Individual and integrated methods on tough lovegrass control

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ABSTRACT: The current study evaluated the efficiency of mechanical, physical, chemical and cultural methods, used exclusively or integrated, to control tough lovegrass. The experimental design was completely randomized, with 15 treatments and four repetitions. Physical control of tough lovegrass was based on the application of fire, whereas mechanical controls consisted in mowing and harrowing/plowing procedures. The herbicide clethodim and different glyphosate salts were evaluated for chemical control. Glyphosate and soil fertility correction were applied as cultural and integrated methods, in addition to isopropylamine + potassium salts combination, soil fertility correction and implantation of one of the following forage plants: Elephant grass, Pangola grass, Forage peanut and Birdsfoot trefoil. The effect of treatments on the incidence of tough lovegrass and on its botanical composition was evaluated one year after their applications. Isolated control methods, except for glyphosate using, did not present efficient tough lovegrass control. Glyphosate salts could control tough lovegrass plants, but their association with improved soil fertility and Pangola grass implantation was the best strategy to control the invasive plant.

Key words: Eragrostis plana Nees, native pasture, weed control.

INTRODUCTION

Tough lovegrass (Eragrostis plana Nees) is an exotic plant native from South Africa that is one of the main limitations to forage production of native species in the Pampa biome (LISBOA et al., 2009). It stands out in native pasture degradation areas in this biome, since it spreads and occupies spaces in detriment of native plant used for grazing such as Paspalum spp. and Axonopus spp.

Farmers usually adopt manual and/or mechanized techniques based on plough the soil to control tough lovegrass. This management technique is not recommended; since it enables seeds on soil surface to integrate the soil seed bank, whereas seeds in deeper soil layers are exposed to soil surface (FERREIRA et al., 2008). Mowing the weed can be initially efficient; however, this method can spread the seeds around, specially during reproductive stage. Tough lovegrass as a perennial plant requires
several mowing procedures in order to effectively being eliminated once there are reserves in its roots (FAVARETTO et al., 2015).

Although, the use of fire to control tough lovegrass infestation is forbidden by Rio Grande do Sul State Law N. 9,519/92 of Rio Grande do Sul State Forest Code, it is still a practice adopted by several farmers. However, further studies on the use of fire to control the herein investigated weed species should be conducted.

Glyphosate-based herbicide use enable controlling Eragrostis plana in a satisfactory way (FALEIRO et al., 2021). However, attention should be given to the efficiency of herbicides presenting different action modes, such as acetylcoenzyme A carboxylase (ACCase) inhibitors, which are specifically used to control plants belonging to Poaceae family (TAKANO et al., 2020). These herbicides should be applied with the aid of selective-application tools to avoid contact between herbicides and the forage plants of interest (GOULART et al., 2009). However, exclusive herbicide using, as isolated form to enable long-term control, can increase the resistance of this weed species to the adopted herbicide and make it even difficult to be controlled.

The use of integrated management combining soil fertility correction and maintenance, weed control through herbicide using and forage species’ introduction to compete with and outperform this weed (SCHUSTER et al., 2018), are factors to be taken into account at the time to plan the best set of actions aimed at weed control. Embrapla has provided data confirming tough lovegrass infestation reduction over the years, based on the Integrated Pasture Recovery Method - MIRAPASTO (PEREZ et al., 2015; LAMEGO et al., 2020). Therefore, this set of associated practices appears to be more effective in controlling tough lovegrass than unique practices without continuity. Thus, the present study evaluated isolated and integrated methods to control tough lovegrass aiming to recover the native pasture.

MATERIALS AND METHODS

A study was conducted in the experimental area of Federal University of Pampa, Campus Itaqui - RS (latitude 29° 9' 21.37" S and longitude 56° 33' 9.97" W) from February 7, 2019 to March 15, 2020. Climate in the region is Cfa type, according to Köppen classification and the soil is classified as Haplic Plinthosol of widespread occurrence in lowlands on the Western Frontier of Rio Grande do Sul.

