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Can Flaming Be Performed as Selective Weed Control Treatment in Turfgrass?

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Warm season species are the most suitable species for turfgrass in Mediterranean conditions but can suffer weed competition after transplanting. Flame tolerance of *Cynodon dactylon* and *Paspalum vaginatum*, during the first 5 weeks of development, was tested for selective flaming treatments. The plants were grown in a greenhouse and transplanted in 30 cm long 23.5 cm wide and 5 cm deep pots, containing peat based substrate. Four plants were hand transplanted in each pot. The thermal treatments were performed using a test bench equipped with a belt conveyor driven by an electric engine, a 25 cm wide prismatic burner and an LPG feeding group that allowed to operate with different values of pressures and speeds. Digital images were analysed with an automated procedure with the aim to assess crop canopy one week after treatments. Crop biomass was assessed at the end of the cycle. *Cynodon dactylon* was the most sensitive species showing on average a 50% reduction of the canopy using around 15 kg ha^{-1} of LPG, a maximum biomass loss of 75% with one treatment and 100% with two or more treatments. *Paspalum vaginatum* appeared more tolerant showing on average a 50% reduction of the canopy at about 30 kg ha^{-1} of LPG, a maximum biomass loss of 65% with one treatment and 100% with two or more treatments. However, selective flaming could represent a possible option to perform weed control in warm-season turfgrasses.

1. Introduction

The increasing concern about agrochemicals and the current EU directive on pesticide use is moving more and more the farmers and consumers interest into integrated and organic farming systems and products (van der Weide et al., 2008; EU, 2009; Raffaelli et al., 2013a). Moreover, a consistent reduction of the number of available active ingredients (the ones considered potentially dangerous from the Commission) recently occurred (EU, 2009), a problem of particular importance to minor and specialty crops due to the reduced number of registered and labelled herbicides (Fennimore, 2008; Fontanelli et al., 2013). These factors contributed to the increased adoption of the physical weed control especially in horticultural crops, within integrated and organic but even in conventional farming systems (Fontanelli et al., 2015).
The EU Directive specifies also guidelines for the application of pesticides in non-agricultural areas like municipalities, public or private green areas, sport facilities, roads, etc. In this context, farmers and green keepers are encouraged to use “integrated pest management means”. Besides, “sustainable, biological, physical and non-chemical methods must be preferred to chemical methods if they provide satisfactory pest control” (EU, 2009), meaning that the idea and the concept of organic/integrated agriculture is now moving to non-agricultural areas.
Weed control is always a major issue both in rural and urban areas (Raffaelli 2013b; Martelloni et al., 2016). Among non-chemical means, flaming is probably the most common and easy to apply for non-agricultural areas maintenance (Raffaelli et al., 2013b; Frasconi et al., 2016). It can be easily applied broadcast on hard surfaces (pavements, concrete, etc.) as the treatment is not selective in this case. On the other hand, non-chemical weed management in turfgrasses can be a challenging task mainly due to the sensitivity of the plant response to these techniques. It is known that warm season turfgrasses, which are becoming very popular in Mediterranean countries, are very tolerant to different kind of stresses (Croce et al., 2004). Thus, direct flaming could be an interesting opportunity for a selective weed control in these species, which can be very

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sensitive to weed competition in the first developing stages especially in untilled soil. However, flaming tolerance of turfgrass species need to be addressed before any adoption and for a better design of weeding strategies. Based on this, the aim of this work was to test the response of two common turfgrass species to either single or repeated treatments of flaming as investigated for a selective weed control.

2. The trials

The trial was carried out in greenhouse and the flaming treatments were performed on 30x23.5x5 cm trays using a test bench. Each tray contained 4 transplanted plants of warm season turfgrasses (Figure 1). Tests were carried out in two different species: *Cynodon dactylon* hybrid and *Paspalum vaginatum*.

Figure 1: Test bench flaming treatment performed on a tray containing four warm season turfgrasses plants.

The first part of the trial consisted in one single flaming treatment performed 1, 2 or 3 weeks after the transplanting (Figure 2a). The second part of the experiment consisted in different multiple treatments in three weeks: 1) two treatments, 1 and 2 weeks after transplanting); 2) two treatments, 1 and 3 weeks after transplanting; 3) two treatments, 2 and 3 weeks after transplanting; 4) three treatments 1, 2 and 3 weeks after transplanting (Figure 2b). Each treatment was performed according to 9 different LPG doses ranging from 0 to 200 kg ha^{-1}, replicated three times and following a completely randomized block design.

