# MACHINES AND IMPLEMENTS FOR NON-CHEMICAL WEED CONTROL IN ORGANIC VEGETABLE GROWING

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***Abstract:*** *Organic agriculture finally renounces the use of herbicides. Taking into account the positive qualities of weeds, the aim is not to their complete elimination, but to reduce the available quantity, which is not harmful to yields. With these prerequisites weed control on the non-chemical way is becoming more important as a major place occupied the variety of crop rotation and other indirect ways to control the weeds. For their regulation by a non-chemical route in practice farmers use appropriate machines and devices and therefore pay particular attention to the mechanical implements, automatic systems and thermal control of weeds. In organic farms for vegetables use also cultivators with automatic diverting knives and cultivators with automatic rotating knives, controlled by video cameras and sensors. Robotic machines for weed control have also been developed in recent years, controlled by GPS agricultural navigation.*

**Keywords**: WEED CONTROL, ORGANIC, CULTIVATION, FLAMING, AUTOMATIC.

## *1. Introduction*

Weed control in organic farming is direct and indirect.

**Indirect control** is an obligatory component of the weed control practices. The practices included in it can be divided into two groups: 1) Protective practices - these are those activities that prevent the entry of new weed seeds or weed reproduction organs into the arable land; 2) Practices to ensure the fast and proper development of crop plants so they can suppress weeds themselves.

Protective practices are the basis of rational weed control. If we do not apply them, it is more difficult and expensive to exterminate the weeds. Some practices are: the use of pure seeds of the main culture - without weed seeds; timely and correct harvesting of the culture; timely weed control in uncultivated areas and the roads, in irrigation and drainage channels; fertilizing with pure manure (without weed seeds), stored in an appropriate manner through the regulation of aerobic and anaerobic processes to complete destruction of viable weed seeds.

It is need first be placed practices supporting crops in their competition with weeds, providing fast and jointly germination of crops, which requires primarily high-quality seeds, providing a uniform crop with optimal density, proper fertilization, timely care in vegetation, proper crop rotation [Карoв, 1999].

**The direct weed control** is down to exterminate of the emerging weeds, weed seeds in the soil and weed propagation organs. It is performed with various physical-mechanical and biological processes and methods.

**Physical-mechanical weed control**

In physical and mechanical practices to control weeds most widely used and of most practical importance is soil tillage – ploughing and cultivation [Walter, 1995]. The soil tillage of vegetable crops includes several practices - ploughing, additional surface tillages after ploughing (before sowing or planting), surface tillages during the crop growing, depending on the species composition of weeds and weather conditions during the season.

The aim of the work is to make a review of machinery and equipment in the present stage of weed control in the cultivation of vegetables in organic farms.

## *2. Weed Control During the Growing Season of Vegetables*

**Manual hoeing** is carried out with a variety of tools such as hoe and variations of the hoe, hand cultivators with knife-bracket, hand cultivators with support wheel (wheel hoe) etc. (Figure 1).

***Fig. 1.*** *Different tools for hand hoeing.*

On small areas and sufficient manpower can be applied **weeding by hand.** It is very difficult work -associated with an unnatural position of the body of the worker, which leads to rapid fatigue and pains in joints and muscles. To avoid these negative consequences **tractor mounted platforms** have been developed, hung on the linkage of the tractor.

They have from 6 to 12 working stations where workers lie on their stomach, their arms are hanging down to the rows of plants so that they can touch the ground and pull the weeds (Figure 2). The angles of inclination of the panels comply with ergonomic requirements for the convenience of the body of the worker. Tractor moving at low speed and at every workplace is set to alarm button that can be used by the worker to alert tractor driver to stop briefly when a greater density of weeds are in the row.

***Fig. 2.*** *Tractor platform for manual weeding.*

The mechanical control of weeds during vegetation is carried out by cultivation. It is very important that the first tillage is done in time because the crop plants are very sensitive and easily damaged by cultivator working bodies. When we delay with tilling and the weeds suppress the crop plants, it is necessary to carry out a manual labour after the cultivator. It takes a lot of work and time.

**Cultivators for mechanical weeding**

**Cultivator for row cultivation.** These types of cultivators are used for tillage the soil and for killing the weeds between the rows of the crops [Walter, 1995]. The unprocessed area on the left and right of the row is called the protection zone (designation “c” in fig. 3). Tillage between the rows of crops (row cultivation) is carried out at a depth of 4 to 10 cm depending on the type of cultivator, type of soil, number of weeds per unit area and others.