Fifteen treatments were implemented based on a completely randomized design, with four repetitions including the untreated check (CONTROL) (Table 1). Sixty plots of 9 m², presented tough lovegrass infestation level of 65%, on average, at flowering and seed production stages. The treatments consisted of: a) Mechanical method: mowing (MOWING) carried out with manual mowing, leaving residual height of 5 cm and revolved (REVOLV) the soil at 10 cm depth; b) physical method: technical fire (FIRE) applied in a controlled manner throughout the plot; c) chemical method: application of herbicides such as clethodim (CLET) and glyphosates salts; d) integrated methods: herbicide + soil fertility correction and implantation of forage species.

The chemical method was based on herbicide application with controlled manual applicator (PEREZ, 2008). CLET was used at usual dose of 120 g a.i. (active ingredient) ha⁻¹. Glyphosate was used in different formulations (salts): ammonium (AMMONIUM), di-ammonium (DI-AMMONIUM), isopropyamine (ISOP), potassium (POT) and isopropyamine + potassium (ISOP + POT). The adopted dose was 356 g a.e. (acid equivalent) ha⁻¹ and the herbicide tank mix was prepared at total volume of 1.350 L, according to recommendations (PEREZ, 2008).

Integrated methods consisted in applying the ISOP + POT herbicide in association with liming and fertilization (HLF); as well as the combination of the ISOP + POT herbicide, liming, fertilization and forage species implantation, as follows: HLFK (herbicide + liming and fertilization + elephant grass (Pennisetum purpureum Schum., cv. BRS Kurumi)), HLFDIGDE (herbicide + liming and fertilization + Pangola grass (Digitaria decumbens)), HLFAPI (herbicide + liming and fertilization + forage peanut (Aranchis pintoi)) and HLFLOTCO (herbicide + liming and fertilization + birdsfoot trefoil (Lotus corniculatus L., cv. Sáo Gabriel)).

Liming (2.8 ton ha⁻¹) was spread out one month before plant species implantation and the fertilization was carried out at the time of implanting the forages; 200 kg of N ha⁻¹, 190 kg ha⁻¹ of P₂O₅ and 140 kg ha⁻¹ of K₂O were used in the HLF, HLFK and HLFDIGDE treatments, respectively; whereas 170 kg P₂O₅ and 100 kg K₂O ha⁻¹ were used in the HLFAPI and HLFLOTCO treatments, respectively.

Forage species were implanted 15 days after herbicide application by vegetative parts of adult plants spaced 0.5 x 0.5 m from each other in HLFK, HLFDIGDE and HLFAPI treatments. Sowing (6 kg ha⁻¹) in the HLFLOTCO treatment was carried out in rows (0.2 m spacing between rows).

All the evaluations were performed one year after treatment applications, in March 2020.
Herbicide control efficiency was measured based on visual scale ranging from 0% (absence of herbicidal symptoms) to 100% (plant dead), 365 days after treatments application. The number, identification and dominance of species were evaluated by counting the total of species and the individuals in each species in each plot. Occupied area (%) assessments were based on the percentage of the plot occupied by tough lovegrass plants. The parameter Uncovered area (%) corresponded to the area that did not present plants of any species. Relative density (RD) indicated the participation of each species in comparison to the total number of tough lovegrass plants and it was calculated through the following equation:

$$RD = \left( \frac{n_i}{N} \right) \times 100$$

Wherein \(n\) is the total number of tough lovegrass plants and \(N\) is the total number of plants of all species within the plot.

Statistical analyses and result presentation were divided into four stages. Stage 1 - Evaluation of mechanical/physical methods: CONTROL, MOWING, FIRE and REVOL treatments were compared through Fisher’s least significant difference test (LSD). Stage 2 - Evaluation of chemical methods, including CONTROL, through the application of non-orthogonal contrasts (three): C1: CONTROL vs. glyphosate salts; C2: CLET vs. glyphosate salts; and C3: CONTROL vs. CLET. Glyphosate salts were compared through Fisher’s test (LDS). Stage 3 - Evaluating fertility management and forage species inclusion, based on the application of orthogonal contrasts (five): C1: effect of soil fertility (ISOP + POT vs. fertilized treatments); C2: effect of forage addition (HLF vs. forage treatments); C3: effect of forage family (Poaceae vs. Fabaceae); C4: effect of Poaceae species (Elephant grass vs. Pangola grass) and C5: effect of Fabaceae species (Forage peanut vs. Birdsfoot trefoil). Stage 4 - Treatments presenting the best results in the previous stages were compared to each other through Fisher’s test (LDS).