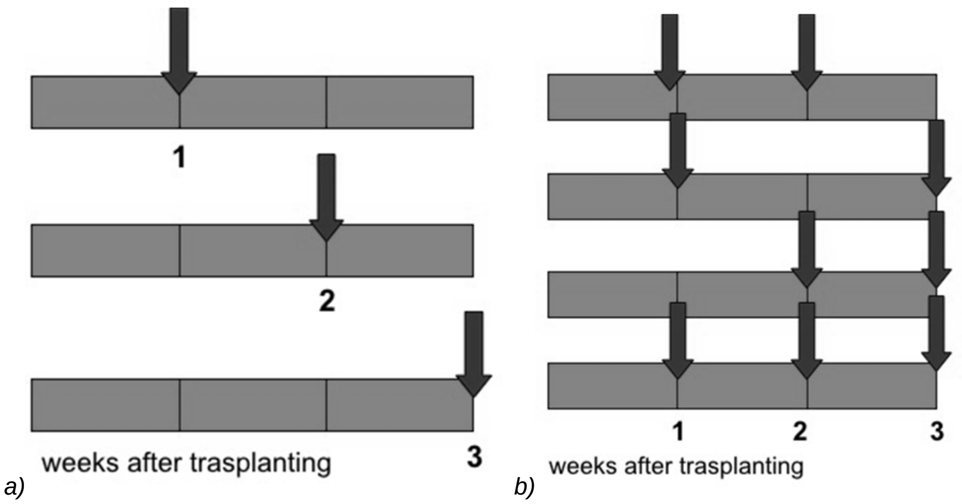

Figure 2: Different flaming treatments tested in warm season turfgrasses, the arrow points out the treatment.

3. Turfgrass assessments and statistical analysis

Turfgrass canopy was assessed one week after each treatment for the first part of the experiment and one week after the last treatment for the second part of the experiment. Digital images were analysed with the automated procedure described in Rasmussen et al. (2007), which originally was programmed in MATLAB3 and later developed into a web-based software (www.imaging-crops.dk). Turfgrass dry biomass was assessed aroundone month after the end of the cycle of treatments for both parts of the experiment.
Dose response non-linear regression curves were fitted using the drc package of R software (Ritz et al., 2015); Turfgrass canopy (%) was analysed utilizing a three parameter log-logistic model:

$$Y=D/1+exp(B(logX-logE)) \quad (1)$$

where Y=response(%); D=upper limit(%); B=slope of the line around the inflection point; X=LPG dose (kg ha^{-1}) and E=is the dose resulting a 50% response (ED50, kg ha^{-1}). Effective doses 10 and 20 (ED10 and ED20), resulting in a 10 and 20% response, were also calculated (kg ha^{-1}).
Turfgrass dry biomass was analysed utilizing a yield loss (%) hyperbolic model:

$$Y=I*d/(1+I*d/A) \quad (2)$$

Where Y=yield loss (%); I=the slope; d=LPG dose (kg ha$^{-1);}$ A=asymptote of the hyperbolic line (%). Biomass loss 50 index, which gives the dose (kg ha^{-1}) resulting in a 50% biomass reduction was also calculated.
Before fitting curves, ANOVA was performed according to a general linear mixed model to test the significance of the dose effect at $P<0.05$. The experimental design was a completely randomized block.

4. The test bench

The test bench was equipped with one burner fixed into the frame, while trays containing plants could be driven to the flame by a specific chain belt conveyor (Figure 3). The burner was equipped with one external carburettor with a nozzle. The carburettor was optimized for enhancing thermodynamics performances and reduce fuel (common commercial LPG) consumption. The open flame prismatic burner used for this specific research was 25 cm wide and equipped with one external nozzle (diameter of 1.1 mm) (Raffaelli et al., 2015). The LPG supply was provided by a tank equipped with a pressure regulator and a manometer, placed inside a heat exchanger and connected to the burners by means of pipes (on which security switches and valves were placed).

