plot. In each plot, we determined the density of *L.camara* plants. Three different treatment regimes for controlling *L. camara* were used:

1. Cut stump (CS): Plants were cut to 3 to 6 cm above ground level using brush-clearing saws. Workers then used 15 l knapsack sprayers equipped with hollow cone nozzles to apply herbicide to the cut stems. The herbicide Picloram (0.1% concentration) and an emulsifiable mineral oil (trade name H and R oil) wetter/spreader agent (0.5% concentration) were mixed with 20 L of water. A dye (0.01% concentration) was added to the mixture for marking of sprayed stumps to prevent re-treatment and wastage of herbicide. The mixture was used to fill the knapsacks for spraying.
2. Foliar spraying (FS): As for CS, workers used 15 L knapsack sprayers equipped with wide spray nozzles for foliar application of herbicides. The herbicide Picloram (0.75% concentration) and an emulsifiable mineral oil (trade name H and R oil) wetter/spreader

Table 1. Treatment data for *L. camara*.

Per hectare (ha) treatment information					
Treatments	Time taken*	Stems treated	Regrowth	New growth	Plants missed
CS	22 h 21 min	10,925	17	2,550	217
FS	75 h 18 min	75,767	0	500	1100
HP	975 00 h	925	0	633	0

*Based on average values for a single labourer.

agent (0.5% concentration) were mixed with 20 L of water. The mixture was used to fill the knapsacks for spraying.

3. Hand pulling (HP): Plants were removed using a manual plant puller to pull them by their stems, removing the plant and its roots from the soil in the process.

Treatments

In six plots we did CS treatments, in another six we did FS and in two we did HP. Hand pulling was restricted to two plots due to the intensive nature of the treatment. For each plot we recorded the time taken and the number of workers required to do the treatments. In plots where chemical herbicides were applied, the quantity of herbicide used was recorded. This information was used for cost calculations and analyses. Plots were initially treated in October 2011. We surveyed the plots a month after the initial treatment to collect data on the effects and responses of the treated plants to the various treatments. We collected data on regrowth and new growth. Two months after the initial treatment we applied a second FS treatment to kill any plants we missed in the initial treatment and to kill any new growth or regrowth.

Contribution index

A contribution index (CI) was calculated for n = 7 different parameters (collected and calculated) for the various treatments applied. Parameters included:

1. Initial treatment costs,
2. Follow-up costs,
3. Time taken,
4. Stems treated,
5. Regrowth,
6. New growth,
7. Plants missed.

We used the CI to compare the various parameters across treatments. The formula for calculating the CI is as follows:

$$CI = \left(\frac{P_x}{\bar{x}(P_x)}\right) \times 100$$

Where P_x= Parameter treatment values.

All cost calculations were done using labour and consumable prices available at the time of the study.

Statistical analysis

We did a series of Pearson's chi-square tests to determine whether there were associations between the three different treatments (CS, FS and HP) for re-growth and new growth in the plots after the treatments were applied. Standardised residual post hoc tests were done for significant results. For all tests, alpha was set at 0.05. Statistical analyses were performed using the SPSS™ (version 20) statistical analysis software package.

RESULTS

Data from treated plots and follow-up surveys showing time taken, stems treated, regrowth, new growth and plants missed are depicted in Table 1.

Initial cost breakdowns of the various treatment optionsfor *L. camara* are shown in Table 2. Follow-up treatments were carried out in the plots two months after the initial treatments. Cost breakdowns for follow-up treatments of any *L. camara* new growth and regrowth are depicted in Table 3.

Investigations of the association between the various types of treatments (CS, FS and HP) in the 14 plots and *L. camar a*re growth were not significant$(X^2(2) = 1.44, P = 0.488)$. There was, however, a significant association between the types of treatments and new growth in the plots $(X^2(2) = 14.00, P = 0.001)$.

Calculated contribution indices for the various parameters collected and calculated across the various treatment options are presented in Table 4. For six of the seven parameters investigated, high values represented a negative contribution that was not desirable. The exception was 'Stems treated' where high values represent a positive contribution that is desirable. To cater for the positive contribution of 'Stems treated' in the index, we had to adjust values for this parameter accordingly. Doing this adjusted the contribution value for the parameter and reflected its true contribution to the index.

