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# INTEGRATING THE FLAME TREATMENT IN THE GROWING CYCLE OF ASPARAGUS FOR A SUSTAINABLE CULTIVATION

## SUMMARY

Manual, mechanical and chemical techniques are used to control weeds in asparagus fields. Chemical weed control is permitted by protocols, except for organic production, but prohibited during spear harvest, because shoots continuously emerge. In the harvest phase, the bed must be kept free from weeds to facilitate picking. Inadequate weed control increases infestations over the years. In this context, liquefied petroleum gas (LPG) flaming is effectively used in three phases of the annual cycle: harvest period, fern production period, end of growing cycle. A specific range of flaming machinery has been designed and adjusted for accomplishing treatments in each phase. During the harvest period, a broadcast flaming machine performs the treatment multiple times. Field tests identified suitable operative parameters to control weeds effectively, safeguarding the emerging spears (5km $h^{-1}$ treatment speed, 0.8 bar gas pressure). During the fern production phase, intra-row flaming is applied to eliminate weeds and prevent seed dispersal. A special flaming machine is used to move through the narrow aisles, treating both sides at the same time (4÷5 km $h^{-1}$ speed, 1.2 bar gas pressure). A laminar air flow provides a barrier to protect the fronds from rising heat. At the end of the growing cycle, the fern fronds are shredded mechanically and the residues are burned, eliminating disease inoculum and weed seeds. The flaming machine promotes the ignition of fern residues, improving combustion. A recent innovation is represented by a combined machine for shredding and flaming the residues simultaneously, reducing work time (3÷4 km $h^{-1}$ speed, 1.6 bar gas pressure).

**Keywords:** Asparagus officinalis, flaming, weeds, organic production, mechanization.

## INTRODUCTION

Asparagus is a perennial crop that is produced in several regions of Italy. With a total area harvested of about 5560 ha, Italy ranks 9th in the world, and 3rd

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in Europe after Germany (19634 ha) and Spain (9900 ha) (Benson, 2012; FAOSTAT, 2016). The major areas of Italian asparagus production are located in Campania (1300 ha), Veneto (1600 ha), Emilia Romagna (1000 ha) and Puglia (900 ha). Each area has specific weed problems and differences in climate and soil types that affect weed management decisions (Falavigna, 2007).

Two distinct periods occur during the multiyear asparagus production cycle: stand establishment requires two years after planting; the following mature planting phase has an economic lifespan of 5 to 20 years. Both periods require specific weed management strategies with respect to plant development and related constraints.

Before planting the asparagus crowns, special care must be given to prepare the site by eliminating perennial weeds (Abell et al., 2006). Timely weed control during stand establishment assures optimal crop development. Mechanical cultivation of the beds, hand removal of weeds or herbicide treatments are needed during the first establishment year until a uniform fern cover is produced (Pedreros et al., 2002).

In established asparagus plantations weed control is only possible during a short window of opportunity, lasting about 4 months. In spring, before the spears emerge, preharvest cultivations and/or pre-emergence herbicides can be used for weed control. The harvest season spans from early spring through early summer, lasting up to eight weeks. In this period the spears develop continuously and the fields are harvested every 1-3 days. To facilitate harvest and increase soil temperature the beds must be kept weed-free. Control of annual weeds is difficult since the spears provide no shade to reduce weed competition. If infestations spread into the field during the harvest period they have to be removed manually or mechanically. Disc cultivation of the bed tops will interrupt harvest to for up to 10 days, reducing yield and profit (Mohler, 2001). Chemical weed control is prohibited in harvest.

Once harvest is finished the spears grow into dense ferns for the rest of the season, to replenish the nutrients for next year's spear production. Adequate weed control during the fern stage is required to prevent seed dispersal and weed seedbank buildup (Brock, 2012). Inadequate control increases infestations over the years, compromising yield and stand duration. Postharvest cultivation is possible until the fern becomes too tall to limit mechanical activity. However a heavy fern cover restricts light, thus providing competition against late emerging annual weeds. The application of herbicides from the end of harvest is an option for summer weed control in conventional production. (Boydston, 1995).

To improve the sustainability of asparagus, both in conventional and organic farming systems, an innovative weed management strategy was tested. LPG flaming was tested to control weeds in the three main phases of the annual asparagus growing cycle: the harvest period, the fern growth period, the end of the growing cycle. In this paper, the range of dedicated flaming machinery developed specifically for use in asparagus fields is described. Flaming may be a sustainable option for weed management, reducing the competition of annual and

perennial weeds, but avoiding the use of chemicals, while safeguarding yield and quality of produce.

## MATERIAL AND METHODS

An array of flaming machines was developed by "Officine Mingozzi", an Italian based company specializing in flaming machinery for the farm. Researchers at CREA-ING tested the innovative machines to establish appropriate operative parameters for effective weed control during the different phases of the growing cycle. Field tests were conducted in a 6-year-old commercial asparagus plantation, grown with cultivar "Ercole", on a two hectares farm located in a primary production area of Latium region. The field design consisted in a single line of plants per row, an 80 cm bed width, a 25 cm plant-to-plant spacing, a density of 18000 plants per hectare, and a 2.2 m row-spacing for a total row length of about 4545 m/ha.