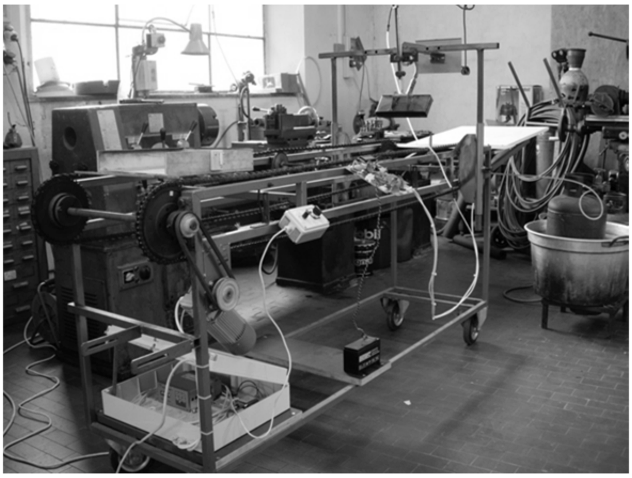

Figure 3: Test bench for flaming treatments in warm season turfgrasses.

5. Results

Concerning the effect of one single flaming treatment on *Paspalum vaginatum*, the ED10, ED20 and ED 50 of canopy ranged from 12.8 to 52.6 kg ha^{-1} when the plants were flamed 1 week after transplanting. The values were relevantly lower when the plants were flamed 2 weeks (from 6.1 to 32 kg ha^{-1}) and 3 weeks (from 5.9 to 20.6 kg ha^{-1}) after transplanting. This means that the sensitivity increases if the treatment is performed later after the transplanting, probably because there is more biomass exposed to the treatment. However, the maximum biomass reduction observed one month after the treatment ranged from 60% to 70% and the dose resulting in a 50% biomass reduction was much higher when flaming was applied later (ranged from 64.8 to 172.51 kg ha^{-1}). This means that, for this parameter, the sensitivity decreases when the treatment is performed later on (Figure 4).

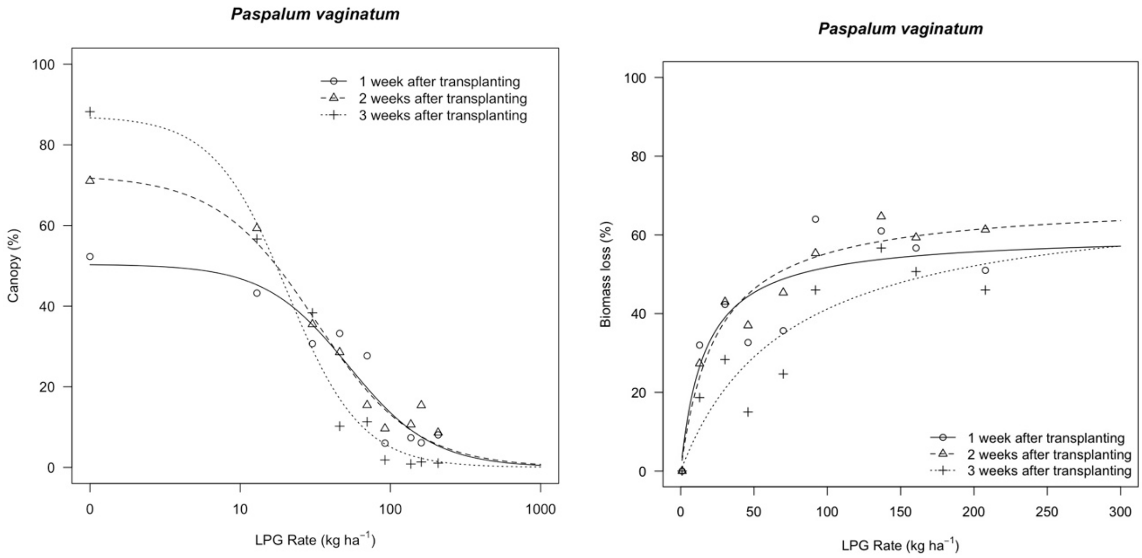

Figure 4: Paspalum vaginatum canopy and biomass loss as affected by LPG dose of one flaming treatment.

