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Thermal weed control in strawberry

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Abstract. Weed control with herbicides is impossible in perennial organic agricultural systems. Alternatively, in these systems, weeds can be destroyed mechanically, thermally or by mulching with a plastic film, to minimize negative weed influence, but not to exterminate all of them. Thermal weed control requires knowledge of the plants' thermal sensitivity. The most common weeds growing between strawberry rows in Lithuania are shepherd's purse (Capsella bursa), common groundsel (Senecio vulgaris L.) and common chick-weed (Stellaria media). We have been researching thermal sensitivity of these weeds. Research has shown the results of preheating a 2-mm diameter weed stem up to 70°C: shepherd's purse (Capsella bursa) 2.0 s., common groundsel (Senecio vulgaris L.) – 2.4 s. and common chick-weed (Stellaria media) 1.7 s. Weeds between rows were burned as mechanical control is not allowed when strawberries are flowering. To estimate the effectiveness of this method, when thermal weed sensitivity was researched, the unit speed was selected depending on the degree of weed development.

Key words: thermal weed control, shepherd's purse, common groundsel, common chick-weed

INTRODUCTION

Currently herbicides are the main means of weed growth control in the world. However, research conducted in various countries has proved that herbicides used for crop protection has caused serious ecological problems, polluting rivers, waters and even drinking water. Intensive usage of herbicides has also resulted in the development of new biotypes of weeds which are resistant to herbicides, therefore farmers have been forced to use new and more expensive means of weed growth control. The spread of alternative non-chemical means of weed growth control was stimulated by increased demand for green foodstuff. It is believed that in the future, thermal or combined thermal-mechanical weed control will be used increasingly often.

The most important fuel used in burners - Liquid gas (LPG), usually propane - has been evaluated (Ascard, 1995) however, some revived alternatives, such as hydrogen, have been also assessed (Andersen, 1997). Although flame weeding may seem cheaper than weeding by hand, the price for flame weeding machines is quite high (Ascard, 1990; Nemming, 1994). Flame weeding may be used when the ground is too wet for mechanical weeding and there is no soil violation which would stimulate further emergence of weed. It is necessary to use foliar contact treatment when weeding by flame.

The essential research on thermal weed control was conducted in the United States from 1940 until the mid-1960s. A number of researchers studied thermal weed control in peanuts, cotton, beans, Lucerne, corn, etc. (Albrecht et al., 1963; Parks, 1964; Reese et al,. 1964; Thompson et al., 1967; Chappell, 1968; Hansen et al., 1968), and in vegetables, raspberries, strawberries and grapes (Wolfe & Horton, 1958; Hansen & Gleason, 1965).

Burning weeds when soil is wet destroys sprouts in the upper layer of soil since wet ground is heat-permeable. This equipment can be used to dry onions in order to advance the harvesting or to reduce bacterial activity *Botrytis cinerea* in strawberries (Lampkin, 1990). Much research has been conducted to determine the optimal parameters of the flame cultivator (Douzals et al., 1993; Parish, 1993). The optimal angle of burners is 22.5^{o}– 45^{o}. Certain models have been created to describe the effect of flame on plants: three have been assessed to describe how thermal effect on a plant depends on the intensity of flame. The research was conducted in the open air on white mustard (*Sinapis alba*). Investigations have shown that the required dose largely depends on the size of plants; plant density proves to have a relatively small impact (Ascard, 1995).

There have been investigations of the burning of Italian ryegrass (*Lolium multiflorum*) and white mustard (*Sinapis alba*) by experimental flame cultivator. Subsequent investigations of the effect of flame on a wide range of weeds have shown that narrow-leaved weeds are more resistant to burning than broad-leaved ones (Parish, 1990a & 1990b).

Investigations of the resistance of weed mixture composed of fat-hen (*Chenopodium album*), scentless mayweed (*Matricaria inodora*) and timothy grass (*Phleum pratense*), among others, to various doses of burning have shown that all kinds of weed are more sensitive to burning in their early growth stages. Ascard (1995) concurs. When burning rates are low, weeds revive very quickly and their biomass is larger than that of the unburned plants (Rahkonen & Vanhala, 1993).