Data were analyzed through PROC MIXED (normal distribution) and PROC GLIMMIX (non normal distribution) using SAS (version 9.4) at the 5% level of significance. The experimental model was: \(Y_i = \mu + T_i - i + e_i\), wherein: \(Y_i\) is the observed value of the dependent variable; \(\mu\) is the general average; \(T_i\) is the fixed effect of the treatment; \(-i\) is the random error associated with the plots; and \(e_i\) is the experimental error. Heterogeneous variances were used in each treatment.

Table 1 - Treatments used to tough lovegrass control. UNIPAMPA, Itaquí-RS, 2019.

| Treatments* | Herbicide          | Liming            | Fertilizer | Forage              |
|-------------|--------------------|-------------------|------------|---------------------|
| 1- CONTROL  | -                  | -                 | -          | -                   |
| 2- MOWING   | -                  | -                 | -          | -                   |
| 3- FIRE     | -                  | -                 | -          | -                   |
| 4- REVOL    | -                  | -                 | -          | -                   |
| 5- CLET     | Clethodim          | -                 | -          | -                   |
| 6- AMMONIUM | Ammonium           | -                 | -          | -                   |
| 7- DI- AMMONIUM | Di-ammonium     | -                 | -          | -                   |
| 8- ISOP     | Isopropilamina     | -                 | -          | -                   |
| 9- POT      | Potassium          | -                 | -          | -                   |
| 10- ISOP+POT | Isopropylamine + potassium | - | - | - |
| 11- HLF     | Isopropylamine + potassium | Ok | Ok | Elephant grass     |
| 12- HLFK    | Isopropylamine + potassium | Ok | Ok | Pangola grass       |
| 13- HLFDIGDE| Isopropylamine + potassium | Ok | Ok | Forage peanut       |
| 14- HLFARAPI| Isopropylamine + potassium | Ok | Ok | Birdsfoot trefoil   |

* Tough lovegrass plants were at flowering and seed production stages when the treatments were applied.

CONTROL: untreated check; REVOL: Revolved soil (plough); HLFK: Isopropylamine + potassium + liming + fertilizer + elephant grass cv. Kurumi; HLFLOTCO: Isopropylamine + potassium + liming + fertilization + forage peanut (Arachis pintoi); HLFDIGDE: Isopropylamine + potassium + liming + fertilization + forage peanut (Digitaria decumbens); HLF: Isopropylamine + potassium + liming + fertilization; Ok: Fertilization and/or liming was carried out.
RESULTS

Soil turning (REVOLV) has reduced the number of tough lovegrass plants present in 365 DATA but increased the number of other species, in comparison to mowing (Table 2). In addition, REVOLV has increased the uncovered area rate and reduced the occupied area rate in comparison to the others strategies (mechanical/physical control). Thus, REVOLV has reduced the relative density of species, in comparison to the CONTROL and MOWING treatments. FIRE treatment did not reduce the number of tough lovegrass plants 365 DATA. However, it reduced the uncovered area.

All the glyphosate salts were efficient in tough lovegrass control (=100%) compared to CONTROL (Table 3). Comparing CLET herbicide with glyphosate salts, these herbicides were superior, as showed by reduced tough lovegrass plants m². CLET did not differ from CONTROL according to tough lovegrass plants m² and control 365 DATA. However, the number of species was not affected by herbicides.

The orthogonal contrast C1 showed that the liming and fertilization even with the herbicide application increase the number of tough lovegrass m² compared with the herbicide alone (Table 4); however, HLF also increase the number of species once tough lovegrass is controlled and more space is available. When the grass forages were compared with legume forages (C3), Pangola and Kurumi showed higher reduction of tough lovegrass plants m².