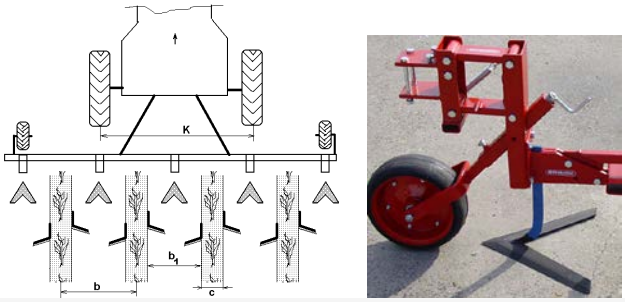


***Fig. 3.*** *Scheme of the cultivator for row cultivation and working section: c - protection zone; b – spacing between the rows; $b_1$ – processed area; k - distance between the wheels of the tractor.*

The work bodies are located in the sections in such a way as to provide a suitable "c" protection zone (Figure 3). It must be wide enough to preserve the stems, leaves and roots of the crop plants. It is usually from 8 cm to 20 cm depending on the crop and the degree of plant growth.

When working at high speeds or in low-growing crops, these cultivators are provided with protective devices in the form of shields, discs or other. The aim is not to put soil over the crop plants. In this type of cultivators the ways of reducing the protection zone are as follows: use of cultivators with a steering wheel and an auxiliary worker seat; use of front linkage cultivators; use of cultivators on self-propelled chassis tractors; use of cultivators with electronic sensors and video cameras.

***Fig. 4.*** *Self-propelled chassis with mounted cultivator for tillage of carrots.*

***Fig. 5.*** *Cultivator for hoeing with rotating teeth bodies with passive action.*

**Combined cultivators for inter-row and intra-row soil tilling.** Several companies, which produce agricultural machinery, offer additional work organs to traditional row crop cultivators. These organs enter into the protection zone and tilling the soil around crop plants without damaging them.

An example of this is the developed cultivator with rotation fingers and passive action. The fingers are made of flexible material (plastic or rubber), placed on a metal disc (Fig. 5). The disc is attached to the axle with bearings. On the disc are also mounted metal fingers, bent to the soil, which ensures the rotation of the working organ and the loosening of the soil near the crop plants [Янчева, 2003].

**Cultivators with rotating working bodies with active action.** In organic farms weed control in vegetable crops, which is grown on a high flatbed, is complicated by the fact that the inter-row distances are small and the use of ordinary cultivators is limited. Therefore, in most cases, manual weeding and soil tilt with hand tools is applied. These practices are low-productive and require more human resources.

Another way of weed control in these crops is the use of cultivators with active working organs. For the accurate driving of the aggregate in the narrow rows, it is required to use another operator (except the tractor driver) that guides the work organs so that they do not damage the crop plants. This group of machines includes rotating soil-cultivating tillers and brush cultivators.

Rotary brush cultivator with a horizontal axis. It is mainly intended for the mechanized growing of vegetables such as carrots, red beets, leeks, onions [Fogerlberg, 1991]. It is composed of brush rollers (Figure 6) with a diameter of 50-60 cm driven by one shaft. The drums tilling the soil between the rows. They are made from a base 1 on which plastic fibers 2 with a diameter of 5-6 mm are fastened, with high stiffness and strength, forming a cylindrical brush.

The drive shaft is connected to the PTO of the tractor through a transmission, gearbox and chain drive The machine is equipped with an operator seat, handlebar, steering wheels, tunnel type 3 safety panels (Figure 6), which keep crop plants from not being covered with soil. Behind the drums is placed 2-3 mm thick plastic brush that acts as a reflector for the discarded soil.

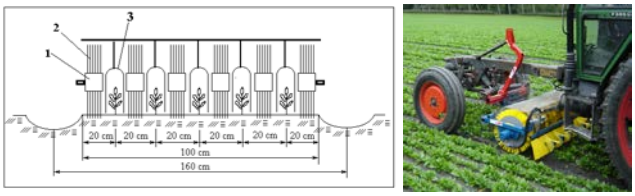


***Fig. 6.*** *Brush cultivator (rear view): 1 - drum base, 2 - plastic fibers, 3 - protective tunnel.*

Cultivators are hinged and allow joining from the front, rear or between the front and rear wheels of the tractor (as with the self-propelled chassis - Figure 6).