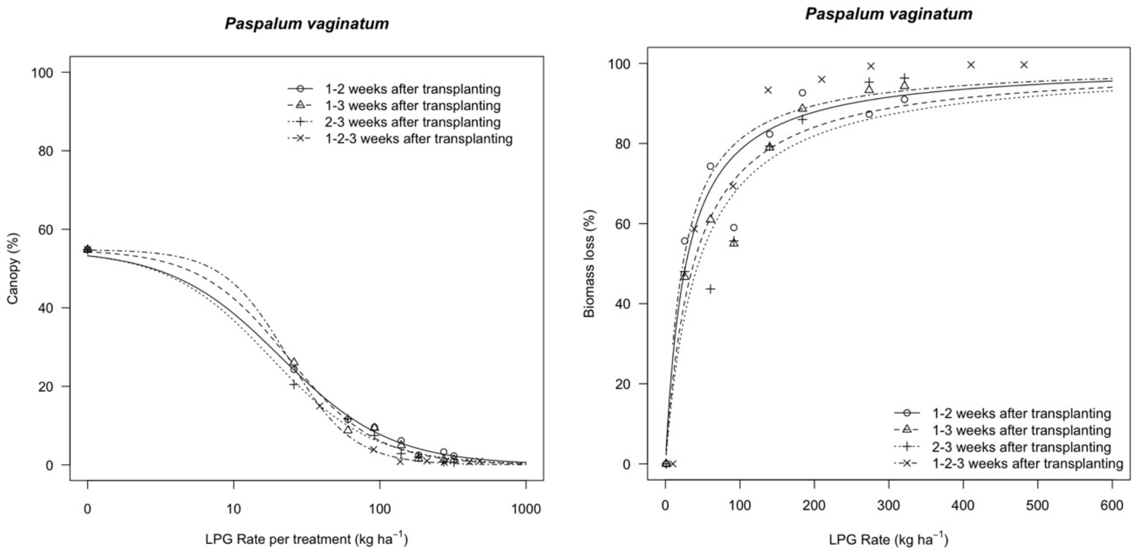

Figure 5: Paspalum vaginatum canopy and biomass loss as affected by LPG dose of multiple flaming treatments.

Concerning the multiple treatments in *Paspalum vaginatum*, the different combinations gave similar results in terms of canopy reduction. The ED50 was on average about 20 kg ha^{-1}. The maximum value of biomass reduction was 100% for all the different combinations (Figure 5). However,the Biomass loss index values were lower with respect to those observed for one single treatment. The biomass loss 50 values ranged from 24 to 44 kg ha^{-1}. The lowest value came from the triple treatment, while concerning the double treatment, the highest value was observed when the treatments were performed later. This confirms the trend observed for one single treatment.

The effect of one single flaming treatment on *Cynodon dactylon* hybrid was more relevant with respect to the *Paspalum vaginatum*. The ED10, ED20 and ED50 of the canopy ranged from 2 to 16 kg ha^{-1} but did not vary with the application time. Concerning the biomass loss, the maximum value was about 70% for all the combinations. However the Biomass loss 50 doses were lower with respect to those observed in *Paspalum vaginatum*, and the trend was opposite, as the maximum value was observed when the treatment was performed one week after transplanting (values from 20 to 108 kg ha^{-1}) (Figure 5).

For the multiple treatments, the ED values of canopy were similar to those observed in *Paspalum vaginatum* but the value was considerably lower when the triple treatment was performed (about 11 kg ha^{-1}). Concerning the biomass loss when multiple flaming treatments were applied, the same trend as the other species was observed. The 100% of biomass loss was always reached and the biomass loss dose value increased in the later double treatment (about 30 kg ha^{-1}) (Figure 6).