REVOLV, POT + ISOP and HLFDIGDE treatments were selected to compare the best mechanical/physical, and chemical strategies associated with increased soil fertility and forage establishment in tough lovegrass control (Table 5). All treatments based on the chemical method (POT + ISOP + HLFDIGDE) have reduced the number of plants, the occupied area and the relative density of species in comparison to the REVOLV. In relation to REVOLV, the POT + ISOP treatment has increased the uncovered area, whereas the HLFDIGDE treatment has significantly reduced it.

DISCUSSION

Mowing is often used to control weeds, but it is not significantly effective in controlling grasses, especially perennial as tough lovegrass. HANSEN & WILSON (2006) have shown reduced growth rate of Agropyron cristatum L. only two years after the first mowing. The single mowing performed in the present study may have compromised the effectiveness of this treatment in controlling tough lovegrass infestation. This procedure should have been performed many times since this plant species has broad reserve structure in the roots (FAVARETTO et al., 2015), and an importat fact to be considered is the amount

### Table 2 - Effect of mechanical and physical tough lovegrass control methods on plant community composition 365 days after treatment application (DATA). UNIPAMPA, Itaquí- RS 2019/20.

| Treatments ¹ | Tough lovegrass plants ² | Number of species ³ | Uncovered area ⁴ | Occupied zone ⁵ | RD ⁶ |
|--------------|--------------------------|---------------------|-------------------|----------------|-------|
| CONTROL      | 12.11 ab*                | 5.50 ab             | 27.75 b           | 50.00 a        | 254.42 a |
| FIRE         | 19.86 ab                 | 5.75 ab             | 25.00 b           | 57.50 a        | 100.63 ab |
| REVOL        | 8.70 b                   | 6.00 a              | 52.50 a           | 15.00 b        | 39.03 b  |
| MOWING       | 16.00 a                  | 5.50 b              | 35.00 b           | 46.25 a        | 213.80 a |
| Mean         | 14.16                    | 5.68                | 35.06             | 42.18          | 151.97   |
| SEM*         | 2.27                     | 0.68                | 3.65              | 3.93           | 36.59    |

¹Means followed by lowercase letters in the column differed from each other in the Fisher’s least significance difference test (LSD) at 5% significance level. SEM: Standard error of the mean.

²CONTROL - untreated check; FIRE: technical fire; REVOLV- Revolved soil (plough); MOWING – mowing lefting residual height of 5 cm.

³Number of tough lovegrass plants per m²

⁴Mean incidence of species that are not equivalent to tough lovegrass, such as: Andropogon bicornis, Brachiaria plantaginea, Echinochloa crus-galli, Eragrostis plana Nees, Paspalum urvillei and Setaria viridis (Poaceae); Cyperus rotundus and Poptochaetium monteviense (Cyperaceae); Ipomoea purpurea (Convolvulaceae); Aeschynomene denticulata and Mimosa bimucronata (Fabaceae); Polygonum hydropiper (Polygonaceae).

⁵Area of the plot that did not present plants (uncovered soil), %.

⁶Plot area occupied by tough lovegrass plants, %.

⁷Relative density of species in each treatment, %.

⁸SEM: Standard error of the mean.
Flowering stage, evaluated 365 days after treatment application.

- Standard error of the mean.

| Treatment    | Tough lovegrass plants | Number of species | Uncovered area | Occupied zone | RD | Control |
|--------------|-------------------------|-------------------|----------------|--------------|----|---------|
| CONTROL      | 12.11                   | 5.50              | 23.75          | 50.00        | 254.42 | 0       |
| CLET         | 10.67                   | 5.00              | 40.00          | 36.25        | 267.92 | 16      |
| AMMONIUM     | 0.31                    | 6.50              | 73.75 a       | 1.00         | 3.3    | 100     |
| DI-AMMONIUM  | 0.84                    | 6.00              | 62.50 c       | 2.00         | 7.55   | 100     |
| ISOP         | 1.08                    | 7.50              | 61.25 c       | 2.00         | 9.64   | 100     |
| POT          | 0.25                    | 6.00              | 78.75 a       | 0.50         | 4.73   | 100     |
| ISOP+POT     | 0.39                    | 5.50              | 67.25 b       | 1.00         | 4.96   | 100     |
| Mean         | 3.66                    | 5.96              | 58.17          | 13.25        | 7.893  | 73.71   |
| SEM          | 0.47                    | 0.63              | 2.94           | 1.30         | 30.85  | 0.37    |

* Means followed by lowercase letters in the column differed from each other in the Fisher's least significant difference test (LSD) at 5% significance level.

