

Alternatives to herbicides for weed management of a pear orchard

Alternativas ao uso de herbicidas na gestão de infestantes em pomar de pereiras

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ABSTRACT

Nowadays, there is growing pressure from society, governmental organisations and farmers to find sustainable weed management solutions that reduce or even eliminate the use of herbicides. We evaluated the efficacy and viability of alternative methods for weed management in a pear orchard (*Pyrus communis*). We compared the use of light-reflecting and non-reflecting tarps, thermal weeding using steam with and without prior weed mowing to the chemical control with flazasulfuron and a mixture of glyphosate + diflufenican + MCPA in autumn followed by glyphosate in the end of spring, and control (untreated). The assay was setup in the end of November 2019. An analysis of the economic viability of the treatments on the quantity and quality of the fruit was made. The tarps had an average efficacy of over 90 %, but they entail a high initial investment. The highest yields were obtained with tarps, followed by flazasulfuron and the thermal method with mowing. Flazasulfuron had an average efficiency of 75%, and 100% for the weedy species of the genus *Equisetum*. The costs of this method were quite high compared to the mixture of other herbicides, which had an average efficacy of only 56%. The efficacy of thermal weeding with and without prior mowing was 45% and 57% respectively. At the time of the trial, the high water consumption and low working speed were the negative aspects of this method. The integration of thermal weeding with other control methods should be the object of future research.

Keywords: thermal weeding, mulching tarps, 'Rocha' pear, flazasulfuron, glyphosate

RESUMO

Atualmente, assiste-se a uma pressão crescente da sociedade, organismos estatais e agricultores na procura de soluções sustentáveis de gestão de infestantes que permitam a redução, ou mesmo a eliminação, do uso de herbicidas. Neste trabalho avaliou-se a eficácia e viabilidade de estratégias alternativas de gestão de infestantes num pomar de pereiras (*Pyrus communis*), designadamente telas refletoras e não refletoras de luz, monda térmica com vapor de água com e sem corte prévio de infestantes, em comparação com o uso de flazassulfurão e mistura de glifosato+diflufenicão+MCPA no outono seguida de glifosato no final da primavera, e controlo (testemunha não tratada). O ensaio foi instalado no final de novembro de 2019. Realizou-se uma análise da viabilidade económica dos tratamentos e dos efeitos na produtividade, nomeadamente na quantidade e qualidade da fruta. As telas tiveram eficácias médias globais acima de 90%, no entanto o custo da sua instalação e aquisição é bastante elevado. Nas modalidades com telas obtiveram-se maiores produções, seguidas do flazassulfurão e monda térmica com corte. O flazassulfurão teve uma eficácia média global de 75% e 100% para infestantes do género *Equisetum*. Os custos desta modalidade são bastante elevados comparativamente à modalidade com mistura de herbicidas, que teve eficácia média de apenas 56%. A eficácia da monda térmica com e sem corte das infestantes foi de 45% e 57%, respetivamente. À data do ensaio, o elevado gasto de água e a baixa velocidade de trabalho foram os aspetos negativos deste método. A integração da monda térmica com outros métodos deve ser objeto de futura investigação.

Palavras-chave: monda térmica, telas anti-infestantes, pera 'Rocha', flazassulfurão, glifosato

INTRODUCTION

The search for alternatives to chemical weed management has increased due to the excessive and continuous use of herbicides that are known to have several consequences for ecosystems, and promotes herbicide weed resistance (Merfield *et al.*, 2017). These alternatives need to be effective, easy to apply, economically viable and sustainable (Westwood *et al.*, 2018). There are diverse non-chemical options for weed management such as crop rotation, false sowing, soil covering (mulching), mechanical weeding and thermal weeding. Although some authors are making research efforts on these issues (e.g. Rifai *et al.*, 2002), there is still a lack of knowledge on the efficacy of these methods in row crops, such as orchards. Thermal weeding can be done by flaming, or using hot water or steam, and consists of heating weeds to high temperatures, leading to the collapse of their cells (Ascard, 2007). The first thermal weeding methods began to be patented in 1852 and were widely used in the USA until the appearance of the first selective herbicides. In Europe, with the emergence of organic agriculture in the eighties, this method began to gain relevance (Collins, 1999). Nowadays, with technological advances, a new window of opportunity for thermal weeding arises. Another potentially successful alternative method is the use of mulching tarps, but the effects and economic feasibility on orchards have not been thoroughly investigated. Mulches prevent penetration of light or exclude certain wavelengths that promote the germination and growth of seedlings, while

increasing soil temperature and retard the loss of soil moisture. This work aims to study the efficacy of diverse weed control methods in a pear orchard (*Pyrus communis* L.), Alcobaça, Portugal. Specifically, we compared the use of light-reflecting and non-reflecting tarps, thermal weeding using steam at 100 °C, with two herbicide treatments and a control (untreated).