Comparative results of research conducted on resistance of various weeds to burning in various stages of growth determined that common chick-weed (*S. media*), fat-hen (*Chenopodium album*) and annual nettle (*Urtica urens*) are quite sensitive to burning. Shepherd's purse (*C. bursa-pastoris*) and rayless mayweed (*Chamomilla suaveolens*) are moderately sensitive to burning and are likely to revive quickly.

The most resistant to burning appeared to be *Annual meadow grass* (*P. annua*) with its covered leading shoot, which usually is not exterminated; it revives quickly and starts dominating the declining weeds. Burning of weeds does not reduce their further growth, and in some cases the growth is even activated. (Ascard, 1995). Nevertheless, exterminating weeds by burning does not disturb the soil and thus does not stimulate emergence of a new wave of weeds as does mechanical weed control. Moreover, flame cultivators are superior to mechanical ones in that they can be used to exterminate weeds when the soil is too wet to use mechanical cultivators.

MATERIALS AND METHODS

In thermal weed control, a temperature exchange takes place between the device and weed. When the temperature of the device is higher than that of the weed, the weed is heated up and vice versa. For the thermal control of weeds, an experimental device with a gas burner, which was directed at a 30^{o} angle back against the isolated casing, was used (Fig. 1). Gas to the burner was supplied at a pressure of 0.1 MPa, which corresponds to the consumption of propane for one meter of working area 5.02 kg h^{-1}.

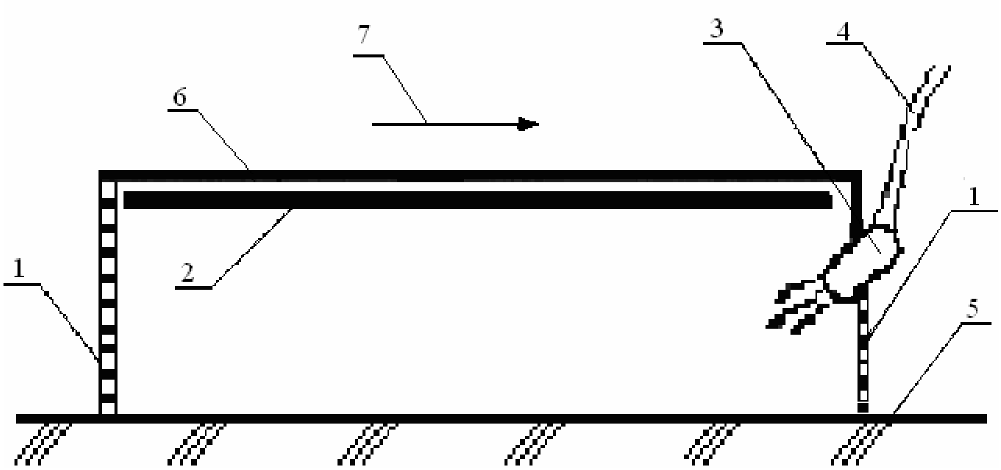

Fig. 1. Gas burner: 1 – chains, 2 – casing screen, 3 – burner, 4 – gas supply hose, 5 – ground, 6 – casing, 7 — driving direction.

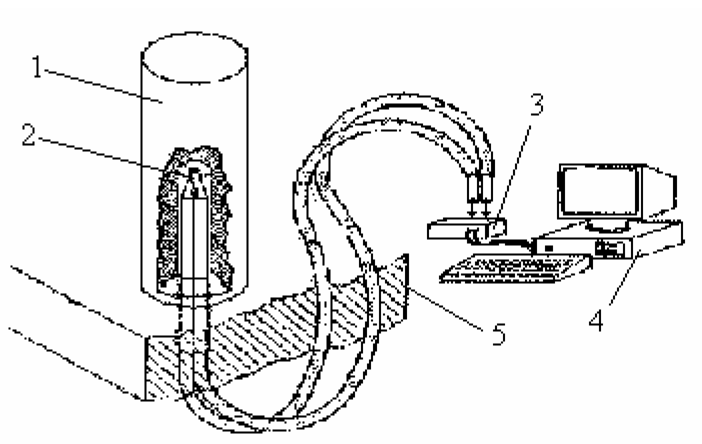

Fig. 2. Measurement scheme: 1 – plant, 2 – thermocouple, 3 – data accumulator, 4 – computer, 5 – ceramic plate.