1Treatments: CONTROL - untreated check; CLET-clethodim; AMMONIUM-ammonium salt; DI-AMMONI- salt Di-Ammonium; ISOP- Isopropylamine salt; POT- potassium salt; ISOP + POT- isopropylamine salt + potassium salt.

2Number of tough lovegrass plants per m²

3Mean incidence of species that are not equivalent to tough lovegrass, such as: Andropogon bicornis, Brachiaria plantaginea, Echinochloa crusgali, Eragrostis plana Nees, Paspalum urvillei and Setaria viridis (Poaceae); Cyperus rotundus and Piptochaetium montevidense (Cyperaceae); Ipomoea purpurea (Convolvulaceae); Aeschynomene denticulata and Mimosa bimucronata (Fabaceae); Polygonum hydropiper (Polygonaceae).

4Area of the plot that did not present plants (uncovered soil), %.

5Plot area occupied by tough lovegrass plants, %.

6Relative density of species in each treatment, %.

7Herbicide control efficiency was measured based on visual scale ranging from 0% (absence of symptoms) to 100% (dead plant).

8Effect of treatment on the evaluated variables: Orthogonal contrasts - C1: Control x glyphosate salts; C2: Clethodim x Glyphosate; C3: Clethodim x Control.

9SEM: Standard error of the mean.

The efficiency observed for the glyphosate herbicide used was similar than reported by FALEIRO et al. (2021), who recorded levels of control higher than 98%. Long period (years) without regrowing these plants provides more time for desirable species to develop. This will happen if an enough seedbank exists and not only tough lovegrass seeds predominate. RODRIGUEZ & JACOBO (2013) have reported significant reduction in the number of perennial species in pastures subjected to total spraying of this herbicide. Low effectiveness of herbicides belonging to the ACCase group, such as the CLET evaluated in the current study, was reported in the literature (GOULART et al., 2009), which has classified them as insufficient for tough lovegrass post-emergence.
of the most efficient forage used to cover the soil and conditions (TIKAM et al., 2017). These makes it the one adapting and es species to establish. Pangola grass has a potential to prostrate growth habit that makes it difficult for other species, compared to the peanut forage, which has a area available for the emergence of native forage trefoil may be an option. This forage provides greater improve the diversity of native species, birdsfoot on the perspective of having biomass for pasture and initial establishment (BELGERI et al., 2020). Based to leguminous forages as they can present faster efficient in the control of tough lovegrass compared (HADDAD et al., 1999).

Table 4 - Integrated methods used to control tough lovegrass plants, evaluated 365 days after treatment application (DATA). UNIPAMPA, Itaqui-RS 2019/20.

| Treatments¹ | Tough lovegrass plants² | Number of species³ | Uncovered area⁴ | Occupied zone⁵ | RD⁶ |
|-------------|-------------------------|--------------------|-----------------|---------------|-----|
| ISOP+POT    | 0.39                    | 5.50               | 67.25           | 1.00          | 4.96|
| HLF         | 0.72                    | 7.50               | 63.75           | 1.00          | 3.67|
| HLFK        | 0.17                    | 4.25               | 30.00           | 0.75          | 7.41|
| HLFDIGDE    | 0.08                    | 5.00               | 6.25            | 0.50          | 1.64|
| HLFARAPI    | 1.92                    | 6.00               | 56.25           | 5.75          | 19.35|
| HLFLOTCO    | 2.56                    | 8.25               | 71.25           | 3.50          | 34.34|
| Mean        | 0.973                   | 6.08               | 49.12           | 2.08          | 11.89|
| SEM⁷        | 0.36                    | 2.65               | 0.86            | 0.54          | 8.88|