MATERIAL AND METHODS

Study area, experimental design and trial

The field experiment was conducted at the National Station of Fruticulture Vieira Natividade, Alcobaça, Portugal (39.552 N, 8.960 W), in a 22-year-old pear orchard (*Pyrus communis* L. cv. 'Rocha'). It was conducted in a randomized block design for five of the seven treatments and with four replications (20 m²; 10 trees). The treatments were as follows: i) thermal treatment with prior weed mowing (ThermM); ii) thermal weeding without prior weed mowing (Therm); iii) mixture of systemic foliar and residual herbicides: (Ghyph); iv) residual systemic and foliar herbicide: flazasulfuron (Flaza), and v) untreated control (Test). The two remaining treatments referred to two different tarps (non-reflecting mulching tarp, NReFIT, and reflective mulching tarp, ReFIT) which were installed in contiguous rows and the replications were randomized within the rows. This option was made due to material limitations. The trial was carried out between November 2019 and July 2020 (Table 1).

Table 1 - Treatments applied during the trial, acronyms, dates and details. a.i.- active ingredient

Treatment	Acronym	Date	Herbicides and dose rate applied
glyphosate + diflufenican+MCPA	Glyph	27.11.2019	glyphosate + diflufenican + MCPA (160 + 40 + 500 g a.i. /100 L water) (Zarpa™, Basf + HERBINEXA 50, Nufarm)
glyphosate		22.05.2020	glyphosate (360 g a.i. / 100 L water) (RoundUP Ultra Max, Bayer Crop Science Portugal)
Non- Reflective tarp Reflective tarp	NReFIT ReFIT	20.01.2020	date refers to the day of the installation
flazasulfuron	Flaza	20.02.2020 26.05.2020	flazasulfuron (200 g a.i. / 100 L water) (ORFEU, Selectis)
Thermal weed control with mowing of weeds	ThermM	20.02.2020 26.06.2020	mowing: 22.05.2020
Thermal weed control without mowing of weeds	Therm	20.02.2020 26.06.2020	

Thermal weeding was applied using the 'Belle Île OliaTec' equipment (provided by the company Teramotriz, Alcobaça, Portugal). It has a 500 L water tank that is heated with a diesel generator. The water is applied using a hose that connects to a plastic gun and equipment similar to a 'vacuum cleaner' with five nozzles (Figure 1a). The estimated average working speed for applying thermal weeding with and without prior cutting of the weeds is 0.22 km/h and 0.14 km/h, respectively. The average time is 2.71 and 4.31 min to treat 10 m in mowing and non-mowing modes. Based on these values, water consumption per hectare was estimated at around 7000 L in the case without cutting and 3600 L with prior cutting of the weeds. NReflT (dark green) and ReflT (pinkish-white) are 0.64 mm and 1.32 mm thick, respectively and are both thermally welded polypropylene, permeable to water, allowing gaseous circulation and nutrient absorption (Figure 1b).

categories, the absolute and relative frequencies of weeds for each replication. One-way ANOVA and post-hoc tests were carried out to test whether there are significant differences in the efficacy of the treatments concerning dominant weeds and the total abundance of weeds. We also tested for significance and analysed the differences between treatments for productivity, the number of fruits, and size.

RESULTS AND DISCUSSION

Overview

We identified 39 taxa of vascular plants, and two bryophytes: the liverwort *Lunularia cruciata* (L.) Dumort. ex Lindb. and a moss of the genus *Didymodon* Hedw. The most represented family was *Poaceae*, followed by *Asteraceae*. The most frequent (>40% of

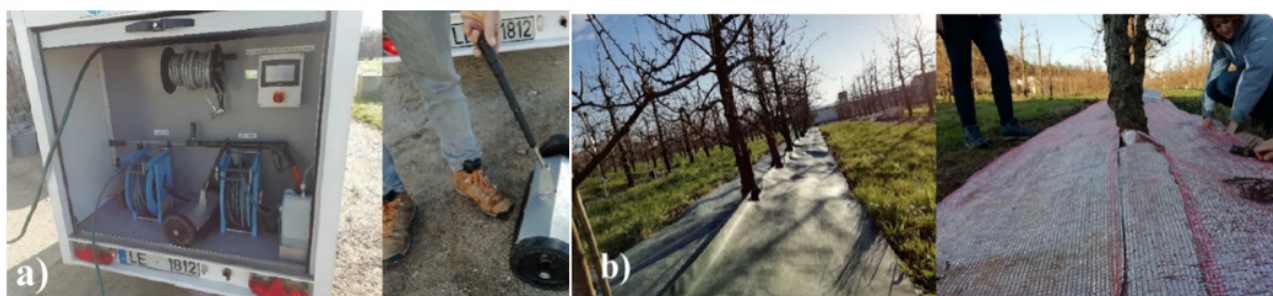


Figure 1 - a) Equipment used in thermal treatments; b) Installation of mulching tarps (January 20, 2020).

