INNOVATIVE STRATEGIES FOR PHYSICAL WEED CONTROL ON HARD SURFACES IN URBAN AREA IN CENTRAL ITALY: DEVELOPMENT OF NEW FLAMING OPERATIVE MACHINES

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

1University 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 In Italy, weed control in urban areas is mainly performed by means of mowing cutting and herbicide application. While trimmers are not effective in reducing weed density and they are also have the potential to cause injuries to hard surfaces and the safety of citizens and operators, chemical control induces resistance to active compounds in spontaneous plants and it is surely a source of environmental pollution and a risk factor for the health of human beings and animals. For this reason the use of herbicides in urban areas is strictly regulated by laws. As an alternative to ordinary weed control devices, thermal equipments can be used successfully for weed control on hard surfaces. Flaming machines are the most efficient among thermal devices and they are suitable for treatments in many urban contexts. Several equipments for thermal weed control were designed, realized and optimized by University of Pisa in order to efficiently perform treatments in urban areas. An experimental trial was also carried out in two cities of Tuscany (Central Italy) aiming to verify machine reliability and to evaluate both the effects of flaming treatments on weed density reduction and LPG consumption and costs (as showed in another specific work submitted to this congress).

Keywords: Flame weeding equipments, flaming operative machines, thermal weed control, urban areas

INTRODUCTION Modern cities are made of concrete, stone, tarmac, pavements and many other hard materials. Moreover, air and water pollution in urban areas is generally high, and biological cycles of many living organisms, plants included, are often negatively affected by human activities (Rossini Oliva & Mingorance, 2006; Brown and Peake, 2006; Nali et al., 2007; Bignal et al., 2007). Nevertheless, a considerable number of 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, and capacity of root system and/or aboveground plant parts to develop even in restricted spaces (Vincent & Bergeron, 1985). For this reason weeds grow almost everywhere in urban areas and their control is absolutely necessary in order to avoid several problems, mainly concerning with (Warscheid & Braams, 2000; Lisci et al., 2003; Benvenuti, 2004):
• preservation of the aesthetics of streets and squares, that is an important aim of public administrators especially in cities rich in historical buildings or monumental areas;
• structural damage to tarmac, pavements, walls and other hard surfaces
• obstruction of urban drainage;
• negative interactions with citizens, drivers and vehicles, such as slipping, limitation of visibility, skidding;
• negative interaction with human health due to the spreading of allergenic pollen in the air during flowering.

