WEED CONTROL METHODS FOR ORGANIC VEGETABLE CROPS

Abstract: Organic vegetable crops are part of niche crops that can provide farmers with high incomes. Controlling weeds in these crops is an extremely important work, constituting today a real challenge for vegetable growers because only non-chemical methods are accepted in the organic farming system for plant protection. Physical weed control is mostly used, which is based on the application of several techniques, the most used being mechanical and thermal control. The paper shows a short synthesis of current non-chemical methods and technical devices used in integrated weed management in organic vegetable crops.

Keywords: plant protection, non-chemical weeds control, integrated management of weeds, thermal control, mechanical control

INTRODUCTION

The organic farming system must be seen as an integral part of sustainable development strategies and as a viable alternative to conventional farming, as it can provide, in particular: less contaminated air, water and agrifood products, safe working conditions for farmers, biodiversity preservation, fertile and healthy soil, nutritional quality of organic products, food security, environmental protection, reduced use of non-renewable resources, economic benefits (Brumă, 2019). With regard to organic farming, Romania is ranked 7th in the top led by Poland, of the 23 Eastern European countries analyzed by FIBL Switzerland. On the other hand, in recent years Poland and Romania registered a decline in certified surfaces ecologically (Mediafax 2018).

The so-called minor crops produce over € 60 billion a year, which represents more than 20% of the EU’s total agricultural output (Pannacci et al., 2017). These include fruit and vegetable crops, plus seed, spice, medicinal and aromatic plant crops. Among these niche crops, organic vegetable crops are also found. According to some authors, the physical combating methods for plant protection fall into two basic types: active and passive. Active methods consist of using a certain form of energy for destroying, injuring, inducing stress in crop pests or eliminating them from the environment, having immediate effect during application. Passive methods, on the other hand, cause changes in the environment and have a more sustainable effect. Depending on the energy used, the physical methods are classified as: mechanical control, thermal control, electromagnetic control, pneumatic control, etc. In the case of weed control in organic crops, they include: manual weeding, hand pulling, mowing, thermal and mechanical methods (Panneton et al., 2007).

Also, in organic agriculture, weed control is achieved by applying certain measures/practices which, depending on the moment and the manner of application, can be preventive and curative (Roman et al., 2008). Preventive practices are necessary for long-term effective management of weeds (Gabe et al., 2014), preventing them from emerging and multiplying. They consist of: crop rotation, application of fertilizers, use of competitive species and varieties, germination bed preparation methods, irrigation/drainage systems, as well as the harvesting method (Walsh et al., 2013).

The curative methods keep under control the weeds already in the crop, using mechanical and thermal weed control equipment, which constitute the traditional non-chemical physical means for organic crops (Shaner and Beckie 2014). Thermal combat is achieved through heat transfer from the specific equipment to weeds, by foliar contact, aiming at the destruction of their vital parts after a short period of time (Nadzeikienė et al., 2009). In order to be effective, heat treatments should lead to an increase of the internal temperature in weeds, between 55 °C and 70 °C, for a period of approx. 0.1 s. Therefore, the amount of heat transferred between the thermal control equipment and the target organism, as well as the duration of exposure to the treatment are important parameters (Ascard et al. 2007). The effectiveness of the treatments also depends on the stage of weed development, the young ones being much easier to destroy. Heat exposure determines the expansion of intracellular water, followed by cell membrane rupture, the primary effect being plant drying together with other chemical decompositions (Peerzeda & Chauhan 2018).

Over the past few years, concerns about the worldwide growth of weed populations resistant to herbicides, the low availability of active ingredients for minor crops (vegetables), the multiplication and development of organic farms have stimulated the development of new non-chemical weed control methods (Harker & O’Donovan, 2013). In this brief analysis, it is not possible to address the many aspects of weed management, so the focus will be on new developments in non-chemical (mechanical/thermal) and intelligent weed control technologies, especially in vegetable crops.

MATERIAL AND METHOD

Soil heating is a promising, preventative ecological method for controlling weeds in niche crops that bring high incomes, such as vegetables and flowers. Ecostar SC 600 self-propelled machine (Celli Spa) (Figure 1) is used for disinfecting the soil with steam and zeolite type (potassium hydroxide and carbon oxide) ecological substances, using the Bioflash system (Figure 2). The machine is destined to be used in greenhouses, solariums and on the field, being equipped with
rubber tracks for improving manoeuvrability and reducing soil compaction. It is fitted with horizontally placed steam generator, for reducing height. The disinfection section placed in the back can be displaced transversally, giving the possibility to conduct the treatment in the inferior and lateral parts of a tunnel greenhouse. The speed of a rotary cutter is of 40-60 rot min⁻¹. The machine is fitted with an automated and ergonomic command and control system, with a biaxial joystick controlling the movement and the speed. Due to the hydrostatic transmission, a continuous range of speeds between 60-6000 m h⁻¹.