The open flame treatments were carried out using three models of flaming machines. These machines share some common features: they are tractor-mounted and connected via three-point linkage; they are limited in size and weight, therefore suitable for use with the compact tractors commonly available on asparagus farms. All models carry two LPG cylinders and the fuel is supplied to the burners in the gaseous phase. This is an important distinctive feature of the tested machines, in contrast with other makes and models that use LPG in the liquid phase. Vapor withdrawal from the LPG cylinders assures safety of use in field work. Accidental damage to the burners or the gas line (field obstacles and uneven terrain) would cause a gas leakage that will quickly dissipate into the air, yet no ignition could occur because the percentage of LPG in the LPG/air mixture would be beyond the limits of flammability.

The following three flaming machines were employed in the field trials: 1) a ***broadcast flaming machine*** to eliminate weeds in pre-emergence and during harvest; 2) an ***intra-row flamer*** to selectively remove weeds along the ferns in post-emergence; 3) a ***combined machine*** with a shredding apparatus coupled to a flaming unit, to treat the residues and clean the field at the end of the season.

Pre-emergence flaming was tested in spring before the spears emerged. Post-emergence selective flaming was tested in the harvest phase, on emerging spears (Figure 1). The tested ***broadcast flaming machine*** (model PTR-C) has 15 gas burners spaced 9 cm apart, mounted on a pipe manifold perpendicular to the row. The flames are directed under a horizontal hood, that extends rearward for about 60 cm to hold down the heat and increase treatment efficacy. The burners have a 1.2 mm diameter nozzle, providing a nominal LPG flow rate of 1.62 kg/h at 0.8 bar gas pressure (Tomasone et al. 2015a). The work width of the machine is 1.6 meters, therefore the flames reach the bed and the adjacent areas on both sides of the row (Figure 2).

In the fern growth phase, mechanical cultivation is used for inter-row weed control, instead selective intra-row flaming can be applied to handle the weeds developing along the row, to avoid weed maturity and seed dispersal.

Fig. 1: Weeds emerging in the harvest phase

Fig. 2: Broadcast flaming in the harvest phase

The aisles between the rows gradually close as the ferns develop. A compact flaming machine, mounted in front of a compact tractor, was specifically designed to access the narrow aisles (Figure 3). The tested *intra-row flamer* (model PFV-D) is provided with a double boom for treating both sides in one pass (Figure 4).

On each boom, 8 burners are assembled in two groups each with four torches. The inclination of the torches can be adjusted to optimize the coverage of the bed area. A laminar air flow is coupled to the flaming apparatus, providing an air curtain barrier to hold down the heat and protect the fronds. The ventilation openings are aligned above the torches and connected to a fan blower, powered by a hydraulic pump connected to the tractor's PTO. (Tomasone et al. 2009; Tomasone et al. 2010). The diameter of the nozzles on the burner is 1.2 mm, the gas pressure at work is set at 1.2 bar, giving a nominal LPG flow rate of 2.1 kg/h. As the tractor moves in the field along adjacent aisles, the treatment is completed on both sides of the bed.

Fig. 3: Side view of the front-mounted flamer

Fig. 4: Double boom intra-row flamer at work

At the end of the season the fronds turn yellowish and the plants dry out. At this stage the foliage must be cut at ground level. The residues are shredded mechanically and either left on the ground or otherwise burned in the field

To improve the combustion of crop residues, in this time of season when field moisture levels are generally high, the *broadcast flaming machine* (model

PTR-C) can be used to promote the ignition of previously shredded fern residues (Figure 5). The treatment speed is fast and the gas pressure is high (6 km/h speed, 1.4 bar) to produce the powerful flames needed to dry out and burn the debris.

A recent innovation was designed for the end-of-season treatment. It is a tractor-mounted *combined machine* (model PTR-K), having a front shredding unit coupled with a rear broadcast flaming unit (Figure 6). The two operations, shredding and flaming, are carried out in a single-step, thus reducing field passes and work time (3 km $h^{-1}$ speed, 1.0 bar gas pressure). The flail shredder carries standard "Y" shaped flails, total cutting width is 1.4 m across and power requirement is 26-30 kW. The heating unit is directly connected behind the flail shredder. The combustion chamber is closed above by an insulated stainless steel hood. The flames are fired by an array of 8 burners, evenly spaced across on a single row manifold. The temperature under the chamber is constantly held above 650 °C (Tomasone et al., 2015b).

