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Effect of flame weed control on various weed species at various developmental stages

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Abstract. Physical methods of weed control as solarization, mulching, use of electricity, steam and flame are now an alternative in the organically grown crop. Flame weeder already has a wide range of practical use**,** particularly in the cultivation of vegetables in alternative form without any chemical treatment. Compared to chemical spraying, the use of flame weeder is more expensive, but we can compensate the costs by the added value of bioproducts. The issue of costs affects the wider use of the method in practice, but it may be offset by increased efficiency of weed control. The correct parameters of flame weeder, such as burner angle, burner height, the gas pressure, speed of weeder as well as the growth stage of the weed, weed species, climate conditions etc., can increase the effectiveness of weed control. Field and laboratory tests carried out in Canada and Slovakia were aimed at verifying the influence of parameters on the effectiveness of flame weed control.

Key words: flame weeder, weed control.

INTRODUCTION

A set of field and laboratory experiments are a continuation of long-term research, which started in 1994 in N.S.A.C. Nova Scotia (Canada) in collaboration with the Faculty of Engineering, SUA Nitra (Slovakia). Field tests, realized in 1994–1995 indicated a big difference in achieving effectiveness (Abrahám & Jablonický, 2007; Abrahám et al., 2011) of weed control with flame weeder Reinert-DA211. Influence of weather and different soil types on flame treatment was recorded. Subsequently, laboratory tests in Slovakia were made to confirm the influence of parameters (flame weeder driving speed, gas pressure, growth stage of the weeds) on flame treatment effectiveness in killing weeds. Different weed species at various developmental stages were tested. Consumption of gas on hectare M_H was established as a main parameter in order to compare effectiveness of the flame weeder.

MATERIALS AND METHODS

In the first experiment in N.S.A.C. (1994) with flame weeder Reinert-DA211 (Fig. 1), simulation of the passage of the flame weeder over the weeds were made to establish its thermal characteristics at different driving speed and different gas pressure.

Thermocouples Omega 5TC-GG-K-30 connected to a PC through a converter was used to measure change of weed temperature by simulated treatment (Bolla et al., 2003). The ends of thermocouples were placed close to the ground, in the middle of the path between the burners in wood skeleton to simulate weed. The flame weeder Reinert-DA211 repeatedly passed over the thermocouples and the change of temperature was recorded. The number of repetitions for one treatment was five. The changing parameters were driving speed of the burner and gas pressure.

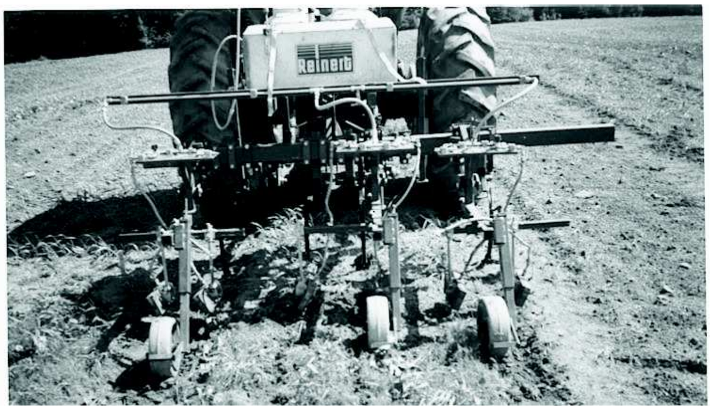

Figure 1. Flame weeder Reinert – DA211.

The flame weeder Reinert-DA211 is a three-row machine with six burners and two 25 kg LPG bottles. The bottles are placed in a bath filled with water with an anti-cloud heating; gas flow scheme is shown on Fig. 2. The gas supply to the burners is provided by hoses equipped with thermal sensors and a gas controller. The distribution of the flame to the weeds is modified by setting the driving speed of the flame weeder from 1 to 5 km h^{-1} and by setting the gas pressure from 0.05 to 0.25 MPa. The burners are turned into a row of plants at 45° angle, which allows the weeds to be treated in the crop line as well. The support wheels provide both directional control and adjustment of the height of the burners above the ground.