The remote-control system allows driving without the operator on board. During the experiments, all the main components of the self-propelled machine (the rolling system, the rotary cutter hydraulic motors and the exothermic compound distribution system) were controlled electronically by a control card and its related software. (Peruzzi et al., 2011).

The technical characteristics of the machine are presented in table 1. (Celoo, Peruzzi et a., 2011).

The Ecostar SC600 machine (Figure 3) was tested using several types of steam injection bars to obtain different steam and heat distribution in the soil. Thus, it was equipped with: standard bar for Bioflash systems, which injected steam at a 200 mm depth; double bar, designed to have a more uniform distribution of steam in the treated soil and to reach deeper layers; carter bar, for surface treatments. During the experiments, a mix of the standard bar and the carter bar was used, with different ratios of steam distribution between the surface and the deep area. During the steam treatment, exothermic substances (CaO and KOH), applied in different doses (0, 1000, 2000, 4000 kg ha⁻¹) were tested with or without plastic film mulching (Peruzzi et al., 2011).

Table 1. Technical characteristics of Ecostar 600

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Measurement unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment type</td>
<td>-</td>
<td>Self-propelled</td>
</tr>
<tr>
<td>Power source</td>
<td>-</td>
<td>Thermal engine</td>
</tr>
<tr>
<td>Engine power</td>
<td>kW</td>
<td>44</td>
</tr>
<tr>
<td>Cubic capacity</td>
<td>cm³</td>
<td>2068</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>kg h⁻¹</td>
<td>11</td>
</tr>
<tr>
<td>Running system</td>
<td>-</td>
<td>Rubber tracks</td>
</tr>
<tr>
<td>Sleight dimensions (length x width x height)</td>
<td>m</td>
<td>1.9x0.32x0.52</td>
</tr>
<tr>
<td>Transmission type</td>
<td>-</td>
<td>Hidraulica</td>
</tr>
<tr>
<td>Speed</td>
<td>m h⁻¹</td>
<td>60-6000</td>
</tr>
<tr>
<td>Exothermal substances bunker capacity</td>
<td>m³</td>
<td>0.23</td>
</tr>
<tr>
<td>Water tank capacity</td>
<td>m³</td>
<td>0.6</td>
</tr>
<tr>
<td>Steam generator type</td>
<td>-</td>
<td>Electric</td>
</tr>
<tr>
<td>Electric motor power</td>
<td>kW</td>
<td>25</td>
</tr>
<tr>
<td>Steam flowrate</td>
<td>kg h⁻¹</td>
<td>600</td>
</tr>
<tr>
<td>Steam pressure</td>
<td>MPa</td>
<td>1.18</td>
</tr>
<tr>
<td>Working width</td>
<td>m</td>
<td>1.6</td>
</tr>
<tr>
<td>Overall dimensions (length x width x height)</td>
<td>m</td>
<td>3.8 x 1.6 x 1.5</td>
</tr>
<tr>
<td>Equipment weight</td>
<td>kg</td>
<td>3000</td>
</tr>
</tbody>
</table>

Following the experiments, soil temperature was measured using a dedicated system. The measured temperatures were divided into four “Classes” (T<40 °C; 40 °C < T < 60 °C; 60 °C < T < 80 °C; T > 80 °C). The amount of time each class persisted in the soil was recorded, along with the highest, average and final temperature (after 3 hours), in order to compare the effects of different treatments. A parameter - thermal addition (ΣT) was calculated as the sum of individual temperatures (measured every minute) for 3 hours after the treatment, including the temperature levels, duration and length of heating (Peruzzi et al., 2011).

The machine was also used to test the effect of five different systems of steam injection (surface or deep steam injection bar and three mixed systems at different steam distribution ratios between the surface and the deep bar: 1:2, 1:1 and 2:1) on an artificial infestation of Brassica juncea and on the natural weed seedbank. Treatments were performed using only steam or in combination with exothermic substances (CaO, KOH) applied at doses of 1000 and 4000 kg ha⁻¹ (Peruzzi et al., 2012).

In order to evaluate both weed control and crop yield after applying different doses of steam in the soil strips together with exothermic substances, a prototype machine (Figure 4) using the Bioflash...
A system (Figure 2) was built, for applying strips. The machine, being towed, operated in aggregate with a 135 HP tractor, from which the hydraulic system and the electric generator were actuated. It was made of a two-wheeled pneumatic chassis that supports: the steam generation system, the steam application system and an exothermic compound (Bioflash system), the electrical system and the hydraulic system. The machine was coupled to the tractor via a drawbar. The application system for steam and exothermic compound was obtained by modifying a rotary cultivator with 12 units. Each unit acted on a width of 0.18m, being covered by a carter, on which the steam injection bar was placed.

