

# Experimental determination of lethal doses of heat in thermal weed control

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## Abstract

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Thermal weed control performed by weeders working on physical principles is already commonly used on farms dealing with bioproducts. It helps to reduce strenuous human labour and to effectively control weeds and, to some extent, pests and diseases threatening the crops. It also prevents other weeds from spreading by destroying them in the early growth stage. In addition, development of weeds is inhibited when the soil is not being ploughed. Effective deployment of these machines in practice is currently addressed by experts in the field, as well as the possibility of rational use of heat energy while achieving the maximum effect on weeds. This method in particular helps to reduce costs of thermal treatment, which are the key factor limiting widespread deployment of weeders. The paper introduces long-term research based on laboratory and field experiments, which is intended to broaden the knowledge regarding this issue.

**Keywords:** weed control; non-chemical cultivation

Nowadays, when the ecological aspects of food production gain importance and intensive agriculture reevaluates the extensive use of chemical products, experts are encouraged to seek alternative methods of cultivation. There are various options of crop production without herbicides – one of them is the use of physical methods in cultivation, whether it is passive (solarisation, mulching, etc.) or active use of energy (flame, electric charge, radiation).

These methods are now commonly used in practice; there is a wide range of machines and systems. However, their effective operation generates a great deal of debate. The pioneer in this field was PARISH (1989), who examined the effect of flame on weeds in different types of crops – mustard and rice. GEIER and VOGTMANN (1986) examined the deployment of mechanical rotary brush weeder. Practical deployment of this machine, combined with thermal treatment, seems considerably effective. RIFAI

et al. (2002) addressed the issue of thermal control in orchards and carried out field experiments with various types of crops. АБРАХАМ (2007) confirmed negative effects of soil compaction on plant production, which favours the deployment of low-weight flame weeder. The results of the pieces of research have indicated that the method of thermal weed control, compared to chemical treatment, is more expensive, laborious and time-demanding. This work deals with improvement of effectiveness of thermal weed control methods and suitable options of weed elimination, which ultimately lead to decrease in costs of weed treatment.

## MATERIAL AND METHODS

Ongoing research at the Department of Transport and Handling, Faculty of Engineering, Slovak

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University of Agriculture in Nitra is based on the laboratory and field experiments conducted since 1994 in Nova Scotia, Canada. Constructed burner connected to a 5 kg propane-butane gas bottle was used. Field experiments were conducted with four-row flame weeder Thermec.

In the first experiment, passages of the flame weeder over treated weeds were simulated. Thermocouples Omega 5TC-GG-K-30 (Omega Engineering, Inc., Stamford, USA) through the converter connected to the PC were used. The ends of the thermocouples were located above the ground in the middle of the track between the burners to simulate the affected weeds. The flame weeder repeatedly passed over the thermocouples, while the number of repetitions per treatment was 5. The parameters of the experiment were as follows: speed (2 and 4 km/h) in combination with gas pressure (0.15, 0.2, and 0.25 MPa). The aim of this experiment was to determine the actual amount of distributed heat and possible losses in its transmission.

In subsequent laboratory experiments, effects of combinations of the following parameters were examined: weeder speed  $v_p$ , gas pressure  $p_p$ , and growth stage of weeds (LORENZ et al. 1994). The combination of the first two parameters represents hourly gas consumption  $M_p$  and gas consumption parameter which is calculated according to the time of treatment  $t_{tr}$  per unit of cultivated area  $M_H$ .

The laboratory experiments were carried out during the period of 1996–2014 on white mustard (*Sinapis alba* L.) and rice (*Oryza sativa* L.) pre-grown in containers 30 × 20 × 10 cm (L × W × H) with a minimum of 15 plants per container. The burner was placed 10 cm above the passing containers at an angle of 45°. The containers with plants were put on

a cart pulled along the railroad by traction element which can readjust the speed by means of adjustable transformer 12 V. Treatment parameters are listed in Table 1. In addition to these data, the weight of the aerial parts of weeds at all growth stages and the density of vegetation were recorded. Weather conditions were also an important factor to consider – temperature, humidity and pressure were observed. The effectiveness of treatment was determined by counting the plants before and after the treatment (interval of three days). The extent of destruction of the plant (total, partial, minimal) was examined by the selected coefficients. Each treatment O1–O23 was performed on three growth stages of mustard and rice and was repeated four times. Experiments were conducted in 2004, 2006 and 2013. Such continuity provides a reliable framework for statistically plausible outcomes. The results were processed by statistical methods of Microsoft Office Excel.

