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Evaluation of different methods to control invasive alien grass weeds in a degraded area

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The objective of this study was to evaluate the efficiency of different methods of exotic grass control in a degraded area in the urban area of Diamantina, state of Minas Gerais, Brazil. The experiment was carried out in a randomized block design, with the following methods of control of invasive grasses: T1) manual; T2) mechanical; T3) chemical; and T4) chemical + mechanical. After one hundred days, regenerants of alien invasive species biomass were sampled for the quantification of fresh biomass and dry biomass. The results found fresh biomass vary among the control methods, with higher values from mechanical control, followed by the combination of mechanical + chemical control. Chemical and manual methods had the lowest fresh biomass production, indicating that they were more effective in controlling the invasive grasses. The production of dry matter did not differ significantly among the methods of exotic grass control, on Tukey test, at 5% significance.

Key words: *Urochloa decumbes*, *Melinis minutiflora*, biomass, restauration.

INTRODUCTION

Brazil is one of the most biodiverse countries on the planet (Forzza et al., 2012). However, with the introduction of alien invasive weeds and the lack of effective prevention and control policies, biological invasion has become the major agent of global change (Early et al., 2016). The establishment, adaptation and dispersion of these species cause great changes in the functioning of natural ecosystems due to their aggressiveness and high invasiveness (D'Antonio and Vitousek, 1992; Rodovalho and Nardoto, 2014; Martins et al., 2017) as well as cause changes in abundance, population size, composition genetics, and community structure (Byers et al., 2002).

The invasive species are present in Brazilian soils since the colonial period, being verified in much of the Brazilian territory, their dispersion threatens to biodiversity, being the Cerrado one of the most affected Biomes (Xavier et al., 2017).

Species of African origin as *Urochloa decumbes* (Stapf) RD, Wabster, *Brachiaria decumbens* Staf. and *Melinis minutifliora* P. Beauv., were introduced for commercial purposes and/or by accident and began to occupy large tracts displacing native species due to their aggressiveness and competitive power. Such invasions

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have contributed to the de-characterization of natural areas and changes to the original vegetation composition (Weber, 2017).

In this sense, the control of these species is of extreme importance. Efforts have involved the implementation of soil and cultural management practices and/or preventive mechanical, biological and chemical means for decreasing the competitive advantage of invasive species with the purpose of the resurgence and reestablishment of local endemic and native species (Vivian et al., 2008). Consideration of cost analysis and control strategies is necessary to support decision-making by ensuring natural ecosystem management when benefits exceed the costs (King et al., 1998; Born et al., 2005).

This paper aims to evaluate the effectiveness of different types of grass control (manual, mechanical and chemical) in a degraded area.

METHODOLOGY

The study was performed from July 2015 to March 2016 in an area of approximately 1.0 ha located a 18° 12' 18.85"S, 43° 34' 9.12" W, on Universidade Federal dos Vales do Jequitinhonha and Mucuri-Campus JK, in the Espinhaço Mountain Range, in the southeast portion of the municipality of Diamantina, Minas Gerais, Brazil.

The average altitude is 1,296 m and the climate is mesothermic, with rainy summers and dry winters. The mean annual temperature varies between 17.4 and 19.8°C (INMET, 2016) and the annual precipitation is around 1,400 mm and occurs among the rainy season (November to January), the dry season (May to September) and the months of transition. Averages for temperature during the experimental period were 24°C in August and September and 27°C in October and November. Average for precipitation of 241 mm was recorded, with 81 mm in August, September and October, and 160 mm in November 2015 based on data from the Instituto Nacional de Meteorologia (INMET, 2016). The predominant soil class of the study site is Entisols, whose main characteristics are sandy texture with simple grain structure, which gives it high macro-porosity, resulting in low saturation capacity and low retention of water available for plants.

The typical vegetal covers of this pedoenvironment are rupestrian cerrado and field formations, ecotypes adapted to seasonal water deficit, since most of the species have a root system adapted to absorb water at great depths (Machado et al., 2013).

The site functioned for solid waste disposal in the urban area of Diamantina, Minas Gerais, and finished in 2002. Currently, it is in the process of recovery. After decommissioning as a controlled landfill, there were concerns about re-vegetating and erosion control due to the exposure of the substrate. Initially random seedlings were introduced in an attempt to form vegetation nuclei besides exotic grass species: *U. decumbes* (Stapf) RD, Wabster and *M. minutiflora* P. Beauv., with the intention of promoting rapid substrate coverage (Machado et al., 2013). At present, the experimental area have predominance of these exotic grasses besides, in their vicinity, some vegetation nuclei with the presence of ruderal tree species (*Psidium guajava* L., *Ricinus communis* L. and *Vernonia polysphaera* Baker), and some native species *Eremanthus incanus* (Less.) Less, *Dalbergia miscolobium* Benth, *Stryphnodendron adstringens* (Mart.) Coville and *Tabebuia ochracea* (Cham.) Standl.