Safety tunnels allow size adjustment depending on crop plants. The brushes process the soil at a depth of 2 to 5 cm and direct the weeds together with the roots to a reflective curtain. As a result of the stroke, the soil is separated from the roots and the weeds remain on the surface of the field where they die for several hours in dry weather because they are mechanically deformed by the brushes.

The working speed of the cultivator is 3-4 km/h and its structural width may be 1.5 to 3.5 m. Apart from brush cultivators with a horizontal axis of rotation, they are also available with a vertical axis of rotation. Brush rotors can be rigidly positioned or displaced side by side by an operator or by an automatic device.

The main advantages of the brush cultivator before conventional cultivators are: a more efficient inter-row processing in the early stages of development of crop plants when they do not tolerate side-pressure; work in smaller protection zones due to safety tunnels of adjustable size and position in relation to crop plants; application to increased soil moisture due to its self-cleaning effect; low probability of clogging with plant mass; more efficient work on stony soils.

Disadvantages of the brush cultivator are: clogging of protective tunnels with stones, relatively low productivity and high cost are reported. But this machine is becoming one of the most promising machines for mechanical weed control in organic farming.

**Cultivator with rotary bodies with spring metal fingers.** It consists of rotors with axes, parallel to the processed row (Figure 7). They consist of shafts fitted with metal discs and steel springs with a body diameter of 5-6 mm. When the machine is moved forward, the tractor rotates the rotors. The height of the thumbs is adjusted so that they loosen the soil to a depth of 2-3 cm in the interior space and destroy the weeds, while not damaging the crop plants. The machine is particularly suited for crops such as garlic and onions that are already well grown up and cannot be affected by partial strokes on the stems and leaves from the metal springs.

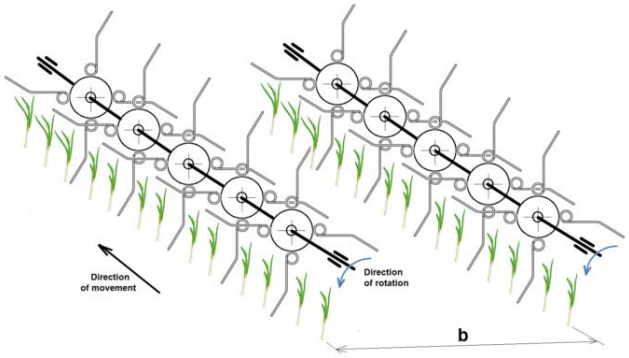


***Fig. 7.*** *Scheme of working organs of a cultivator with rotating bodies with spring metal fingers.*

**Cultivator with automatic diverting knives.** Its operating organs are straight metal knives that are controlled by steel arms connected to hydraulic power cylinders or electromagnets. The blades work within the protection zone, at 3-4 cm deep in the soil. Sensitive devices (video cameras, sensors) irradiate the row of crop plants (Figure 8) and send the signals to the executive device that controls the knives. In this way, they surround the crops and re-entered the row again - the unprocessed areas around the plants are reduced to very low values [7].

***Fig. 8.*** *Cultivator with automatic diverting knives.*

**Cultivator with automatic rotating knives.** Its working organs are arched metal knives of a specific shape (in a difference of the previous cultivator), they are placed on shafts in order to make a rotating movement (Figure 9). The shafts are driven by gearboxes and hydraulic motors (in some models - from electric motors). The blades work within the protection zone, rotating flat, deep to 3-5 cm in the soil. Sensitive devices (video cameras, sensors) irradiate the row of crop plants and send signals to the executive device that controls the rotation of the knives. In this way, they surround the crop plants and process the entire interior space - the unprocessed areas around the plants are of negligible size [8].

Robot analyses images of the crop immediately in front of the weeder. Applying a predetermined grid and best fit logical deduction techniques individual plants are pinpointed and tracked through the image. The weeding rotors are then synchronized to work around each individual plant, the rotor speed being continually adjusted to take into account plant spacing variations. The InRow rotors are then followed up by a set of inter-row cultivation units to complete the all-round cultivation process. Performance is 2 plants per second per row.

***Fig. 9.*** *Cultivator with automatic rotating knives.*

**Robotic machines for weed control**

Such types of machines have also been developed in recent years, controlled by GPS agricultural navigation (Figure 10). In the research project the firm AMAZONE together with BOSCH and the Osnabrück University, work on the mechanical secondary vegetation management in biological carrot cultivation with emphasis on the system integration of robots into ecological farming. For this the robot is equipped with an actuator for weed control.