## RESULTS AND DISCUSSION

The main aim was to determine the heat transfer from the source (burner of the weeder) to the heated object (weed) and actual losses which minimize the effect of weed control. Measurements proved that even a slight change in weeder speed leads to significant reduction of heat transfer to weeds (Fig. 1). At the weeder speed of 2 km/h, the time of heat distribution is four times longer than at the speed of 4 km/h. This fact helps to increase the temperature of affected weeds by one third. While at the speed  $v_p$  of 4 km/h the temperature increases from 280°C to 490°C and exposure time is 0.1–0.2 s, at the speed  $v_p$  of 2 km/h the temperature reaches approx. 760°C

Table 1. Treatment parameters in laboratory experiments

Treatment	Weeder speed $v_p$ (km/h)	Gas pressure $p_p$ (MPa)	Gas consumption $M_p$ (kg/h)	Time of treatment $t_{tr}$ (h)	Gas consumption per hectare $M_H$ (kg/ha)
O1	2	0.5	2.34	5	11.70
O2	2	0.1	7.24	5	36.20
O3	2	0.15	9.69	5	48.45
O11	3	0.5	2.34	3.33	7.79
O12	3	0.15	7.24	3.33	24.10
O13	3	0.25	12.10	3.33	40.20
O21	4	0.5	2.34	2.25	5.26
O22	4	0.15	7.24	2.25	16.29
O23	4	0.25	12.1	2.25	27.23

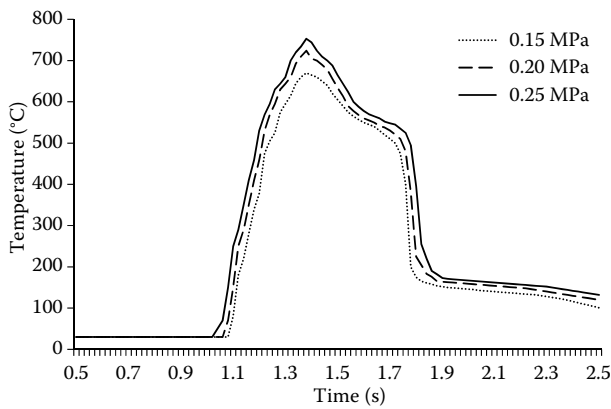


Fig. 1. Thermal characteristics at weeder speeds of 2 km/h

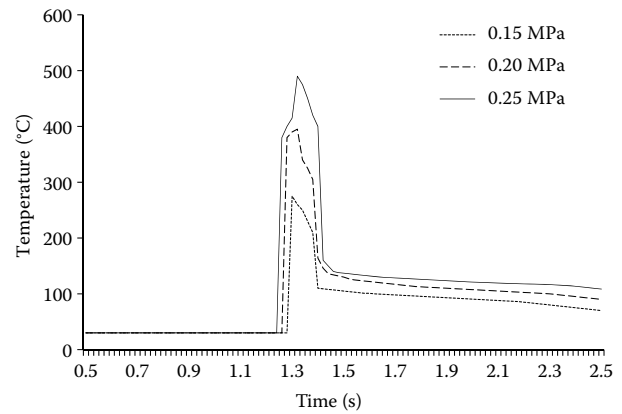


Fig. 2. Thermal characteristics at weeder speeds of 4 km/h

and exposure time is prolonged to 0.7–0.8 s. It was also observed that the change in gas pressure has no significant influence  $P \geq 0.05$  on the change of the heat effect of the treatment at lower speeds.

The second phase of the experiments was aimed at the amount of impact heat on particular plants. Selected representatives of dicotyledonous (white mustard – *Sinapis alba* L.) and monocotyledonous (rice – *Oryza sativa* L.) plants were exposed to precisely defined thermal effect. Thermal effect was defined as a parameter of gas consumption, which is a combination of the weeder speed and gas pressure settings during the treatment. The effect of regulation of white mustard (Fig. 2) in the growth stage of 3–5 cotyledons ranged between 30–75%, depending on gas consumption. The growth stage had a significant influence  $P \leq 0.05$  on the effectiveness of weed control. In the area that is notable in terms of practical application of the flame weeder (gas consumption of 20–40 kg/ha), the effectiveness of weed control is reduced by half.