Due to these features, intervention by means of control was necessary since these grasses prevented the development of the seed bank and were in direct competition with the tree species established there, making it difficult to interconnect fragments, thus hampering the recovery processes.

The experiment was performed in a randomized block design, four blocks with dimensions of 16 m × 40 m (640 m^2) as shown in Figure 1. The treatments were constituted by the following methods of invasive grass control: T1) manual; T2) mechanical; T3) chemical; and T4) chemical + mechanical. All of the blocks had a predominance of individuals of *U. decumbes* and *M. minutiflora*. Each block had distinct characteristics, but was internally homogeneous. In each one, 16 plots with dimensions of 4m × 10 m (40 m^2) were allocated, which were randomly treated by the different methods, with four replications each, in an attempt to control the grasses.

The chemical method used pressurized CO_2 and a 20l model Jacto-PJH sprayer with capacity for glyphosate herbicide application. *Roundup Original®*, containing 36% glyphosate, was applied using the recommended dosage of 4.0 l/ha with a volume of solution of approximately 7.5 L per block (120 l/ha). The herbicide was applied to the locally established grasses that were about 1 m tall in August 2015. The mechanical method used a KAWASHIMA TEKNA AL330TH gasoline powered motorized trimmer. The manual method used a hoe.

The amount of time spent for each plot treatment was recorded and averages calculated for each control method. The labour required for the application of the treatments involved two people for the manual and mechanical methods and a technician for the herbicide application of the chemical method. The elimination of individuals of *U. decumbes* and *M. minutiflora* began in August 2015. For manual method was performed, all individuals of the mentioned species were removed, leaving the substrate totally exposed. In the experimental units where the mechanical and/or chemical methods were adopted, the eliminated individuals were maintained *in loco* in order not to expose the substrate.

The regenerate grasses were sampled one hundred days after the application of the control method treatments. In each experimental unit, 12 points were randomly distributed for the collection of regenerated grasses with the aid of 1.0m-square iron frame, totaling 48 units per treatment. The grasses were cut close to the substrate with scissors and other species were kept in place. After collection, the fresh material was packed in paper bags, weighed and then subjected to a forced-air circulation oven at 65° C for 72 hours to obtain the dry weight.

The proposed transformation by Box and Cox (1964), was applied only to dry biomass data, expressed in kg/ha, in order to meet the normality assumptions according to the Shapiro-Wilk homogeneity of variances by Bartlett, independence of waste by Durbin-Watson and the additivity by Tukey. The value of the lambda transform parameter (λ) of Box-Cox was 0.48.

The fresh biomass and dry biomass data were submitted for analysis of variance (F test) and the means were compared by the Tukey test, both at 5% significance. All statistical analyses were compiled and compared with the aid of R © Version.3.2.3.

RESULTS

The time spent executing the different control methods varied. The manual method had a mean time of 120 min, followed by the mechanical and chemical methods, with mean times of 4 and 2 min, respectively. After the execution of the different control methods (manual, chemical and mechanical), plants were allowed to emerge freely, without the interference of any cultural practice, addition of fertilizer or irrigation, in order not to influence their development and survival.

Figure 1. Location of Diamantina in the state of Minas Gerais and Satellite Image Digital Globe (2015) of the part of the JK Campus of the Federal University of Vales do Jequitinhonha and Mucuri where the 4 experimental blocks were located. The colours of the circles define the type of method performed in each plot: yellow (chemical + mechanical methods); red (mechanical method); blue (manual method) and white (chemical method).

Table 1. Analysis of variance summary for fresh biomass and dry biomass (transformed data) using F-test statistic.

S.V.	D.F	M.S.	
		Fresh biomass	Dry biomass
Blocks	3	929670.0	854.0
Treatments	3	2528982.0*	845.7*
Residue	9	338975.0	468.2
CV_{exp} (%)	-	24.40	15.50

SV: Source of variant; D.F: degrees of freedom; M.S: middle square; *significant at 5% probability by the test F. CV_{exp}: Coefficient of experimental variation

The manual method exposed the substrate, which favours the development of seed banks and seedlings. During the entire experiment, 241 mm of precipitation was recorded, of which 160 mm was in November 2015. Due to the low precipitation in the period between September and October, no seedling development was observed. With the increase of precipitation in November, the seedlings could not compete with the grasses and eventually died.