The prevailing weeds in Lithuanian strawberry open furrows are the following: shepherd's purse (*Capsella bursa*), common chick-weed (*Stellaria media*) and common groundsel (*Senecio vulgaris*); thermal sensitivities of these weeds were assessed. Temperature changes in the core 1 of a weed were measured every 0.2 s with the help of 0.1 mm thick nickel-chrome bimetal sensor ZA9020 – SS (Germany) 2 (Fig. 2). Sensor signals were accumulated in ALMEMO accumulator 3 and read by the computer 4. The diameter of blades was determined with the help of microscope MPB – 2 (Russia), the value of a step was 0.05 mm.

Experiments were carried out in Central Lithuania in 2006–2007 in the open air, in the field of strawberries *Pandora*, which were planted leaving open furrows of 0.7 m, in loam soil. The size of squares was 0.5 m × 10 m and the arrangement of squares during the experiment was accidental. All investigations were repeated four times. The investigation was conducted during the two- and four-leaf stages. The speed of the device in both cases was 0.58, 0.50, 0.40, 0.27 m s^{-1}. The number of weeds in the area of 0.25 m^2 was measured in each variant before burning and six days after it.

Soil temperature was measured using a PC with the help of nine sensors DS18S20 connected by adapter and the program Long Temp. The sensors were inserted into the soil at the depth of 5, 10 and 20 mm.

The dampness of weed blades was determined using standard methods. Data obtained by investigation was evaluated using methods of dispersion and correlation–regression analysis. Arithmetic means, their standard errors, and confidence intervals at probability level 0.95 were determined.

RESULTS AND DISCUSSION

When weeds are treated with high temperature their cells heat rapidly and their membranes chap or the coagulation of proteins takes place, both of which kill the plant. (Morelle, 1993; Pelletier et al., 1995).

The thermal sensitivity of plants varies with physical differences (Ellwanger et al., 1973). Thermal weed control can only be used effectively when thermal sensitivity of weeds is known (Ascard, 1994; Leroux et al., 1995).

The thermal sensitivity of shepherd's purse (*Capsella bursa*), common chick–weed (*Stellaria media*) and common groundsel (*Senecio vulgaris*) was investigated (Fig. 3). Picture 3 shows that a 2-mm thick blade of common chick–weed (*Stellaria media*) heats up from 20ºC to 70ºC within 1.7 s. while common groundsel (*Senecio vulgaris L.*) and shepherd's purse (*Capsella bursa*) - within 1.8 seconds. The investigations have shown that the dampness of common chick–weed (*Stellaria media*) blade is 90.1%, common groundsel (*Senecio vulgaris L.*) – 86.6% and shepherd's purse (*Capsella bursa*) – 74.9%, therefore it is true to say that the weed blade heating speed does not depend directly on their dampness.

The dependency of weed blade heating time on blade diameter was also investigated. It was determined that the larger the blade diameter, the longer it's heating time (Fig. 4). A 1-mm thick blade of Shepherd's purse (*Capsella bursa*) heats up to 70ºC within 1.1 s. and 2.8-mm thick blade – within 2.7 s. Thus in order to exterminate shepherd's purse (*Capsella bursa*) with a 2.8-mm blade, we will have to drive 2.7 times slower than when the diameter is 1 mm, at the same time increasing gas consumption by as many times.