The target is that the robot, thanks to its complex picture processing – initially with help from a man as "picture processors at the telework station" and later on also alone – will recognize the difference between the useful plants and weeds by “eye”. Here the field robot has to work under the influence of many disruptive factors and under variable conditions.

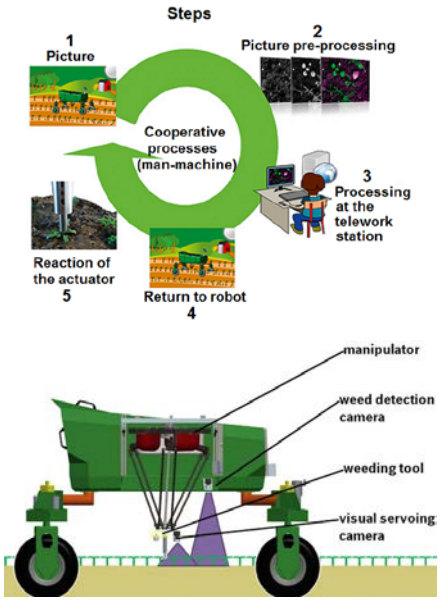


***Fig. 10.*** *Web-based robot assisted secondary vegetation control.*

**Physical ways to kill weeds** such as mulching and burning (thermal treatment) are also applied. As a means of weed control, mulching is used to completely prevent light access to weed plants from which they stop to grow and die. It has an effect mainly against the young weed plants. Thermal treatment is applied to heat the weeds with an open or closed flame to make coagulation of the proteins and gradual dying [Трифонов, 2000].

**Thermal treatment of weeds.** A relatively new approach in organic farming is the use of differences in the thermal resistance of crop plants and weeds depending on their developmental phases.

**Effect of flame on weeds.** Weeds are harmed by the heat influx created by open flame machines or infrared emitters. This technique heats the weeds to a temperature of 90-100° C for a duration of 0,5-1,0 seconds, in which they do not burn but die for two reasons - dehydration due to cell expansion and cracking and irreversible changes in the protein in temperatures above 50-60° C.

The weed plant perishes after 3 to 7 days. To achieve an effective thermal action on weeds, it is recommended that the working temperature of the flaming technique is above 940-1000° C. This type of cultivator is good to be used in sunny and dry weather.

Both ways of thermal treatment have led to two varieties of thermal cultivators – with open flame and infrared burners. Flame cultivators are with burners operating with gaseous or liquid propane fraction (Figure 11). Depending on how they move around the field, they are hauled on a tractor, hand-moved and portable on the back, which determines their overall device [Ascard, 1992].

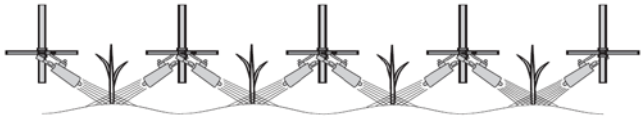

***Fig. 11.*** *Scheme of working organs of a flame cultivator for work in a culture that has already emerged.*

Thermal cultivators offer a variety of application options, some of which are validated by practice, others are under test. The main ways of using these cultivators are:

a) Pre-emergence thermal treatment of the main crop - this technological operation is widely used in organic farming for the cultivation of carrots, red beets and others. Cultivated plants are thermally treated in the immediate post-emergence rows, and post-emergence mechanical treatment is recommended. Determination of germination time is critical to the effect of heat treatment. In order to determine the exact moment, the germination of several plants is accelerated by covering a part of the row with glass.

b) Post-emergence thermal treatment of the main crop - inter-row treatment is applied when the crop has reached certain sizes. At work, it is recommended to use protective devices to protect crop plants from heat. In some crops, it is necessary to use the devices for lifting their leaves to treat the row spacing.

Thermal treatment is a risky operation and therefore requires a precise estimation of the factors influencing the effect of its application, namely: the type of weeds; species of crop plants; soil condition; heat treatment time.

**Technical parameters of the heat cultivators**

Research on the work of thermal cultivators has shown that their work depends on many technical factors: temperature and duration of action of the flame; contact area of the flame with the plant; distance and slope of the burner to the soil; position of the burner relative to the treated plants; soil and climatic parameters.