Floristic surveys were carried out from November 2019 to June 2020. We used the weed density scale of Barralis (1976) to estimate weed abundance data. In August 2020, all fruits were harvested from four trees randomly selected per each treatment and replication. These fruits were separated by size and weighed to determine productivity.

Statistical procedures

The control was randomized to obtain the efficiencies of treatments. We calculated the average abundance, using the central value for the Barralis

all plots) and abundant species (average >45%) were *Cirsium arvense* (L.) Scop., *Convolvulus arvensis* L., *Bromus catharticus* Vahl, *Equisetum telmateia* Ehrh. and *Equisetum ramosissimum* Desf.. *Mentha suaveolens* Ehrh., *Lolium multiflorum* Lam. and *Arum italicum* Mill were also abundant and frequent.

Effect of treatments

Immediately after the thermal weeding, the soil surface temperatures ranged from 30 °C to 70 °C and dropped considerably from the first few centimeters of the soil (Figure 2a).

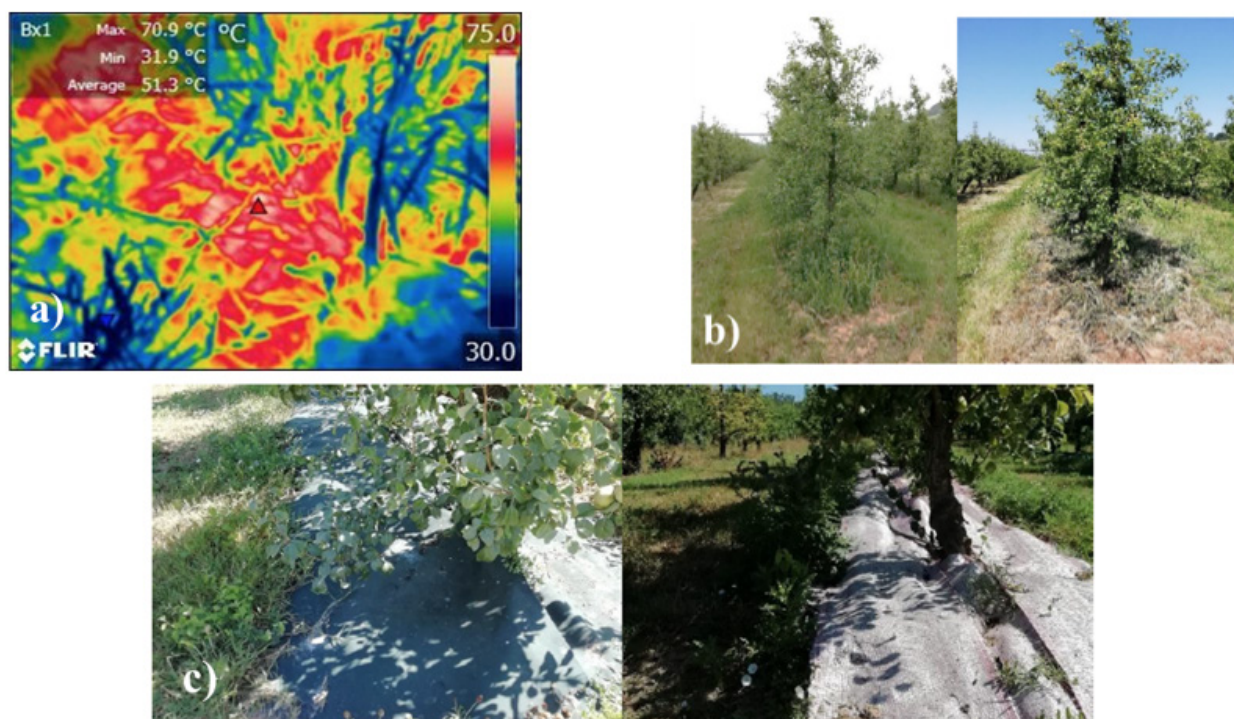


Figure 2 - a) Photographs taken with a 'Flir E5' thermal camera (FLIR Systems, Inc., Wilsonville, USA) (May 25, 2020) immediately after thermal weeding; b) Comparison before and 6 hours after thermal weeding treatment (May 25, 2020); c) Mulching tarps 6 months after installation (July 20, 2020).

