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INNOVATIVE STRATEGIES FOR PHYSICAL WEED CONTROL ON HARD SURFACES IN CENTRAL ITALY: RESULTS ACHIEVED IN TWO DIFFERENT CITIES

A. PERUZZI¹, L. LULLI¹, M. FONTANELLI¹, C. FRASCONI¹, M. GINANNI¹,
M. RAFFAELLI¹, F. SORELLI¹

¹ University of Pisa, Dipartimento di Agronomia e Gestione dell'Agroecosistema, Sezione Meccanica Agraria e Meccanizzazione Agricola, Via del Borghetto 80, 56124 Pisa, Italy, aperuzzi@agr.unipi.it

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ABSTRACT Concern about environment and water pollution has lead researchers to find and set up alternatives to urban herbicide application all over Europe. Moreover, the ordinary non chemical weed management in the Italian cities is mostly carried out by means of mowers, that are neither effective nor safe for citizens and operators. As an alternative to ordinary devices, thermal equipments can be used successfully for weed control on hard surfaces. Flaming machines are the most efficient and versatile among thermal devices and are suitable for treatments in many urban contexts. A research was carried out in 2006-2008 in two important towns of Tuscany (central Italy), Pisa and Livorno, in order to evaluate the effects of different weed managements (flaming, mowing, herbicide application, and integrated use of flaming and herbicide application) on both weed dynamics and total working times and costs in order to define the best strategies to be used on hard surfaces in a typical Mediterranean environment. Each site was characterized by different plant population, density, and hard surface typology. Flame weeding at low and high frequency was compared to mowing (4 treatments year⁻¹) in Pisa, and to chemical (2 treatments year⁻¹) and integrated (1 herbicide + 3 flame weeding treatments year⁻¹) management in Livorno. The results showed that flaming reduced weed density more effectively than the other methods. Moreover, in the second year, according to the reduction of the number of treatments needed to maintain an acceptable level of weed coverage, the costs of flaming decreased reaching values lower than those of mowing and similar to those of herbicide distribution.

Keywords: flame weeding, weed control in urban areas, hard surfaces.

INTRODUCTION Many spontaneous plant species grow in urban contexts according to their high propagation or seed dispersion rate and adaptability to environmental pollutants, low water availability resistance, capacity of root system and/or aboveground plant parts to develop even in restricted spaces (Vincent & Bergeron, 1985). Their control is necessary in order to avoid several problems, mainly concerning with: a) preservation of the aesthetics of streets and squares; b) structural damage of hard surfaces; c)

obstruction of urban drainage; e) spread of allergenic pollen in the air (Warscheid & Braams, 2000; Benvenuti, 2004).

Flame weeding is a good alternative to mowing and herbicides for weed management on hard surfaces (Raffaelli & Peruzzi, 1998, Peruzzi et al., 2007). This method consists in increasing the temperature of the air around the vegetal tissues to about 1000-2000 °C, that causes the disruption of cell membranes, and the devitalisation of the epigeal organs thereafter (Ellwanger et al., 1973a and 1973b). Flaming is not injurious for most hard surfaces, because the thermal radiations persist only few tenth seconds. These strategies were tested and in many cases also used in the practical weed flora management in many North European Countries (Kristoffersen et al. 2007). On the contrary, in Italy the use of flaming in urban area on hard surfaces was not investigated before 2004. Perennial species, especially belonging to the Asteraceae and Poaceae families, are typical of the urban flora in Central Italy. Climatic conditions of costal Tuscany (moderately cold and rainy winter and warm summer) determine constant rate of weed development, so that the control of weed flora results hard and expensive. On this regard the University of Pisa has been studying the application of flaming in urban areas from 2004, but this technique is far from being introduced into conventional weed management programs of public administration (Peruzzi et al., 2005, 2007, Raffaelli et al., 2007). In order to define a proper strategy for weed control on hard surfaces in urban areas, a two-year research was carried out in two representative and important cities of Tuscany (Central Italy) with the aim of evaluating the effectiveness of different techniques in weed suppression and the costs of the operations.