In the plots where the mechanical and chemical control methods were implemented, the resulting material was kept in the areas to cover the substrate, thereby avoiding its exposure, which could contribute to the degradation of the already fragile area. The presence of this material does not permit sunlight from reaching the surface, which prevented the development of seedlings from the seed bank, as had occurred in the plots of the manual method.

The assumptions of normality, homogeneity of variances, residue independence and additivity were met. The coefficients of variation were less than 25%, relatively low for field experiments. Analysis of variance with the F test indicated a statistically significant difference between treatments ($p \leq 0.05$) both for the production of fresh biomass and that of dry biomass. Methods for the control of invasive grasses influenced biomass production 100 days after experimental installation (Table 1).

Figure 2 summarizes the data evaluated for (i) the production of fresh biomass (fb), as measured by initial weight after harvesting at 100 days and (ii) dry biomass (db), as measured by the weighing of post-dried material, obtained for the different control methods. The

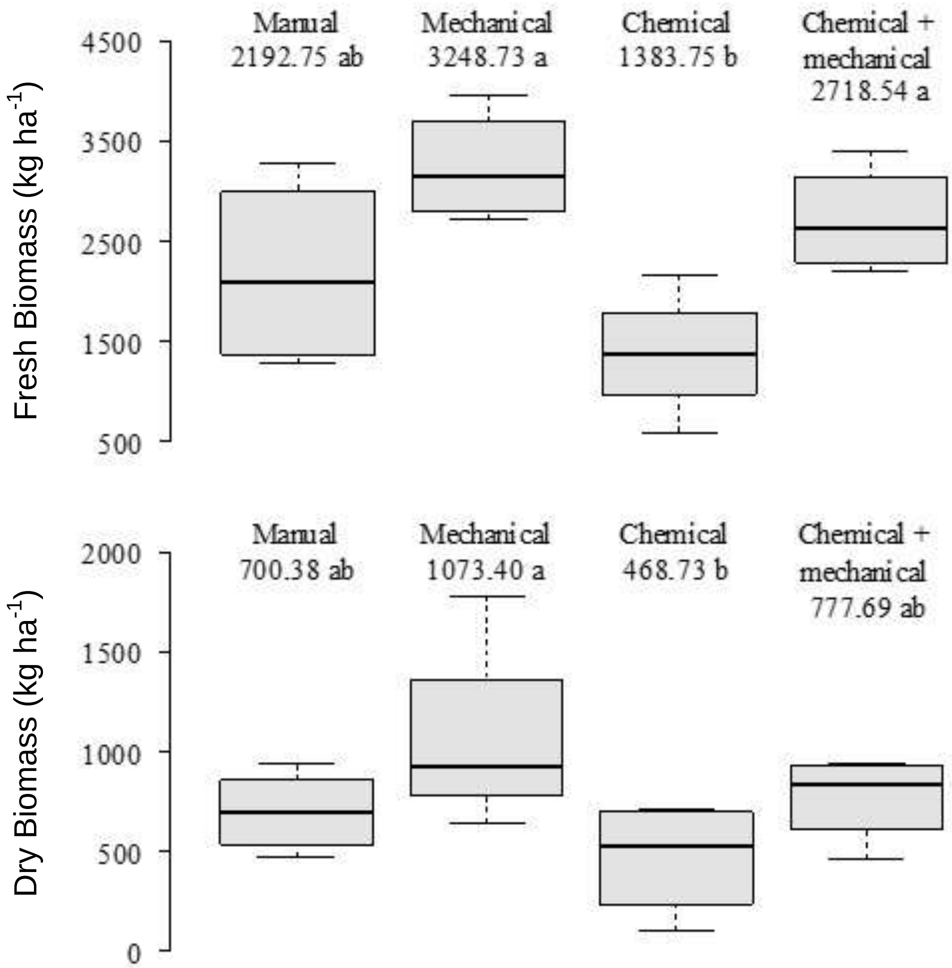

Figure *2*. Quantification of fresh and dry biomass of *Urochloa decumbes* and *Melinis minutiflora* with different types of invasive control methods after 100 days. Means followed by the same letter do not differ by the Tukey test at 5% significance.

comparison of the means by the Tukey test showed a lower production of fresh biomass of invasive grasses when the manual and chemical control methods were used. These two methods and the combination of chemical and mechanical control promoted lower production of dry biomass of grasses (Figure 2).

DISCUSSION

The seed banks in the area are composed mostly of invasive herbaceous species and no shrub-tree species (Machado et al., 2013). Therefore, the increase in precipitation in November produced suitable conditions for the development of the seed bank, with a predominance of exotic grasses, thereby hindering the process of ecological succession of the study area.