DISCUSSION

Cut stump

Treatment took the least amount of time to apply; however, noticeably less stems were treated than with foliar spraying. Regrowth and new growth was highest for cut stump treatments. Some plants were missed by this treatment, but not as many as with foliar spraying. This

Table 2. Per hectare costs for removing *L. camara* using three control techniques (CS, FS and HP).

Per hectare (ha) costs																			
Treatment	Labour*			Herbicide			H&R oil			Dye			Petrol			2 stroke oil			Combined
	h	R/h	Total R	L/ha	R/l	Total R	L/ha	R/L	Total R	L/ha	R/L	Total R	L/ha	R/L	Total R	L/ha	R/L	Total R	
CS	22:21	3.75	83.81	0.4400	192.59	84.74	0.0020	31.45	0.06	0.0002	143.00	0.03	3.1300	11.40	35.68	0.0200	54.00	1.08	**205.40**
FS	75:18	3.75	282.38	1.8000	192.59	346.66	0.7070	31.45	22.24	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**651.28**
HP	975:00	3.75	3,656.25	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**3,656.25**

* Based on average values for a single labourer.

Table 3. Per hectare follow up costs for treating previously infested areas where *L. camara* was removed using three control techniques (CS, FS and HP).

Per hectare (ha) costs																			
Treatment	Labour*			Herbicide			H&R oil			Dye			Petrol			2 stroke oil			
	h	R/h	Total R	L/ha	R/L	Total R	L/ha	R/L	Total R	l/ha	R/l	Total R	L/ha	R/L	Total R	L/ha	R/L	Total R	Combined
CS	13:20	3.75	49.99	0.1800	192.59	34.67	0.0010	31.45	0.03	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**84.69**
FS	6:15	3.75	23.44	0.0010	192.59	0.19	0.0010	31.45	0.03	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**23.66**
HP	8:.50	3.75	33.13	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**33.13**

*Based on average values for a single labourer.

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Table 4. Contribution index of the various parameters measured and calculated for the three control techniques (CS, FS and HP).

Contribution index (CI) for the various parameters across treatments								
Treatment	Initial treatment costs (CI)	Follow-up costs (CI)	Time taken (CI)	Stems treated (CI)*	Regrowth (CI)	New growth (CI)	Plants missed (CI)	Total (CI)
CS	13.7	179.6	10.9	-37.4	300.0	207.7	49.4	723.9
FS	43.3	50.2	6.5	-259.4	0.0	40.7	250.6	131.8
HP	243.1	70.2	282.6	-3.2	0.0	51.6	0.0	644.3

*To correct high values being favourable, parameter values for treatments was multiplied by -1.

technique required two labourers, one to cut and the other to spray herbicide onto the cut stump. Cut stump was the least expensive option for the initial treatment, but cost more than foliar spraying during the follow up treatment. Combined initial and follow-up costs were lowest for CS. Cut stump treatment was difficult to implement on steep slopes, slowing progress whilst posing a danger to the cutting machine operator. Steep slopes are more conducive to treatment by foliar spraying.

Cut stump treatment works well in thickets where foliar spraying is not possible. Areas inaccessible to other treatment options are opened up and stem treatments of large numbers of plants can be done relatively quickly using CS. Borrel et al. (2011), found that there was complete die off, and that no plants were missed using this treatment option; these authors attribute this to the dye incorporated into the herbicide mixture, allowing for the identification of already treated plants.