MATERIALS AND METHODS The research was carried out in the cities of Pisa (43°43' N, 10°24' E) and Livorno (43°33' N, 10°19' E) in 2006-2008. Experimental plots were set in five different sites in both cities, but in this work only the results obtained in the areas of Piazza San Paolo a Ripa d'Arno in Pisa and Accademia Navale in Livorno are reported. Different plant population and density, and different hard surface typologies characterized each site. Firstly for each site, according to aesthetical and functional standards, a maximum tolerable level of weed coverage was defined (MWC) (Table 1).

Table 1. Specifications of the typology and of the maximum tolerable level of weed coverage for each areas.

Area (municipalities)	Surface Typology	Architectonical and turist importance	MWC
			%
Piazza San Paolo a Ripa d'Arno (Pisa)	Porphyry blocks	High	10
Accademia Navale (Livorno)	Gravel	High	10

Flame weeding at low (LF) and high (HF) frequency was compared to an untreated control and to mowing (4 treatments year⁻¹) in Pisa, and to chemical (2 treatments year⁻¹) and integrated (1 herbicide + 3 flame weeding treatments year⁻¹) management in Livorno. For each area the number of flaming treatments year⁻¹ of HF was double than LF and varied with the aim of maintain weed coverage below the MCW level. Flaming was carried out with a machine equipped with a 15 kg LPG tank and a manual lance. The

burner was a 0.15 m wide rod shaped type with external nozzle ($\square = 0.7$ mm), and it was characterized by a specific LPG consumption of 1.0 kg h^{-1} at 0,2 MPa pressure. Mowing was performed with a standard string trimmer while herbicide (glyphosate 5% solution) was applied using a knapsack sprayer. Weed density was determined at the beginning of the trials and periodically thereafter according to Braun-Blanquet method (1932) and data were transformed into percentage of weed cover. For each treatment working time and LPG consumption was determined. At the end of the research total working time, total costs, Manpower Index (mean working time \times mean weed density/100) and Economic Index (mean cost of treatment \times mean weed density/100) were calculated on a base of LPG price of 1.73 €kg^{-1} and professional fees of 0.36 and 0.044 €m^{-2} for mowing and herbicide treatments respectively. Experimental design was a randomized block with four replications. Data of weed density were statistically treated by ANOVA with repeated measures using the CoHort Software (2002). Means were separated by Fisher LSD test at $P \leq 0.05$ (Gomez & Gomez, 1984).

RESULTS

Weed Control

Piazza San Paolo a Ripa D'Arno (Pisa) This area was characterized by a porfiry block surface and the weed flora was mainly composed of *Cynodon dactylon* (L.) Pers., *Cyperus* spp., *Parietaria officinalis* L. and plants belonging to the family of *Asteraceae*. The initial weed cover ranged from from 22 to 45% (Fig. 1).

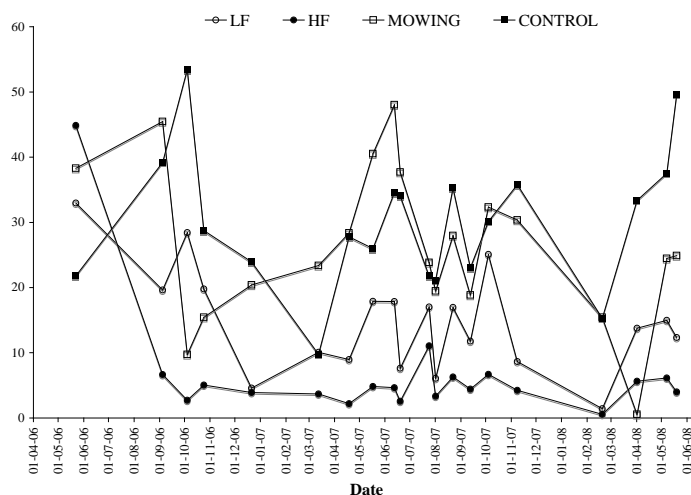


Figure 1. City of Pisa, weed density at Piazza San Paolo a Ripa d'Arno during 2006-2008.

During the two years period, flaming HF meanly allow to maintain the average weed cover to a statistical significantly lower level with respect to the other typologies of management, while flaming LF reduced significantly the level of weed cover in comparison with mowing (Fig. 2). The ordinary management adopted by the municipalities of Pisa (mowing) was decidedly inadequate to control weed flora, as the

mean level of weed canopy was not statistically different from the untreated control (Fig. 2).