The chemical method had lower biomass production and greater control of exotic grasses after 100 days, whereas the mechanical method had the opposite extreme. Thus, it is clear that the chemical method is the most effective at controlling invasive grasses since it produced less biomass over the period of 100 days than did the other types of methods. In addition, the chemical method required less manpower and time for its implementation.

Each herbicide has its particularity, the mode of action, either in the plants or the applied environment, being glyphosate (systemic) one of the most used herbicides, due to its versatility and effective control (Silva et al., 2013; Timossi et al., 2016). Generally, after the effect of the herbicide, the dead and dried plant materials provide soil cover and thus conditions conducive to the germination of plants in the seed bank. The use of action herbicides other than glyphosate, such as paraquat (contact), which only acts via contact with plants, can compromise the control of invasive grasses.

Several works have had success using the chemical method and they are widely used and recommended for large open areas, which generally have greater potential for re-infestation of grass (Mantoani et al., 2016). According to them, the cost of chemical control is 34.1% lower than mechanical treatment. The chemical control employed in the present study, when done successively, provides a reduction in infestation and a consequent decrease of cost due to the smaller amount of herbicide used. This is why reforestation companies do prefer chemical treatments.

On the other hand, chemical control can become costly and requires caution since the use of herbicides in the same area over continuous periods may favour the establishment of resistant weed species (Heap, 2014). In areas close to fragments of vegetation, cover crops are better than herbicide application. The planting of species of fast initial growth and high production of biomass will serve to shade the area and consequently the weeds, thus leading to their death (Gomes and Christoffoleti, 2008).

The other types of control methods used in the present study (mechanical and manual) allow close cutting or complete removal of the vegetative material, which can lead to intense exposure of the substrate and lead to intensification of erosion. An alternative would be the use of manual control in small areas under the early stages of invasive species development. The results of a study showed that the control of weeds in the period of 30 and 40 days after emergence provided a reduction of 45.1 and 84.0% of dry matter accumulation of the invasive species as compared to a control area lacking a control method (Galon et al., 2008; Noce et al., 2010). Such action reduces the amount of biomass and labour costs.

The mechanical and mechanical + chemical methods both generated an accumulation of dead vegetation in the plots. This material can influence, in an antagonistic way, the development of the seed bank, and lead to increased humidity and decreased surface temperature. However, on the other hand, this material can function as a physical barrier, mechanical damages, erosion and release of substances with allelopathic properties. These factors prevent the development of other species as well as obstruction of passage from light to the soil/substrate (Costa et al., 2018). The presence of this dead vegetation may have other negative consequences for deactivated controlled landfill areas, such as the area of the present study, such as risk of fire due to the significant concentrations of methane gas released into the environment due to the intense decomposition of the various types of solid wastes.

These observations can contribute to taking decisions on the control of invasive species, specifically, the use of the mechanical method must coincide with the flowering of the weed species because it is the period that the weeds reserves are converted to the production of seeds, and thus possess limits resources for regrowth. Therefore, it is necessary to know the period when the target species is at its apex of growth, thus reducing its infestation and, in some cases, reducing or dispensing with the need of employing cultural practices. With the control of invasive species, it is necessary simultaneously introduce native species with the potential for revegetation, which is a gradual process of re-establishing local biodiversity, including genetic diversity. A study in mining areas degraded (about 1 km from the study area) indicates that the remaining vegetation is still having low floristic richness when compared with other studies carried out in the region (Pereira et al., 2015). The authors found species such as *Eremanthus erythropappus, E. incanus, Tibouchina candolleana* and *Tremble Yacf*. *parviflora* that even exist in the area of this study. They will contribute to the shading of the area, avoiding the accentuated proliferation of exotic grasses.

Therefore, in the study area continuous evaluation and the use of measures to control invasive grasses are necessary in order to minimize direct competition with native species. Furthermore, because it is a small area, the manual method is the best option due to the complete removal of the material, despite requiring a greater effort and time. The insertion of pioneer species could be beneficial by controlling invasive grasses in the medium term.

In the search for the most efficient methods of invasive grass control, further detailed studies of other methods of control are indispensable. Several factors can influence the response of these invasive species to control, especially in areas of solid waste deposits that present a huge variation due to the different deposited materials and stages of decomposition, which interfere directly with the properties of the substrate. This fact may affect directly the resilience of the environment, making the site unsuitable for development of any species and making it difficult to recompose the vegetation in these places.

Conclusion

Among the distinct types of methods used to control exotic grasses, the most practical and effective for the degraded area analysed in this study was the chemical method, resulting in less regenerated biomass. On the other hand, the mechanical method was the least effective, as evidenced by the greater production of biomass.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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