In subsequent laboratory experiments on Faculty of Engineering, Slovakia, verification of the effect of combinations of burner parameters in weeder driving speed v_p, gas pressure p_p, and weed growth stage (Lorenz et al., 1997) on weeds was made. A combination of the first two parameters results in a parameter of hourly gas consumption M_p. and a parameter of gas consumption M_H, which was converted by the time of treatment t_{tr} to consumption per hectare of treated surface (Majdan et al., 2011). The gas consumption M_p was determined by the measurement of the difference in LPG bottle weight in 25-minute intervals, and subsequently, recording of the treatment time of an area of 600 m^2 was verified with conversion to 1 ha.

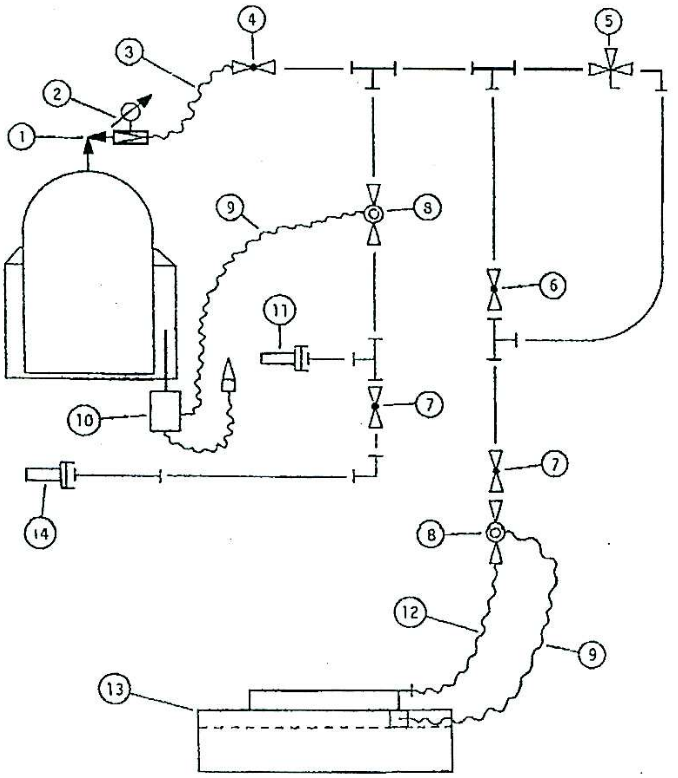

Figure 2. Gas flow scheme Reinert – DA211: 1 – gas bottle; 2 – pressure regulator; 3 – connecting hoses; 4 – throttle valve; 5 – starter; 6 – quick shutter; 7 – shut-off valve; 8 – safety valve; 9 – thermal fuse; 10 – thermal sensor; 11 – heating bottles; 12 – supply hoses; 13 – burner; 14 – ignition burner.

Laboratory experiments were carried out in 2013–2015 for Chenopodium album L. and Avena fatua L., which were pre-cultivated in containers 30 x 20 x 10 cm (L x W x H) in the minimum quantity of 15 pieces per container. The same burner DA-2011 connected to bottle of 25 kg LPG was used in a position of 10 cm above the passing of weeds at 45° angle. The containers with pre-cultivated were placed on a car pulled by rail with a small traction member enabling the setting of movement speed using an adjustable transformer 12 V. The treatment parameters are listed in Table 1. The effectiveness of treatment was monitored by counting the weeds before and after the treatment. Degree of plant damage was evaluated as completely (100%), partially (60%) or minimally (40%) damaged weeds, based on selected coefficients. Each treatment O01–O91 was performed in three growth stages of weeds, 3, 5 and 8 cotyledons for Chenopodium album L., and 3, 6 and 10 cm for Avena fatua L., and had four repetitions, which represented 120 treatments per weed species in total. For statistical evaluation the 'Analysis of Variance' was used to evaluate the impact of each factor separately. The calculated values P (Fisher test) were compared with table P_x value and when $P > 0.05^-$ (difference is not probable), $P > 0.05^+$ (difference is probable), and $P > 0.01^{++}$ (difference is highly probable).