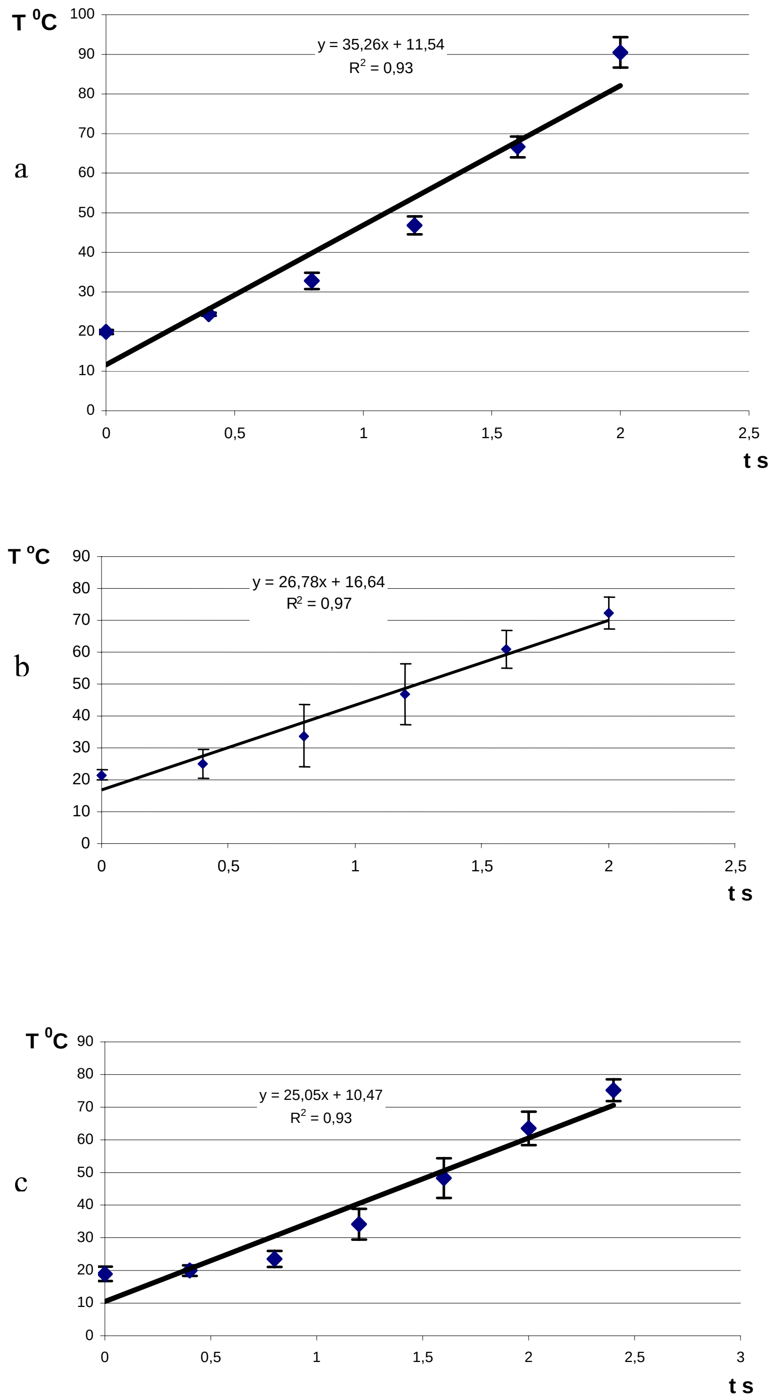

Fig. 3. Change of temperature *T* in the weed stalk core of the diameter of 2 mm under the impact of flaming: a – common chick–weed (*Stellaria media*), b – shepherd's purse (*Capsella bursa*), c – common groundsel (*Senecio vulgaris L.*).