The treatment of the plant is most effective when the flame has a formed core, the weeds are covered by the outer third of the flame, the angle of attack is 30 to $40^0$ with an inclined forward burner, its height from the soil surface is 0,12 to 0,15 m and varies with gas pressure.

The operating speed determines the duration of the temperature impact and the performance of these machines. For open flame cultivators the speed is from 3 to 4 km/h, and for infrared units the speed is 1 to 2 km/h, but they have lower gas consumption per unit of treatment.

I present my construction of a hand-operated flame cultivator PLAM-1L for weeding (Figure 12). This cultivator uses gas propane-butane and is developed at the request of the Demonstration Organic Farm at the Agroecological Center of the Agricultural University of Plovdiv. The cultivator is used successfully for 5 years in the cultivation of 1 ha of onion from seeds and 1 ha of carrots without the use of herbicides, combined with a brush cultivator [Трифонов, 2000].

***Fig. 12.*** *A 3-wheeled gas-flame cultivator PLAM-1L for hand-moving*

This flame cultivator is manually moved by two workers over one bed. Its traction system is made of two light bicycle wheels and one small front wheel for copying the terrain and maintaining a constant height of the burners.

The cultivator is equipped with two parallel connected bottles 1 (Figure 13) for propane gas. The nozzles 2 are specially adapted to provide a greater flow of gas to the burners. Pipeline 3 is made of a gas-resistant rubber hose. Crank 5 provides an "Idle - workflow" operation of the burners - the switching is done when performing maneuvers at the end of the field.

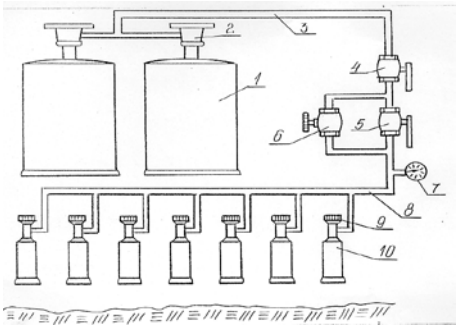


*Fig. 13. Principal scheme of the flame cultivator PLAM-1L: 1 - propane gas cylinders; 2 - nozzle; 3 - main pipeline; 4 - central shut-off valve; 5 - "idle - workflow" valve; 6 - throttle flow controller; 7 - pressure gauge; 8 - distributor; 9 - a flame control valve for a flame force in a running position; 10 - gas burner.*

An experiments have been carried out with this cultivator on the field of the Demonstration Farm for organic farming at the Agroecological Center of the Agricultural University of Plovdiv with pre-emergence carrots and with onion from seeds once before germination and again immediately after germination.

When re-treating the onion, its tips are burned, but it has an inner leaf-growth area and restores quickly. The cultivator is set in the mode of operation according to Table 1.

The predominant weeds were amaranthus retroflexus, atriplex hortensis and setaria viridis. It has been found that good results are obtained at a gas pressure of 0,2 MPa and at a speed of 4 km/h.

***Table 1****: Plam-1L Cultivator Operation Mode*

| | |
|---|---|
| Movement speed | 3 - 4 km/h |
| Working width | one bed with a width of 1 m |
| Burner height | 10 - 12 cm |
| Angle of the burners to the soil | $50^0$ - $90^0$ |
| Gas pressure | 0,15 - 0,20 MPa (1,5 - 2,0 bar) |
| Productivity | 0,3 – 0,4 ha/h |
| Gas consumption per hour | 7 kg/h |
| Gas consumption per hectare | 20-30 kg/ha |

The results of the work of the flame cultivator are encouraging and give reason to believe that this is a good working machine for successful non-chemical weed control on organic production farms.

## *Conclusion*

Weed control machines and implements for the organic growing of crops are presented such as: ordinary cultivators for row crops, cultivators with passively rotating working bodies, cultivators with actively rotating operating organs for working in the protection zone, brush cultivators, flame cultivators and cultivators with automatic action. Different kinds of cultivators are presented and the conditions under which they must work to ensure a high

quality of the agricultural operation for minimal damage to the crop plants and make recommendations for obtaining better treatment.

In organic farms for vegetables cultivators with automatic diverting knives and cultivators with automatic rotating knives are used, controlled by video cameras and sensors. Robotic machines for weed control have also been developed in recent years, controlled by GPS agricultural navigation.

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