Table 1. Treatment parameters at laboratory trial

Treatment	Speed v_p (km h^{-1})	Pressure p_p (MPa)	Consumption M_p (kg h^{-1})	Time of treatment t_{tr} (h)	Consumption M_H (kg ha^{-1})
O01	2	0.05	2.34	5	11.7
O11	2	0.1	9.69	5	48.45
O21	2	0.15	7.24	5	36.2
O31	2	0.25	12.1	5	60.5
O41	3	0.05	2.34	3.33	7.79
O51	3	0.15	7.24	3.33	24.1
O61	3	0.25	12.1	3.33	40.2
O71	4	0.05	2.34	2.25	5.26
O81	4	0.15	7.24	2.25	16.29
O91	4	0.25	12.1	2.25	27.23

RESULTS AND DISCUSSION

Experiments carried out with the three-row flame weeder Reinert – DA211 in Canada 1994 were used to determine the intensity of heat effect. Field trials with weeder passages over heat sensors at variable driving speed v_p and gas pressure p_p indicate a real time of heat application and its real value (Figs 3 and 4). While the increase of pressure p_p at speed 4 km h^{-1} leads to a temperature increase from approx. 280 °C up to 490 °C, and the time of application increase from 0.1 to 0.2 seconds, at speed 2 km h^{-1} and pressure 0.25 MPa a temperature of 760 °C was recorded, and the time of exposure extended to 0.7 seconds.

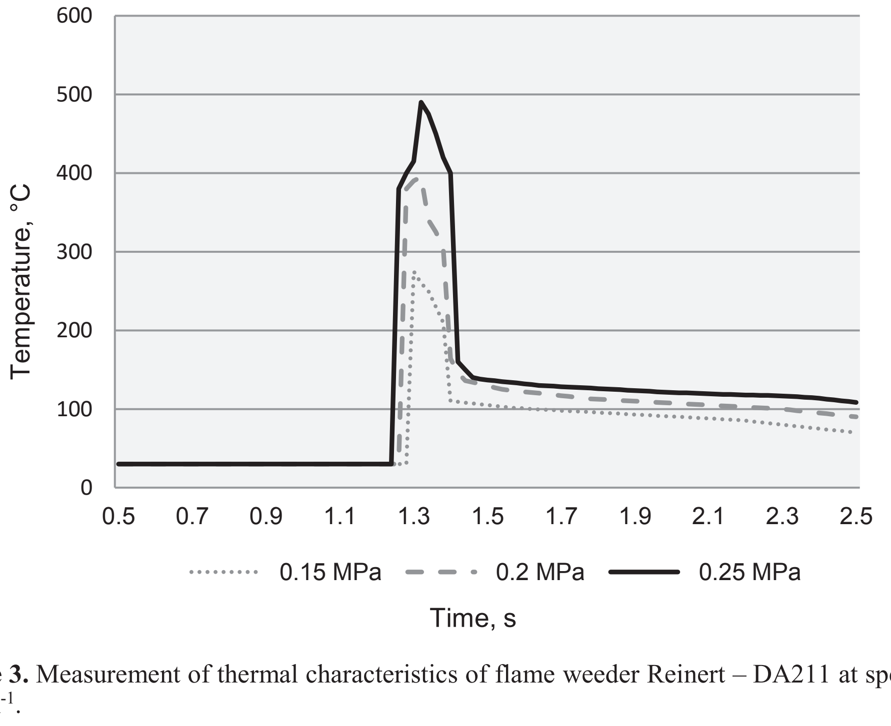

Figure 3. Measurement of thermal characteristics of flame weeder Reinert – DA211 at speed of 4 km h^{-1}.

The results help us to identify the effect of flame treatment on a given weeds accurately. Other aspect is the absorption area of weeds, which is represented by its gradual development and the number of cotyledons. An important finding is the fact that driving speed v_p has a more significant effect ($P > 0.01^{++}$) on the killing weeds than pressure change p_p ($P > 0,05^{+}$).