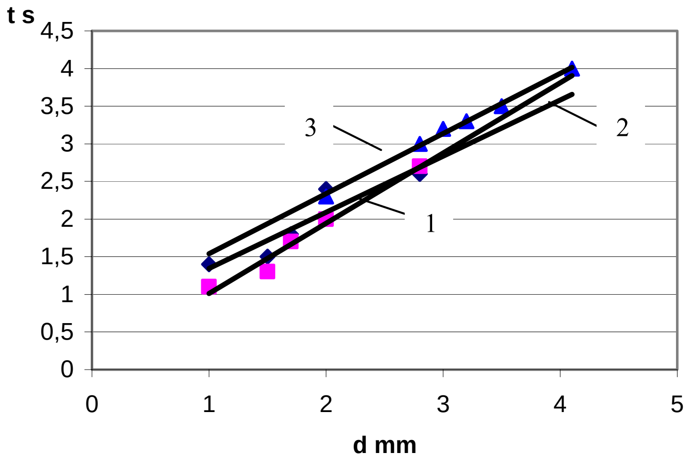

Fig. 4. Weed blade heating duration *t* depending on the diameter *d* of the blade: 1 – common chick-weed (*Stellaria media*) (y = 0.79x + 0.74, R^2 = 0.99); 2 – shepherd's purse (*Capsella bursa*) (y = 0.74x + 0.59, R^2 = 0.86); 3 – common groundsel (*Senecio vulgaris L.*) (y = 0.93x + 0.08, R^2 = 0.97)

Analogous results have been obtained by Morelle, 1993. He found that the thermal sensitivity of weeds vary depending on their stage of growth. Young, small plants are especially sensitive to thermal treatment; therefore thermal weed extermination at the beginning of a season saves considerable energy.

In order to determine the impact of flame on soil microorganisms the soil heating temperature was measured when the dampness of soil was 30±2% and the driving speed of the device was 0.58 m s^{-1}. The soil temperature at a depth of 5 mm rose by 3.0°C, 10 mm - by 1.0°C and at a depth of 20 mm, the temperature remained unchanged. Therefore it is true to say that the impact of flame on soil microflora is minimal.

Similar results have been obtained by Dierauer & Pfiffner, 1993. They claimed that weed burning by flame cultivators did not have any impact on the variety, density and activity of insects. When flame intensity was 4600 MJ ha^{-1} the microbial mass in the soil layer of 0-5 mm decreased by 19%. The flame had minimal impact on microbial mass in the deeper soil layers. Rahkonen et al. (1999) has also concluded that the negative impact of flame on microorganisms is small.

CONCLUSIONS

Investigations have shown that thermal sensitivity of plants depends not only on the diameter of a blade but also on other factors (e.g. the thickness of a protective wax cover, etc.). Moreover, weed thermal sensitivity depends on their stage of growth since a 1-mm thick weed blade heats up to 70ºC 2.7 times faster than 2.8-mm thick blades. Therefore, flame weeding is advisable in the early stage of plant growth when gas consumption will be relatively lower.

Thermal wedding by flame in open strawberry furrows causes little negative effect on soil microflora since, in the depth of 5 mm, the temperature of soil rises only by 3.0°C.

REFERENCES

Albrecht, K.J. et al. 1963. Flame cultivation of corn and related crops. *American Society of Agricultural Engineers*. St. Joseph, MI. USA, ASAE Paper 63–606.

Andersen, J. 1997. Experimental trials and modeling of hydrogen and propane burners for use in selective flaming. *Biological Agriculture and Horticulture* **14**, 207–219.

Ascard, J. 1990. Thermal weed control with flaming in onions. *Proceedings of the 3rd International Conference on Non-chemical Weed Control.* Austria, Linz, pp. 175–188.

Ascard, J. 1994. Dose-response models for flame weeding in relation to plant size and density. *Weed Research* **34**, 377–385.

Ascard, J. 1995. Effects of flame weeding on weed species at different developmental stages. *Weed Research* **35,** 397–411.

Chappell, W.E. 1968. Flaming in corn, soybeans and vegetable crops. *Proceedings of the Fifth Annual Symposium on Thermal Agriculture.* Natural Gas Producers Association et National LP–Gas Association, pp. 55.

Dierauer, H. U. & Pfiffner, L. 1993. Effects of flame weeding in organic vegetable growing on ground beetles (Col. Carbides). Communications of the 4th International Conference I.F.O.A.M. Non Chemical Weed Control, France, Dijon, pp. 137–140.