Foliar spraying

Foliar spraying took longer than cut stump treatments, but less time than for hand pulling. This technique treated the highest number of stems with no recorded regrowth. New growth was the lowest for FS. A disadvantage of this treatment was that small plants and the seedbed in the soil were unaffected as only larger plants were sprayed with herbicide. Spraying only the larger plants resulted in foliar spraying having the highest number of missed plants. This technique only required one labourer for spraying of herbicide. Foliar spraying cost more than cut stump for initial treatment but was least expensive during follow up treatment. In general, FS was faster in areas where plants were below 1.5 m tall and not growing in thickets. When thickets were encountered, movement of the people doing the spraying was hampered and accessibility to plants was reduced. This treatment option was the fastest and most effective for treating new growth during follow-up treatments. Labour time was lowest for FS and it took only one person to treat a large area quickly. Weather conditions do however affect the efficiency of this technique. Wind causes overspray of herbicide onto non-target plants, which are detrimentally affected. Humidity and temperature affects the absorption rate of the herbicide into leaves, with high temperatures and humidity increasing absorption rates (Vermeulen et al., 1996).

Rainfall within three hours of a treatment can wash the herbicide off leaves before it has been absorbed, effectively neutralizing the treatment (Vermeulen et al., 1996). High numbers of plants are often missed with foliar spraying due to the inability of being able to identify which plants have been treated before the herbicide mixture dries, especially on sunny days when temperatures are high. A recommendation is to add a dye to the herbicide mixture for identifying treated plants. Applying dye to the herbicide mixhas had been found to be effective with the treatment of *Psidium guajava* in Swaziland (Borrel et al., 2011). Cost comparisons for foliar spraying between this study and *P. guajava* differed as foliar treatment was not the lowest cost option for the *P. guajava,* or the option with the best success rate (Borrel et al., 2011). Foliar spraying did however have the lowest cost and highest success rate of the treatments for *L. camara*.

Picloram is an effective herbicide for treating *L.camara*. Plot 1 (Figures 2 and 3) shows *L. camara* cover before and after treatment. Goodall et al. (2010), found that the ingredients found in the herbicides Metsulfuron and Picloram were most beneficial to increasing desirable indigenous grass species composition in constantly disturbed habitats.

Hand pulling

Hand pulling was a labour intensive treatment that took the longest time of all treatment options to apply, whilst treating the lowest number of stems. Sharma et al. (2005) found that mechanical removing was labour intensive and a low efficiency technique. There was no regrowth for this treatment but a moderate amount of new growth did occur. No plants were missed when doing hand pulling. Two labourers were required for this treatment. Hand pulling was the most expensive treatment option during initial treatment, but less expensive than cut stump during follow up.All plants had to be cut by hand to allow access to their stems before ‘pulling’. It was not possible to hand pull stems with a diameter of less than 12 mm because they broke off where the puller attached. Dense thickets hamper the pulling process, as removed plants needed to be cleared away before the next plant could be accessed. Rocky ground and uneven terrain hamper the effectiveness of this treatment option.

Sharma et al. (2005) found that mechanical control is inefficient in dealing with extensive invasions on undulating, rocky terrain. In general, hand pulling disturbs the area where the treatment is applied. Pulling of plants on drainage line banks or steep slopes considerably increases the chances of erosion due to the removal of plant roots, which stabilise the soil. Grass growth in the plots treated with this technique is slower than for the other treatment options. Root removal and slow grass growth lead to increased erosion. Hand pulling could be a justifiable alternative in chemically sensitive areas. This treatment option is slow, but follow up treatments have fewer plants to treat.

Post treatment observations revealed that three non-target species were negatively affected by herbicide treatments, *Ziziphus mucronata*, *Cussonia paniculata* and *Pterocarpusangolensis*. *Z. mucronata* trees died shortly after the *L. camara* around them were treated. *C. paniculata* dropped all their leaves for a two-month period before new leaves appeared. *P. angolensis* dropped all their leaves for three months before new leaves appeared. Trees that showed signs of fire damage on their bark and trunks died after exposure to the herbicide from overspray during foliar spraying. Some trees in areas where cut stump treatments were applied showed signs of exposure and dropped their leaves. This might be due to the herbicide being released from dead *L.*

Figure 2. Photo of plot1 taken before treatment.

Figure 3. Photo of plot1 taken six months after treatment.

camara roots into the soil in close proximity to the non-target species roots, and being absorbed into the non-target plant.