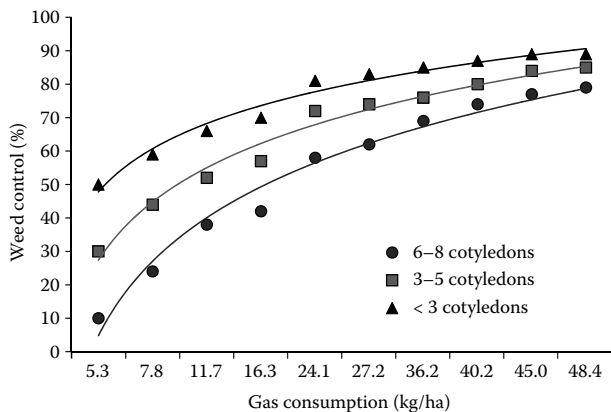


Fig. 3. The impact of parameter changes on weed control of white mustard (*Sinapis alba* L.)

Different results were observed in treatments of rice (Fig. 3). In the growth stage of 3–6 cm, the effectiveness of weed control ranged between 35–70%, depending on gas consumption. The growth stage of weeds considerably  $P \leq 0.05$  affects the effectiveness of weed control. In the area that is notable in terms of practical application of the flame weeder (gas consumption of 20–40 kg/ha), the effectiveness of weed control is reduced by 40%. The results also point out that increasing the heat distribution above the level of gas consumption of 50 kg/ha does not significantly enhance  $P \geq 0.05$  the weed control.

Obtained results provide basis for further research into weed control methods by flame. The experiments are focused on the combination of mechanical and thermal weeders (Fig. 4), as a more effective way of weed control in organic farming, which would reduce the treatment costs and eliminate the need for strenuous human labour.

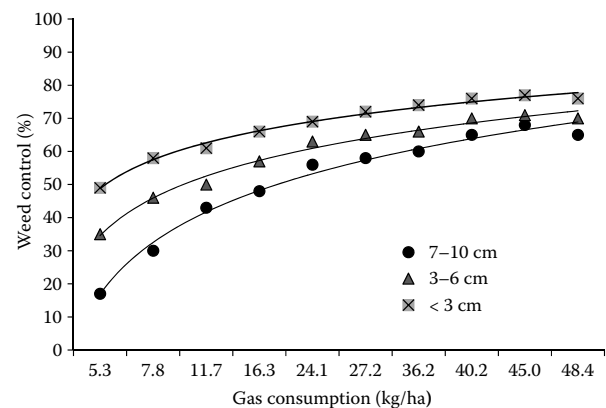


Fig. 4. The impact of parameter changes on weed control of rice (*Oryza sativa* L.)



Fig. 5. Efficient use of thermal weeder (Rainer) is achieved in combination with mechanical cultivator (Bartschi)

## CONCLUSION

The flame weeder can be very useful in regulating weeds in rows of cultivated vegetables, especially in alternative farming without chemicals. Its application is nowadays apparent in the treatment of urban greenery, growing potatoes or treatment of orchards. Advantages of this method have been described by numerous authors. The key benefit is that the soil remains intact and therefore the root systems of plants are not affected and the growth of weeds is inhibited. When applying this physical method, it is necessary to follow certain procedures which considerably increase the efficiency of weeders and thereby reduce the costs, which particularly limit their use in practice. Weed control by the flame weeder should be performed in the early growth stages of weeds when the effects are most desirable. Heat transfer to weeds should be adequate and accurate. To warm up the weeds of small weight, only a small amount of energy is required. The transfer of this energy from the source should be effective, without unnecessary losses. Between the rows, it is necessary to use mechanical cultivation and aim the thermal effects to the row of crops where the desired effect is achieved with fewer expenses by means of selective combustion. Differences in the efficiency of treatment of monocotyledonous and dicotyledonous weeds, which were observed in all experiments, are linked with the weight of plants and plant tissue structure. Heat transfer should be modified in accordance with these parameters by changing the height and

angle of the burner. Also in Slovakia there are large greenhouses where weed control is performed by flame from burners placed on a railway track. The accuracy of these railways enables to enhance the efficiency and speed up the application.

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