Douzals, J. P., Lemiere, J. P., Juncker, E & Coquille, J. C. 1993. Development of a thermal weed machine. *Communications of the 4th International Conference I.F.O.A.M. Non Chemical Weed Control*, France, Dijon, pp. 157–161.

Ellwanger, T.C. Jr., Bingham, S.W. & Chappell, W.E. 1973. Physiological effects of ultra-high temperatures on corn. *Weed Science* **21**, 266–269.

Hansen, C.M. & Gleason, W. 1965. Flame weeding of grapes, blueberries and strawberries. *Proceedings of the Second Annual Symposium on the Use of Flame in Agriculture.* Natural Gas Producers Association and National LP-Gas Association, pp. 11–12.

Hansen, C.M., Chase, R.W., Tabiszewski, A. & Bowditch G. 1968. Flame weed control in potatoes. *Proceedings of the Fifth Annual Symposium on Thermal Agriculture.* Natural Gas Producers Association et National LP-Gas Association, pp. 63–64.

Lampkin, N. 1990. *Organic Farming*, Farming Press Books, Ipswich, UK.

Leroux, G.D., Douheret, J., Lanouette, M. & Martel M. 1995. Selectivity of propane flamer as a mean of weed control. *Horticulture science* **30**(4), 820–828.

Morelle, B. 1993. Thermal weed control and its application in agriculture and horticulture. *Communications of the 4th International Conference I.F.O.A.M. Non Chemical Weed Control*. France, Dijon, pp. 111–116.

Nemming, A. 1994. Costs of flame cultivation. Engineering for Reducing Pesticide Consumption & Operator Hazards. *Acta Horticulturae* **372**, 205–212.

Parish, S. 1990a. The flame treatment of weed seedlings under controlled conditions. *BCPC Monograph No. 45.* Organic and Low Input Agriculture, pp.193–196.

Parish, S. 1990b. A procedure for assessing flame treatments under controlled conditions. *Proceedings of the 3rd International Conference on Non Chemical Weed Control*. Austria, Linz, pp. 189–196.

Parish, S. 1993. Flame weeding: techniques and equipment. *Proceedings 8th NATIONAL Conference, Organic Food Production*. UK, Cirencester, pp. 40.

Parks, J.H. 1964. Progress of flame cultivation in the Texas high plains and Rio Grande valley. *Proceedings of the First Annual Flame Symposium*. Natural Gas Processors Association, pp. 8–17.

Pelletier, Y., McLeod, C.D. & Bernard, G. 1995. Description of sublethal injuries caused to the Colorado Potato Beetle by propane flamer treatment. J. *Econ. Entomology* **88**(5), 1203–1205.

Rahkonen, J. & Vanhala, P. 1993. Response of a mixed weed stand to flaming and use of temperature measurements in predicting weed control efficiency. *Communications of the 4th International Conference I.F.O.A.M. Non Chemical Weed Control*. France, Dijon, pp. 177–181.

Rahkonen, J., Pietikäinen, J. & Jokela, H. 1999. The effects of flame weeding on soil microbial biomass. *Biological Agriculture and Horticulture* **16**, 363–368.

Rasckhe, K. 1965. Über die physikalischen Beziehungen zwischen Wärmeübergangszahl. Strahlungsaustausche, Temperatur und Transpiration eines Blattes. *Planta* **48**, 200–238.

Reese, F.N., Fitzgerald, L.W., Anderson, L.E. & Larson, G.H. 1964. Flame cultivation of corn and grain sorghum. *Proceedings of the First Annual Flame Symposium*. Natural Gas Processors Association, pp. 22 – 25.

Thompson, V.J., Scheibner, R.A. & Thompson, W.C. 1967. Flaming of alfalfa in Kentucky for weevil and weed control - Results of 1967 winter. *American Society of Agricultural Engineers.* St. Joseph, Ml, USA, ASAE Paper, pp. 637–645.

Wolfe, J.S. & Horton, D.E. 1958. Investigations on the clearing of weeds from bulb beds by flaming. *Journal of Agricultural Engineering Research* **58**, 324–335.