* Means followed by lowercase letters in the column differed from each other in the Fisher's least significant difference test (LSD) at 5% significance level.
¹Treatments: ISOP + POT: isopropylamine salt + potassium salt; HLF: isopropylamine salt + potassium salt + liming + fertilization; HLFK: isopropylamine salt + potassium salt + liming + fertilizer + Elephant grass cv. Kurumi; HLFDIGDE: isopropylamine salt + potassium salt + liming + fertilization + Pangola grass; HLFARAPI: isopropylamine salt + potassium salt + liming + fertilizer + forage peanut; HLFLOTCO: isopropylamine salt + potassium salt + liming + fertilizer + Lotus corniculatus cv. São Gabriel.
²Relative density of species in each treatment, %.
³Plot area occupied by tough lovegrass plants, %.
⁴Number of tough lovegrass plants per m².
⁵Mean incidence of species that are not equivalent to tough lovegrass, such as: Andropogon bicornis, Brachiaria plantaginea, Echinochloa crus-galli, Eragrostis plana Nees, Paspalum urvillei and Setaria viridis (Poaceae); Cyperus rotundus and Piptochaetium montevdense (Cyperaceae); Ipomoea purpurea (Convolvulaceae); Aeschynomene denticulata and Mimosa bimucronata (Fabaceae); Polygonum hydropiper (Polygonaceae).
⁶Area of the plot that did not present plants (uncovered soil), %.
⁷Plot area occupied by tough lovegrass plants, %.
⁸Mean incidence of species that are not equivalent to tough lovegrass, such as: Andropogon bicornis, Brachiaria plantaginea, Echinochloa crus-galli, Eragrostis plana Nees, Paspalum urvillei and Setaria viridis (Poaceae); Cyperus rotundus and Piptochaetium montevdense (Cyperaceae); Ipomoea purpurea (Convolvulaceae); Aeschynomene denticulata and Mimosa bimucronata (Fabaceae); Polygonum hydropiper (Polygonaceae).
⁹Effect of treatment on the evaluated variables: Orthogonal contrasts - C1: ISOP + POT x HLF + forage; C2: HLF x forage; C3: grasses vs. legumes; C4 pangola x elephant; C5 birdsfoot trefoil x forage peanut.
⁰SEM: Standard error of the mean.

control, especially in the more advanced stage of plant development. This inefficiency in the control was also observed in Digitaria insularis plants (PRESOTO et al., 2020).

The implantation of grass forages was more efficient in the control of tough lovegrass compared to leguminous forages as they can present faster initial establishment (BELGERI et al., 2020). Based on the perspective of having biomass for pasture and improve the diversity of native species, birdsfoot trefoil may be an option. This forage provides greater area available for the emergence of native forage species, compared to the peanut forage, which has a prostrate growth habit that makes it difficult for other species to establish. Pangola grass has a potential to adapting and establishing under different environmental conditions (TIKAM et al., 2017). These makes it the one of the most efficient forage used to cover the soil and disturb tough lovegrass growth (BITTENCOURT et al., 2017; BELGERI et al., 2020).

REVOL, POT + ISOP and HLFDIGDE treatments recorded the best indices for weed control. High value recorded for uncovered area in the POT + ISOP is explained by the tough lovegrass biomass plants that remained after herbicide application, which difficulited other species to germinate, by shading or allelopathic effect (FIorenza et al., 2016). Pangola grass can be an alternative for weed control due to its rapid establishment and competition for solar radiation, which is one of the main limitations in the germination of new tough lovegrass plants (BITTENCOURT et al., 2017; BELGERI et al., 2020). Futhermore, this forage specie presents satisfactory biomass yield, and adaptability to subtropical climate, for an implementation as a new pasture to recover areas infested by tough lovegrass (HADDAD et al., 1999).
CONCLUSION

Mechanical/physical methods isolate are not efficient in reducing tough lovegrass population. Glyphosate salts successfully control tough lovegrass plants; however, chemical control in association with soil fertility improvement and forage implantation (as pangola grass), is more effective in controlling tough lovegrass.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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AUTHORS’ CONTRIBUTIONS

All authors have equally contributed to the study design and manuscript writing.

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