The rotary cultivator (with 30-60 rpm min⁻¹ speeds) was divided into three parts, each equipped with four units and a hopper for the exothermic compound. Each hopper was equipped with an adjustable metering unit, a measuring device and the four exhaust tubes, the system being driven by an electric motor. The steam obtained with a fast generator (Diesel type) was applied in 12 strips of 0.18 m, with 4 units grouped for each of the three ridges of 1.28 m width, resulting in a total working width of 4.58 m. In one day after using the machine, it was sown in the middle of the steam-treated strips. The tests were conducted in a carrot crop, organically grown under real field conditions, in order to study the effect of different doses of steam on the crop and on a natural weed seed bank over the entire growth cycle (Raffaelli et al., 2016).

Table 2. Water characteristics

<table>
<thead>
<tr>
<th>Thermal agent</th>
<th>Specific heat (kJ/kgK)</th>
<th>Thermal conductivity (W/m K)</th>
<th>Energy density (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot air</td>
<td>1.01</td>
<td>0.03</td>
<td>101</td>
</tr>
<tr>
<td>Hot water</td>
<td>4.18</td>
<td>0.682</td>
<td>418</td>
</tr>
<tr>
<td>Steam</td>
<td>2.08</td>
<td>0.025</td>
<td>2675</td>
</tr>
</tbody>
</table>

The main technical characteristics of the XL140 (Heatweed Technologies AB) destined for large surfaces (figure 5) are: 1.4 m working width; 34 l/min water consumption; 98-99.6 °C water temperature; 0.5-2.5 km/h working speed (depending on degree of weeding); 2 Diesel / BioDiesel burners; hydraulic transmission, 7x20cm application system with independent sections, 800 l tank volume, burner tank volume 105 l.

Because weeds and crop plants have similar biometric data, there is a problem of crop protection. Thus, the Hydra-Boom (Weedtechnics) system employs two heads of application of the Rowtech 55 (Weedtechnics) saturated steam and hot water mixture for organic horticultural farms. These conical heads follow the shape of the jet, retain the heat and protect the crops. Their main technical characteristics are: diameter 0.55 m, height 0.23 m, flow rate 4-19 l/min, weight 3.5 kg. The Hydra-Boom system is mounted in front of the tractor, with the position of the Rowtech 55 applicators being hydraulically controlled from the cabin. They also have the ability to easily follow the field (Figure 6).
Fobro Hoe Brush equipment (Figure 7) consist of rotating brush units to which the fixed ones are added (Figure 8). The hairs of the brushes are made of durable and flexible materials that allow action near crops, protected by tunnels. The brushes do not move or scratch the ground like other devices, and the weeds dry quickly because the flexible wires pull them out of the root and affect the protective layer.

In general, mechanical methods for weed control between rows in vegetable crops are based on traditional spring harrows and cultivators, but new devices such as finger-weeders, torsion-weeders and intelligent weeders have emerged. (Peruzzi et al., 2017)
occurs (Figure 10), even at the lowest treatment frequency (Heatweed Technologies).

**Figure 9** – Soil temperature variation in strips depending on the time and steam dose applied (Raffaelli et al. 2016)

**Figure 10** – Weed density variation depending on the treatment applied (Heatweed Technologies)

Using the innovative chassis, for the same experimental conditions (working speed, pressure, application height), the results obtained in combating weeds using superheated steamed were superior to those obtained combating using wet steam. They were expressed through several indices, the most important of which was the weed extermination rate and their chlorophyll content, determined by 2 and 3 days of treatment, as well as by weed regrowth determined after 1, 2, 3 weeks after treatment. (El-Sayed & El-Hameed 2017).

In general, for niche organic crops, treatments with traditional hoe with rigid shanks or brush-weeder for inter-row weed control, combined with finger-weeder for intrarow weed control, seems to be the better weed control strategy. For this type of crops obtained by sowing, characterized by small distances between the rows, is recommended to use high precision cultivators. Robocrop rotating cultivator was in general more effective than the standard cultivator, concerning weed density as well as times consumed for removing weeds between the plants on the row, which is executed manually. It behaved well in the transplanted crops, especially in salad crop, where plants were bigger than weeds. In crop sowed using Robocrop achieved a thinning of 22-28%, compared with manual thinning and standard hoeing, therefore yield and net profits were lower.

**CONCLUSIONS**

In non-chemical weed management in organic vegetable crops, physical and mechanical weed control plays a fundamental role. The type of machine that can be used for this depends on the plant type, the cultivation technology, the size of weeds and the type of soil. For these methods of weed control, the development and adoption of efficient precision farming technologies can be a solution. Intelligent camera-based systems, capable of guiding mechanical and/or thermal devices contribute to increasing the working width and speed, which implies financial benefits.

The protection of vegetable plants against thermal destruction represents an important and seldom crucial factor in the technological process of chemical weed control, therefore different techniques need to be created and adapted, adequate for each type of crop. The study and development of weed control using hot water in organic vegetable crops, combined with mechanical ones, in one pass, could constitute an important premise for achieving efficient equipment.

The preventive and curative control methods adopted, together with low tech, low cost or intelligent equipment, should be used within an integrated weed and pest control system in organic vegetable crops, in order to achieve an efficient weed management.

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**Note:**

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