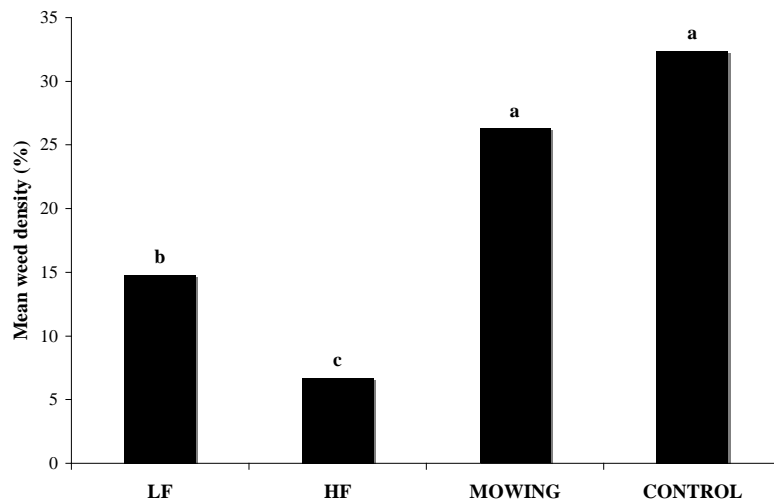


Figure 2. City of Pisa, mean weed density at Piazza San Paolo a Ripa d'Arno recorded during the experimental research. Different letters mean significant statistical difference (Fisher LSD $P \leq 0.05$).

Accademia Navale (Livorno) In this area a high number of weed species was recorded mainly belonging to the family of *Asteraceae* such as *Sonchus* sp., *Taraxacum officinalis* Weber ex F.H.Wigg., *Conyza canadiensis* (L.) Cronq., *Senecio vulgaris* L., *Picris echinodes* L., *Hyoseris radiata* L. The Initial weed cover ranged from 53 to 73% (Fig. 3).

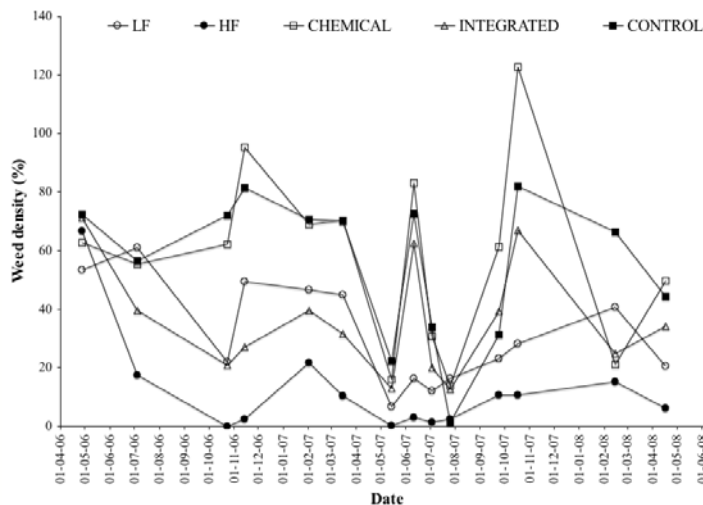


Figure 3. City of Livorno, weed density at Accademia Navale during 2006-2008.

Also in this case, during the two years period flaming allowed to obtain the highest degree of weed control, reducing significantly plant cover in comparison to the other managements (Fig. 4).

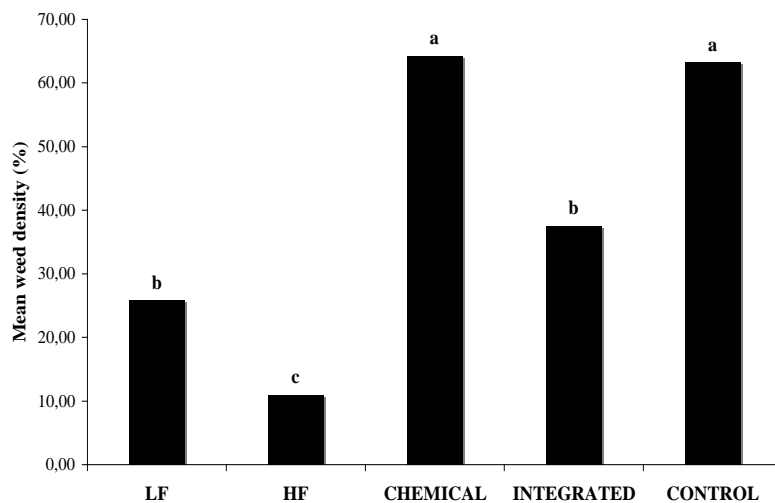


Figure 4. City of Livorno, mean weed density at Accademia Navale recorded during the experimental research. Different letters mean significant statistical difference (Fisher LSD $P \leq 0.05$).