In Italy, urban weed control on hard surfaces is mainly carried out by mowing and/or herbicide application (Peruzzi et al., 2007, Lulli et al., 2007). String trimmers are generally the cutting machines adopted for physical weed management. As a matter of fact, these equipments are light and easy to use but mowing treatments with trimmers are effective only in the short period and also high manpower utilization is needed for the entire operation (cut, harvest and disposal of plant residues as waste). For this reason costs of mowing are high and only four to six treatments are generally carried out between spring and autumn. On the contrary, systemic herbicides are more effective than trimmers because they kill all plant organs but they undoubtedly are a source of air and water contaminants and represent a risk factor for the health of people and animals (Ward et al., 2006; Barr et al., 2006). In this respect, taking into account that chemicals are distributed on hard surface, even active principles characterized by low toxicity and persistence (i.e. glyphosate) may not undergo to the normal processes of decaying that happen in agricultural soils (Rueppel et al., 1977; Aldous & Turrell, 1994; Spanoghe et al., 2005). Moreover as some important weeds are showing resistance to glyphosate, mixtures of different herbicides are usually used to maximise the efficacy of chemical treatments although persistence of active compounds on or their metabolites on hard surfaces increases. Considering the potential risk of agrochemicals, Regional Law of Tuscany n. 36/99 do not allow herbicide distribution close to houses or streets of public domain and chemical treatments must be authorized by sanitary administration in order to protect as much as possible the health of citizens. In many cities of Tuscany sanitary administrations do not authorize more than two operations of herbicide application per year, so that chemical weed management is never really effective if it is not integrated with physical weed control. As an alternative to cutting machines and herbicides, many other devices for physical weed management on hard surfaces have been developed in Europe and U.S.A. (Raffaelli & Peruzzi, 1998). These operative machines for physical weed control on hard surfaces are characterized by thermal actions, and always carry out non-selective treatments. Thermal control methods can be divided in two groups according to their mode of action: a) the direct heating methods (flaming, infrared weeder, hot water, steaming, hot air); b) indirect heating methods (electrocution, microwaves, laser radiation, UV-light) (Ascard, 1995; Hansson, 2002; Hansen et al., 2004; Rask & Kristoffersen, 2006). Flame weeding was the first mean used in north Europe in the middle of 80’s for physical weed control on hard surfaces and it is still the most used thermal control method (Raffaelli et al., 2009). This technique consists in exposing the vegetal tissues to high temperature (1000-2000°C) in order to achieve the breaking of the cell membrane, causing in most of the cases the devitalisation of the epigeal organs (Ellwanger et al., 1973a and 1973b). The treated surfaces do not run the risk of combustion or other damages, because the thermal radiations persist only few
tenth seconds. The operative machines and the equipments are similar to those used in agriculture and are fed by LPG. The more simple and cheap machines are “knap sack” or trolley hand managed by the operator (Raffaelli & Peruzzi, 1998). The last one is more suitable in narrow and steep working environment (staircase or pavement) but is characterized by a low work capacity and, although extremely ergonomic, causes problems to the operators, that have to bring the weight of the LPG tank on their shoulders. When wider surfaces have to be flamed more complex equipments must be used, such as mounted or self propelled machines. The LPG tank can be placed both on the operative machines, and on the tractor. There are two typologies of burner: open flame burner (rod and cylinder shaped) and infrared burners (that are characterized by the absence of flame and so are more suitable for working in the presence of flammable vegetal residuals such as straw or dead dry leaf). The types of burners utilized on hard surface are often covered by a proper carter. The carter provide for an higher thermodynamic efficiency of the burner and an higher level of security considering the field of application. The effectiveness of thermal treatments depends on the technique and characteristics of the operative machine adopted. Generally, open flame weeding allow a very high heat exchange and low energy is required for flame production, although among open flame equipments the energetic effectiveness vary according to the typology of the used burner. If compared to northern Europe, in Italy alternative weed managements are decidedly less investigated. The University of Pisa has been studying the application of flame weeding in urban areas from 2004, and distinct typologies of equipments and operative machines were properly designed realized and optimized in order to operate in each different environmental condition of the urban areas characteristics of the Central Italy.

STUDY, REALIZATION AND SET UP OF INNOVATIVE EQUIPMENTS AND OPERATIVE MACHINES FOR FLAME WEEDING IN URBAN AREAS. Two manual equipments and three self-propelled operative machines were designed and realized by the University of Pisa; each components of the machines were designed with modular conception, in order to adapt shape and dimension of the equipments to the different operative conditions and in particular for the peculiarities of the Mediterranean urban areas. Concerning manual machines, (figures 1 and 2) suitable for treatments on small surface and steep areas, two typology of equipments were realized, both of them characterized by similar elements such as: a proper slot for LPG tank, a manual lance with an ergonomic handle, a pressure regulator and a pressure gauge, maximum and minimum regulator tap, a trigger for LPG supply, a 15 cm rod shape open flame burner equipped with an external nozzle with a diameter of 0.7 mm. The knap-sack equipments was constructed, equipping a backpack for trimmer with a special slot for a LPG tank. The whole mass of the LPG cylinder is 11 kg (5 kg of LPG and 6 kg of tare) the knap sack alone weighs 3.5 kg. Two type of manual lance were set up for this equipments (figure 1): one for treatment on horizontal surfaces and one shorter with different handle for treatment on vertical surfaces. The trolley device is equipped with pneumatic wheel in order to easily carry off a 15 kg LPG tank (gross weight of about 30 kg). The manual lance conceived for this appliance is also supplied with a shoulder strap and an ergonomic cross handle.
Figure 1. Knap-sack flame weeding device with two manual lance typologies

Figure 2. Trolley flame weeding equipment.

The self-propelled flaming machines were conceived in order to improve working capacity and to reduce LPG consumptions and operating cost of thermal treatment. The three operative machines realized were equipped with a 4 stroke gasoline engines. The LPG tanks (it is possible to use different size of commercial tanks) are placed inside a hopper that contains water. The water is heated by means of the exhausted gas of the engine that passes in a copper tube placed inside the hopper; this solution allows a good heat exchange, recovering energy (figure 3). Any LPG tank is equipped with a pressure regulator and a manometer and it is connected with a control systems. The control system of each burner is composed of 2 manual valves and 1 automatic safety valve (figure 3).