Fig. 5: Flaming to promote fern combustion

Fig. 6: Single-step shredding and flaming ofern

## RESULTS AND DISCUSSION

The flaming machines have been tested in the field trials and suitable operative parameters have been identified for applying the heat treatment in the different growing phases. The rate of application of lpg, i.e. The kilograms of gas per hectare, was the main parameter considered. Lpg application rate was obtained by adjusting the tractor's forward speed and the pressure of the gas flow. The appropriate work parameters identified in the tests are shown in table 1 for the different machines and for the treatments made in the different growing phases.

Broadcast flaming can be used in spring before the spears emerge to effectively control early-germinating weeds at an early phase and reduce early-season weed competition. One or more pre-emergence heat treatments can assure a weed-free bed from the beginning (diver, 2002). Flaming can be applied regardless of wet soil conditions, common in spring, and without further soil disturbance that would bring new weed seeds to the surface.

Effective control of weeds is achieved in the harvest phase by applying multiple broadcast flame treatments over the whole surface of the asparagus bed.

The time of exposure to the flames, of the emerging spears, must be kept to a minimum to avoid damage to the partially emerged spears. Appropriate timing is critical for control during the harvest period, subsequent passes are repeated at different time intervals, depending on weed pressure throughout the season. The appropriate work parameters (gas rate, treatment speed, gas pressure, gas consumption) for broadcast flaming (model ptr-c) are shown in table1.

Table 1. Flaming machines used in the different crop phases and appropriate operative parameters

| Machine type: | Model | Phase of the crop cycle: | LPG pressure | nozzle diameter | LPG consumption per burner | Number of burners installed | Machine total LPG consumption | Work width | Treatment Speed | Work capacity | Rate of LPG application |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (bar) | mm | (kg/h) | N° | (kg/h) | cm | (km/h) | (h/ha) * | (kg/ha) |
| Compact broadcast flaming machine | PTR-C | Harvest period | 0.8 | 1.2 | 1.62 | 15 | 24.3 | 160 | 5 | 0.91 | 22.1 |
| Intra-row flaming on ferns | PFV-D | Fern vegetation | 1.2 | 1.2 | 2.10 | 16 | 33.6 | 140 | 4 | 1.14 | 38.2 |
| Compact broadcast flaming machine | PTR-C | End of season | 1.4 | 1.2 | 2.35 | 15 | 35.3 | 160 | 6 | 0.76 | 26.7 |
| Combined shredding and flaming machine | PTR-K | End of season | 1.0 | 1.8 | 4.22 | 8 | 33.8 | 160 | 3 | 1.52 | 51.2 |

* Data calculated for a field having a distance between rows of 2.2 m (inter-row spacing)

*Intra-row flaming* applied in the fern phase has shown to selectively eliminate weeds and prevent seed dispersal. The compact front-mounted flaming machine safely moves through the narrow aisles. The laminar air flow provides a barrier against the heat and protects the fronds. After the ferns have put on sufficient vegetative growth, their stems become resistant to heat and the plants can easily withstand repeated treatments. Optimal speed, LPG pressure and LPG dosage rate for model PFV-D are shown in table 1.

At the end of the growing cycle, the use of the *broadcast flaming machine* promotes the ignition of the shredded residues, improving the complete combustion of crop debris. Optimal parameters for model PTR-C are also shown in table 1. Furthermore the combined machine, model PTR-K, can be conveniently used at the end of the season. The combination, in a single pass, of fern shredding and residue burning improves the combustion of residues because

they are delivered directly into the flames. The residues flow through the heat chamber and ignite before they drop to the ground. The combined treatment streamlines the organization of field work, allowing a timely clean-up of the field while reducing inoculum pressure. Flaming of residues has shown some efficacy towards phytosanitary issues (Tomasone et al. 2015b). Leaving the residues in the field increases disease inoculum, affecting in particular foliar diseases of asparagus, such as rust and purple spot (Hausbeck et al. 2008; Johnson 1990). Plant debris can also harbor insect pests such as eggs of the asparagus aphid (Folwell et al. 1990). Optimal treatment parameters for model PTR-K are indicated in table 1.

## CONCLUSIONS

The broadcast flaming machine is conveniently used for selective weeding of the asparagus bed throughout the harvest period. No treatment residues are produced by the flame treatment and therefore no interruption of harvest operations is required. In the fern phase the heat treatment can be effectively applied for selective in-row flaming. The flames blow through the relatively heat-tolerant asparagus stems, selectively killing the weeds.

This physical method is a significant tool for in-row weed control, available for organic farmers as a non-chemical option. Broadcast flaming used at the end of the crop cycle improves the ignition and combustion of fern residues, but it requires a two-step process (shredding first). The combined machine is a further innovation that reduces work time and field traffic. In both cases the intense heat provided by flaming, in addition to the heat developed by the burning biomass, drastically improves the destruction of field inoculum and weed seeds laying on the soil's surface. To date, many specialized asparagus farms, in Italy and abroad, are currently using the machines and the methods described. In general 'flaming' is considered a low environmental impact technology, since it avoids the use of chemical herbicides in agriculture. Flaming is a technology that may be used both in conventional and organic farming because LPG gas is allowed by the specific regulations of these production systems.

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