Results from analyses of the associations between the various types of treatment options and *L. camar a*re growth and new growth, showed that there was only a significant association for new growth. We investigated this association and found that plots where foliar spraying was done were significantly over represented, making a larger contribution to the differences observed for new growth in the plots (standardised residual for sprayed plots was 2.1). In effect, this means that foliar spraying was the most effective of the three treatments for controlling *L. camara* during this study. Total values from contribution indices calculated for the seven parameters showed that foliar spraying was the treatment option that contributed most towards the cost effective control of *L. camara* during this study.

Conclusion

Cut stump treatment is effective in areas where thickets slow foliar spraying, but costs can be very high when cutting thin stems that are below 1.5 m in height.

Overall foliar spraying proved to be the most efficient and cost effective treatment option for controlling *L. camara* during this study. Foliar spraying was fast to apply in areas without thickets.

Hand pulling is useful for larger plants in chemically sensitive areas, but was not cost effective in the conditions encountered during this study.

In our opinion, the best method for controlling *L. camara* is to combine foliar spraying with cut stump treatment. This will give the best results at the lowest costs. Manufacturer suggested chemical concentrations should be adhered to, ensuring that treatments are effective. Care must be taken to avoid sensitive plants near treatment sites, especially when wind can cause overspray onto non-target species, and where the roots of target plants are in close proximity to the roots of non-target species.

Terrain type must be factored into treatment planning, as chemical mixes and equipment might need to be carried to inaccessible sites, increasing time and labour costs. Planning for regular and consistent follow up treatments must be made to ensure all new growth is prevented and seedbeds are eradicated. The cost of long-term follow up has not been taken into consideration for this study. Such costs should reduce as plant numbers decrease after each follow up treatment.

Costs and effectiveness will vary depending on terrain and the density of plants encountered. Constant monitoring of treatment options used needs to be undertaken to ensure that the correct treatments are applied and that the best effects are achieved.

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REFERENCES

Alpert P (2006). The advantages and disadvantages of being introduced. Biol. Invasions 8:1523-1534.

Borrel AJ, Brown LR, Slater K (2011). Chemical control of invasive *Psidium guajava* in Swaziland: a preliminary assessment of costs and efficiency. Afr. J. Agric. Res. 6(14):3291-3297.

Bothma J du P, du Toit JG (2010). Game Ranch Management. 5th ed. Van Schaik. Pretoria. P. 979.

Bromilow C (2010). Problem Plants and Alien Weeds of South Africa. Briza, Pretoria. P. 424.

Cilliers CJ, Neser S (1991). Biological control of *Lantana camara* (Verbaceae) in South Africa. Agric. Ecosyst. Environ. 37:57-75.

Dye PJ, Bosch JM (1999). Sustained water yield in afforested catchments; the South African experience. In:van Gadow et al. (eds)Sustainable forest management, Kluwer Academic Publishers, Netherlands. pp. 99-120.

Goodall J, Braak M, de Kler J, Keen C (2010). Study on the earlyeffects of several weed control methods on *Pantherium hysterophorus L.* Afri. Range. Forage Sci. 27(2):95-99.

Masacha M, Skidmore AK, Poshiwa X, Prins HHT (2011). Frequent burning promotesinvasions of alien plants into mesic African Savanna. Biol. Invasions 13:1641-1648.

Sharma GP, Raghubanshi AS (2007). Effect of *Lantana camara* on local depletion of tree population in the Vindhyan tropical dry deciduous forest of India. Appl. Ecol.Environ. Res. 5(1):109-121.

Sharma GP, Raghubashi AS, Singh JS (2005). Lantana invasion: an overview. Weed Boil. Manage. 5:157-167.

Van Lil WS, KrugerFJ, van Wyke DB (2001). The effect of afforestation with *Eucalyptus grandis* Hill ex Maiden and *Pinus patula* Schlecht. et Cham. on streamflow from experimental catchments at Mokobulaan, Transvaal. J Hydrol, 48:107-118.

Vermeulen JB, Dreyer M, Grobler H, Van Zyl K (1996). A guide to theuse of herbicides.15th edition. National Department of Agriculture. Republic of South Africa.