Figure 3. Heat exchanger (left) and control panel of burners (right) of the self-propelled flaming machine.
The manual valves allow to adjust the LPG feed (close, high or low levels). The automatic safety valve is connected with a thermocouple located inside the burner and it closes the LPG feed if the flame puts out. All the controls are in front of the operator and are easily adjustable.

The first prototype set up, was a self-propelled flaming machine driven by a walking operator equipped with 4 wheels (the front wheels are driving and the rear free wheels are steering) and a 4.4 kW four-stroke gasoline engine and with a 5 forward and 1 reverse speed gear (figure 4). The forward speed ranges from 1 up to 5 km h⁻¹. The machine net weighs (without LPG tanks and heat exchanger water) 139 kg and it is 140 cm long, 103 cm high and from 95 to 140 cm wide (varying with the adjustment). Two LPG cylinder can be placed in the heat exchanger. The flaming machine is equipped with 5 rod burners 25 cm wide with external nozzle (Ø 1.1 mm), placed frontally on a little frame, and 1 hand lance with a rod burner 15 cm wide with external nozzle (Ø 0.7 mm). The 2 side burners can be easily adjusted for frontal or side treatments, varying the inclination of the lateral parts of the frame with respect to the driving direction (figure 5). The two lateral parts of the little frame are connected with the central part with elastic hinges (type “saloon door”) (figure 5), to avoid damages in case of bumps. All the burners can be easily adjusted varying height and inclination with respect to soil surface. The hand lance is equipped with a gas tube 8 m long that is reeled by an automatic cable reel modified on purpose for LPG gas.

![Figure 4. Self-propelled flaming machine built and set up at the University of Pisa.](image)

![Figure 5 Side burners adjusted for side treatments (left), lateral parts of the little frame connected with elastic hinges.](image)

The second self-propelled prototype set up, was conceived in order to perform flaming treatments in limited dimension areas. The machines is equipped with three wheels, the frontal directional one is pirouetting (figure 6). This device can be driven by a walking operator and if necessary the transmission of the motion, provided by a 4.5 kW four-stroke gasoline engine, on the two rear wheels can be started with a lever on the handle. The highest working speed for this machines is 2.5 km h⁻¹. Two rod burners 25 cm wide with external nozzle (Ø 1.1 mm), placed frontally on a little frame, ensure a working width of 0.5 m. The machine net weighs (without LPG tanks and heat exchanger water)
75 kg. The heat exchanger was conceived to contain one commercial 15 kg LPG cylinder, in order to preserve manageability and lightness of the equipment. This type of LPG tank provides about 5 hours of working continuous time, adopting a working pressures of 0.2 MPa.

The third self-propelled flaming machine with on board operator, was designed to perform treatments on large surface and was equipped with three wheels, two placed in front and driven by two hydraulic engines, and a pirouetting free wheel in the rear (figure 7). This solution allow the machine turning on itself reversing the motion of the frontal wheels, providing high manoeuvrability. The engine of the device is a twin four-stroke gasoline engine with a maximum power of 18kW. The working speed ranges continuously from 0 to 9 km h\(^{-1}\). The flaming machines can be equipped with four commercial LPG cylinders (both 15 and 25 kg), reaching a total LPG capacity of 60 or 100 kg. Four rod burners 50 cm wide with external nozzle (Ø 1.3 mm) provide a working width of 2 m. The burners are placed frontally on a frame linked to hydraulic lift arms. The 2 side burners can be easily adjusted for frontal or side treatments. Each burner is equipped with a proper cover, in order to improve the efficiency of the thermal treatment. The machine net weighs (without LPG tanks and heat exchanger water) 420 kg and it is 2.7 m long. The heat exchanger is placed behind the seat of the operator.

CONCLUSION. Trials carried out showed that the equipments and the new self-propelled flaming machines projected and realized at the University of Pisa were easy to
use, versatile and very suitable for treatments on hard surfaces in urban area. The specific
nozzles and rod burners used, together with the water heat exchanger, allowed a high
efficiency of the machine and a reduced LPG consumption. Finally the innovative self-
propelled machines resulted suitable for non-chemical weed control operations in urban
area and it is possible to suppose a successful use of these devices in horticultural and
protected cultivation conditions and in ornamental plant nursery.

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