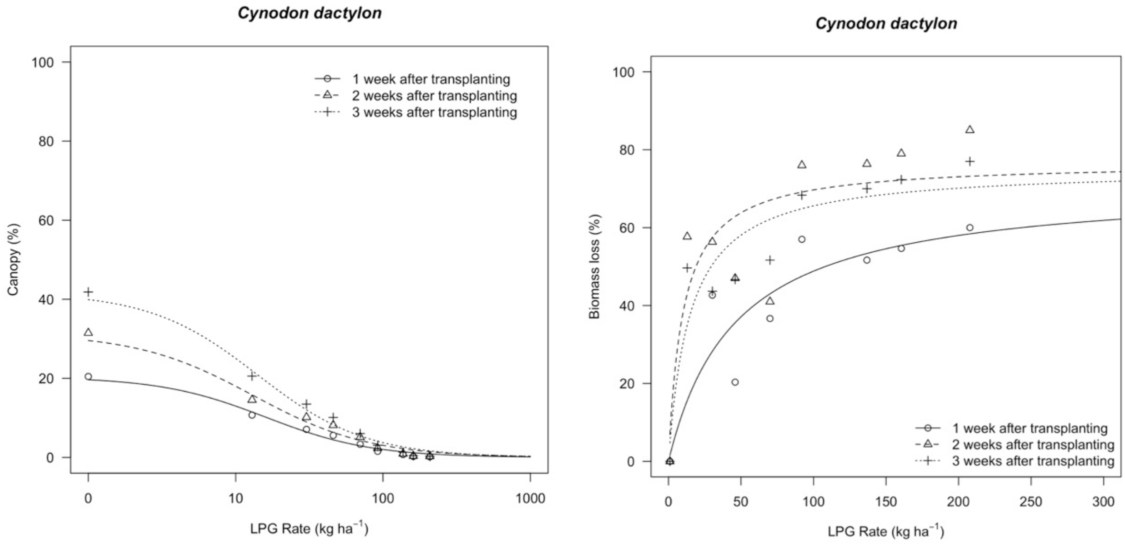

Figure 6: Cynodon dactylon canopy and biomass loss as affected by LPG dose of one flaming treatment.

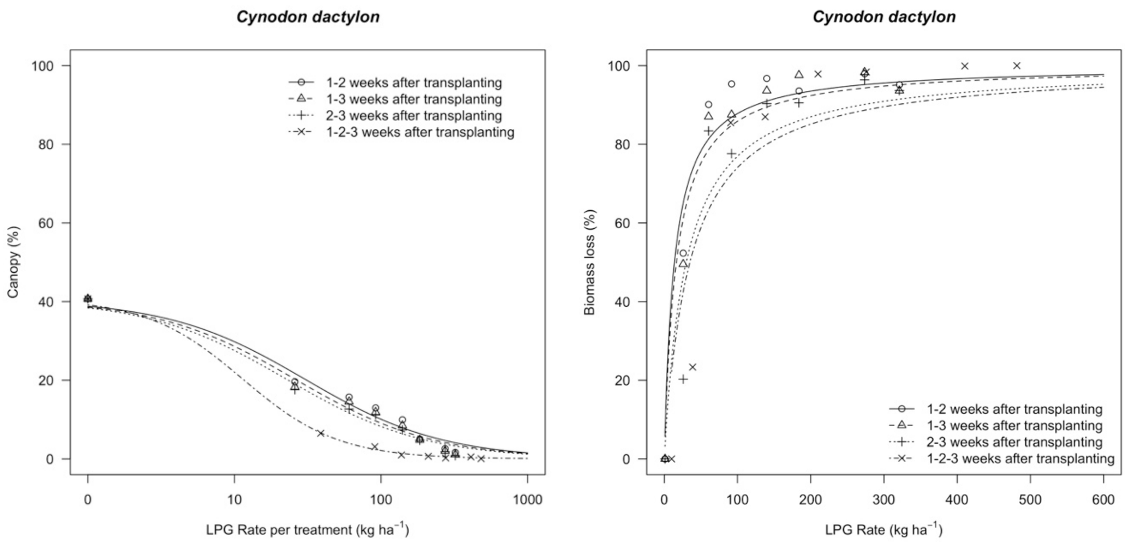

Figure 7: Cynodon dactylon canopy and biomass loss as affected by LPG dose of multiple flaming treatments.

From the results of this trial, flaming seems to be a potential selective weed control opportunity in warm season turfgrasses as these species showed a relevant tolerance to flaming, especially when the treatment is performed once. An LPG dose of about 30-40 kg should be tolerated from both species and should kill most of the weed seedlings. A mature warm season turfgrass in the field is able to regrow after a complete removal of the blades and culms thanks to the presence of stolons and rhizomes. However, weeds could be controlled before the beginning of the growing season of the turf (approximately May) as rhizomes are not affected by flaming because of their location under the soil. Thus higher doses should be realistically expected in the field on a mature turf with respect to the tests done on single potted young turfgrass plants.

6. Conclusions

Increasing interest in environmentally friendly landscaping and urban green areas management and organic lawn care brings domestic and professional green keepers to look for alternative methods for weed control. Flame weeding could be an important choice for selective weed control in tolerant warm season turfgrasses. The two species tested under controlled conditions showed a relevant tolerance to flaming, especially *Paspalum vaginatum*. LPG doses of about 30-40 kg ha^{-1} should control weeds and should be tolerated by the turfgrass, considering the excellent regrowth capacities of these plants. However, care should be taken when multiple treatments are performed; a reduction of the LPG dose in this case may be necessary. Further experiments should be carried out in field to confirm the performance of these techniques and to find out the best setting of the flaming machine. A mature warm-season turf should realistically tolerate higher LPG flaming doses, thus more tests are needed.

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