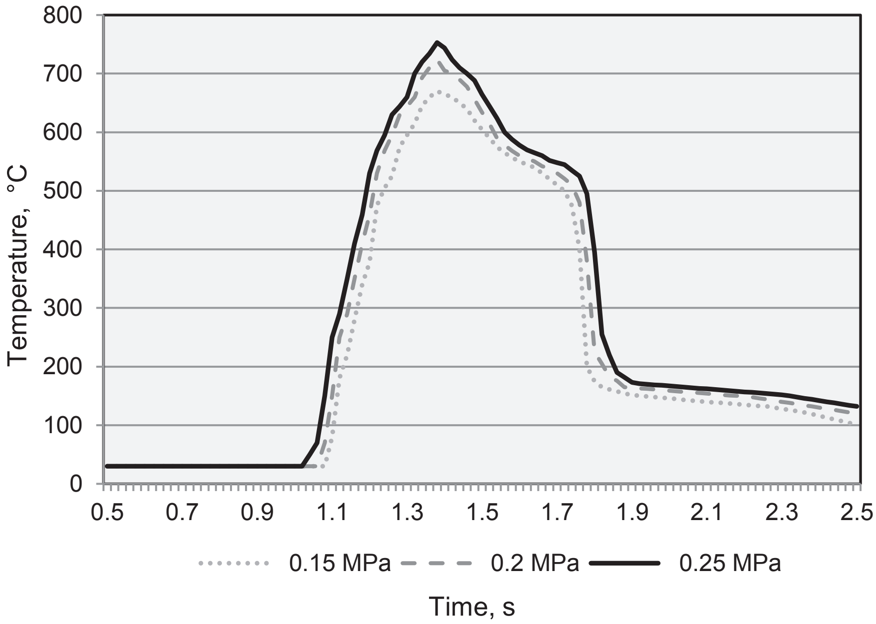

Figure 4. Measurement of thermal characteristics of flame weeder Reinert – DA211at speed of 2 km h^{-1}.

Laboratory experiments with pre-cultivated dicotyledonous and monocotyledonous weeds have been carried out mainly to ascertain the impact of changes in driving speed v_p and gas pressure changes p_p at different developmental stages of weeds. The results of control in Chenopodium album L. are shown in Fig. 5. Change of gas consumption M_H caused a significant effect ($P > 0.5^{+}$) on weeds control change in all growth stages. When gas consumption exceeded 50 km h^{-1}, the effect in all growing stages of Chenopodium album L. was more than 80%. On the other hand, in the case of growth stage under 3 cotyledons, only a half of the gas amount is needed to obtain the same results on weeds. Several experiments were performed even at later growth stages of weeds; however, the efficiency of flame application did not reach practically applicable results. Effect on Chenopodium album L. in 10 cotyledons at consumption 45 kg ha^{-1} was under 50%, which may be considered as financially unprofitable. Many weeds in later developmental stage regenerate after the treatment from its root system (Davis, 1975; Lorenz, 1997). The evaluation of damage extent was made according to the established methodology.

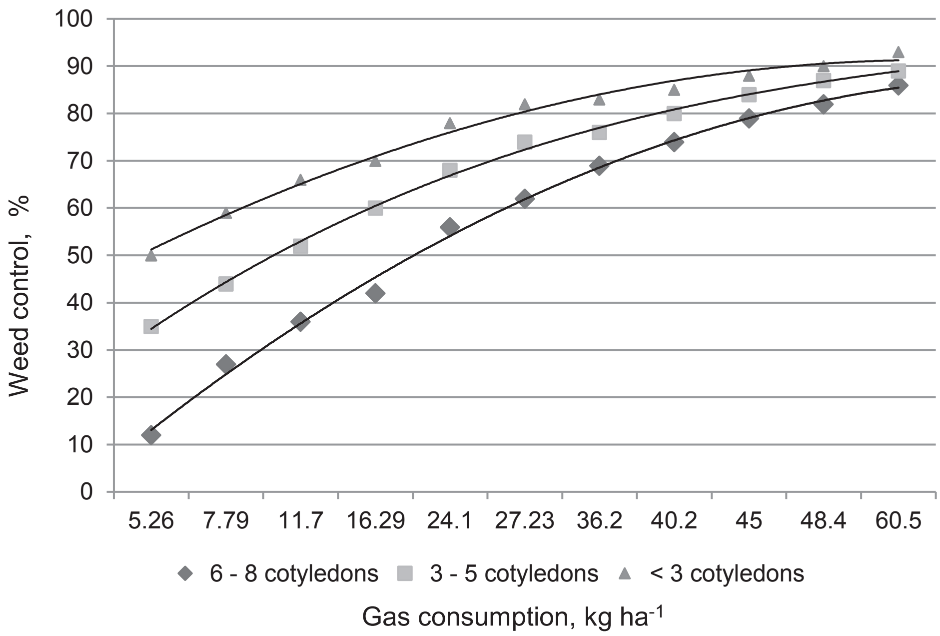

Figure 5. Effect of parameter changes on the flame treatment effectiveness in Chenopodium album L.