Flaming LF and the integrated weed management reduced significantly weed canopy to level of 25% and 40% respectively, with respect to the ordinary chemical weed management and the untreated control.

Manpower and operating costs

In the area of Piazza San Paolo (city of Pisa) the value of total working time of the HF flaming resulted higher than flaming RF and ordinary mowing management (Table 2). Concerning with the total operating costs, highest values were recorded for mowing (Table 2).

Table 2. Values of working time, operating cost and number of treatment recorded for the different weed control managements during the two year period of the experimental research in Piazza San Paolo a Ripa d'arno (Pisa).

	Weed management	Working time (h /1000 m ²)	Operating cost (€/1000 m ²)	Number of treatments
First year	LF	45	619	11
	HF	77	1062	20
	MOWING	37	1440	4
Second year	LF	22	297	6
	HF	35	478	10
	MOWING	41	1440	4
Total	LF	67	916	17
	HF	112	1540	30
	MOWING	78	2880	8

Sharing working times and operating costs in the two years of research, it was possible to observe a decrease of these parameters for both RF and HF flaming management (Table 2). This fact could be explained taking into account the lower number of treatments carried out in the second year. As shown in Table 3, both Manpower and Economic

Indices were much lower for Flaming HF followed by Flaming RF with respect to mowing weed management, because although working times and total costs of alternative and conventional methods were similar weed suppression resulted always higher when flaming was used.

Table 3. Piazza San Paolo Pisa values of manpower index and economic index for the different weed control managements.

Parameters	LF	HF	MOWING
Manpower index	0.58	0.25	2.56
Economic index	0.31	0.13	9.23

Regarding the area of Accademia Navale of Livorno the use of both RF and HF flaming resulted in higher values of total working time and total operating cost in comparison to the integrated and chemical weed control (Table 4). However, also in this case relevant reduction was observed in the second year of research. As a matter of fact in the second year of application the total working times and the costs of flaming were lower than those of integrated and chemical weed management (Table 4).

Table 4. Values of working time, operating cost and number of treatment recorded for the different weed control managements during the two year period of the experimental research in the area of Accademia Navale Livorno.

	Weed management	Working time (h /1000 m ²)	Operating costs (€/1000 m ²)	Number of treatments
First year	LF	71	983	9
	HF	99	1365	15
	INTEGRATED	31	789	4
	CHEMICAL	21	808	2
Second year	LF	37	508	5
	HF	48	666	7
	INTEGRATED	28	736	4
	CHEMICAL	24	808	2
Total	LF	108	1491	14
	HF	147	2031	22
	INTEGRATED	59	1525	8
	CHEMICAL	45	1616	4

The values of Manpower and Economic indexes for the area of Accademia Navale (Livorno), emphasized that the ordinary chemical weed management (independently from working times and costs) was inadequate from a qualitative point of view, as it was not able to maintain a sufficiently low level of weed cover (tab. 5).

Table 5. Accademia Navale of Livorno. Values of manpower index and economic index for the different weed control managements

Parameters	LF	HF	INTEGRATED	CHEMICALS
Manpower index	2.00	0.74	3.00	7.19
Economic index	2.13	0.68	5.25	29.05

CONCLUSIONS Ecological and climatic conditions of urban areas in the Tuscan coast (Central Italy) are generally favourable to weed growth and development, making hard surfaces management very difficult and expensive. Flaming represents a good alternative to mowing and herbicide application for weed management on hard surfaces, as can be easily applied and, does not present any risk of introduction of dangerous substances in the environment. The results of this research carried out in Pisa and Livorno showed how the heterogeneity of the environments make indispensable to define targeted strategies in order to maximize weed control on the different typologies of hard surface and in presence of different weed flora composition and stage of development. Obviously the performances of flame weeding could be further improved on time (after the first season of application), carrying out frequent and timely interventions able to maintain clean the treated areas.

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