The efficacy of heat treatment for perennial weeds was limited. Subterranean weed meristems and other vegetative reproduction structures such as bulbs and buds exhibit lower susceptibility compared to the above-ground plant structures, as was also observed in other similar studies (Rifai *et al.*, 2002). Nevertheless, thermal weeding yields immediate results, with most weeds losing their aerial parts within six hours, leading to the swift elimination of annuals and evident reduction of

the growth of perennials (Figure 2b) (Pessoa, 2021). Tarps were the method with the highest average efficacy, between 80 and 100% of success in controlling the weeds during the trial period (Figures 2c and 3). *Convolvulus arvensis* and *Equisetum telmateia* were observed, but with very low density. There were no significant difference in efficacy between the different tarps. The remaining methods presented high variability of weed abundance during the trial (0-90%). However, significant

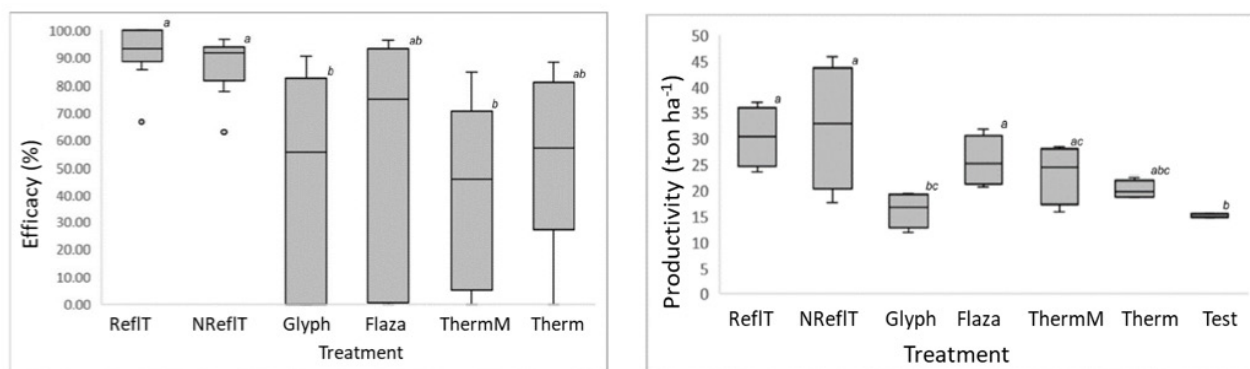


Figure 3 - Box-whisker plot for the overall efficacy of treatments (left graph) and productivity (right graph). Different letters indicate significant differences in medians between treatments ($p < 0.05$).

differences were detected between the Tarps, and Glyph and ThermM. Regarding the chemical control, the average efficacy was 55% for the method generally used in the orchard (Glyph) and 75% for the Flaza treatment. The latter was very efficient for *E. telmateia* and *E. ramosissimum*. Thermal treatments exhibited large variability, averaging 45% without mowing and 57% with mowing. It was also noticeable an important contribution of the tarps on the reduction of root suckers.

Mulching tarps had the highest average productivity, 32.8 and 30.2 ton ha⁻¹ for NRefIT and RefIT, respectively. Thermal treatment with mowing had an average productivity slightly higher than without mowing, and similar to the treatment with flazasulfuron. The usual chemical method used in the orchard (Glyph) displayed the lowest productivity, aligned with the control (Figure 3). Tarp treatments had the highest number of fruits, followed by Flaza and ThermM, which still had a notable difference compared to Therm (no previous mowing). The lowest number of fruits was observed on Glyph. It was also noteworthy that the NRefIT row produced more large size fruits (>70 mm). The trees harvested at RefIT produced eighty-one fruits of the aforementioned calibers, the same number as the trees at Therm (Figure 4).

CONCLUSIONS

The tarps emerged as a highly effective soil management method, maintaining an excellent condition throughout the trial and delivering the

highest productivity. Nonetheless, their installation proved to be both time-consuming and costly. Thermal methods were considered interesting alternatives to herbicides, though they are less effective for perennial weeds. Additionally, they entail an initial investment in equipment and currently exhibit high water consumption and a slow operational pace, factors that can be minimized with the use of more specific mecanization for agricultural use. The usual treatment of the orchard (mixture of systemic foliar and residual herbicides) revealed low productivity, a low number of large fruits, and medium to low efficacy on weed control. Flazasulfuron was effective in areas infested by *Equisetum* species but has high costs. Future research should focus on the integration of available methods for weed management in tree fruit orchards, while assessing their economic and ecological sustainability.

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Fruit nº	RefIT	NRefIT	Glyph	Flaza	ThermM	Therm	Test	Total
<50	246	167	58	182	162	89	101	1005
50-55	103	74	24	75	98	38	45	457
55-60	229	231	93	204	155	118	91	1121
60-65	218	229	175	212	188	129	122	1273
65-70	92	124	59	77	70	88	52	562
70-75	75	95	36	50	47	75	39	417
75-80	6	14	4	3	4	6	10	47
>80	0	0	0	1	0	2	0	3
Total	969	934	449	804	724	545	460	

Figure 4 - Distribution of the number of fruits harvested by size (mm), per treatment.

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