The results of weed control effectiveness in Avena fatua L. are shown in Fig. 6. Changes in gas consumption M_H caused only a minimal effect ($P > 0.5^-$) on weed control change in all growth stages. After the treatment of Avena fatua L., tops of the weeds were damaged by the flame, but quickly regenerated and continued to grow. The previous experiments indicate that for the control of Avena fatua L. it is important to set the flame from the burner at a proper angle so that the whole weeds are reached (Atkinson, 1995) and especially to place the burner as close as possible to the monocotyledonous weed (Bond & Grundy, 2001). At burner angle of 60° to the ground, the effectiveness of killing weeds significantly increases ($P > 0.5^+$). It is also very important to keep the height of the burner above the soil in the range from 10 to 15 cm, because even small deviations cause significantly lower effect on killing weeds ($P > 0.5^+$) – mainly to the lower part of these monocotyledonous weeds. An important factor is also the time of treatment and labour input. Moreover, weed thermal sensitivity depends on their developmental stage (Šniauka & Pocius, 2008). However, in the field of alternative, non-chemical growing of bio-products, this method can find a wider application, particularly when eliminating a high labour cost. The difference in the price of products with a higher added value can eliminate higher inputs in the usage of flame weeder (Birkett et al., 2001). Nowadays big greenhouses in Slovakia use track rollers with mounted burners for the weed control. The accuracy of these pathways considerably increases the efficiency and facilitates its application.

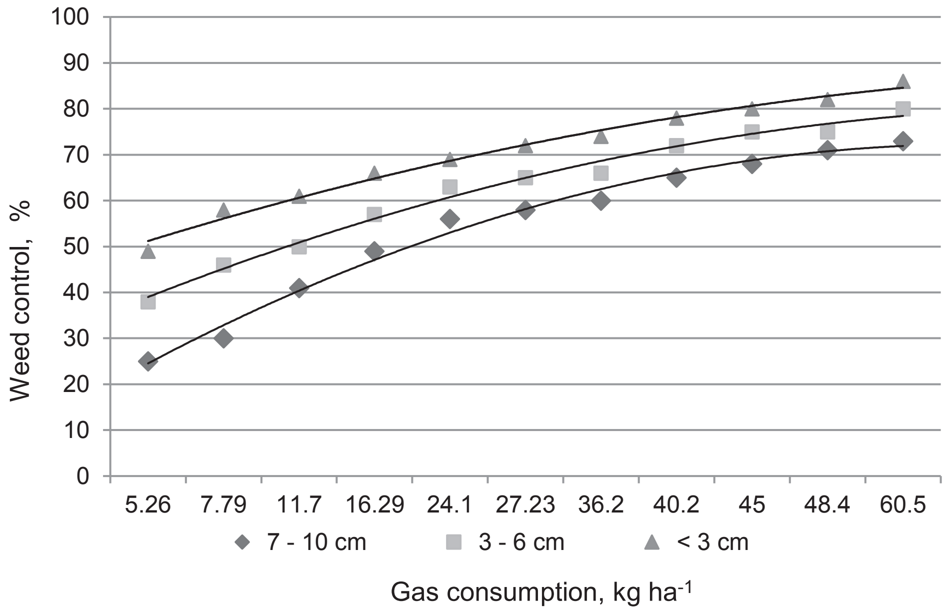

Figure 6. Effect of parameter changes on the flame treatment effectiveness in Avena fatua L.

CONCLUSION

The obtained results show that for practical use of flame weeder it seems to be more relevant to change the driving speed v_p rather than to change the gas pressure p_p. Similar results were recorded in testing rice and mustard (Parish, 1989; Ascard, 1997; Rifai et al., 2002). The flame weeder cannot compete with chemical or mechanical cultivators in terms of the costs (Abu-Hamdeh & Abu-Qudais, 2001). However, there are also other parameters in question, such as driving speed and time of treatment, which limitate the use of this method e.g. only for crops grown in the rows.

Moreover, setting a higher pressure p_p is limited with respect to the possibility of crop damage by distributed heat from burners. At higher pressure p_p, there is an overlapping of heat flow, which affects not only the weeds but also the crop. With a selective treatment, this is not a problem because the crop grows with a certain timing advance before weeds and has greater resistance (Virbickaite et al., 2006). In early stages of application, this can cause slow-down or even discontinuance of crop growth. On the other hand, as for the change in driving speed v_p, practical application is demanding in terms of accuracy due to the burner distance from the crop row, either horizontally or vertically, which is difficult to ensure at high speeds. Laboratory experiments have shown that the parameters of flame treatment must be adapted to the particular weed species and the developmental stage of the weeds, and the treatment has to be performed under favourable weather conditions.

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