Possibilities of weed control by water steam

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Abstract. Damp water steam used for weed control in onion, barley and maize crops was investigated meaningfully for the first time in the world. These investigations show that damp water steam can be successfully used in organic and traditional agriculture for weed control. During weed control by steaming, up to 98% of weed shoots are destroyed. After two weed control treatments by damp water steam in an onion field, the crop yield increased up to 9–10%, compared with three times of weeding; in the maize crop 22%, in the barley crop 10%, compared with the not weeded control.

Key words: weed control, water steam, thermal weed control

INTRODUCTION

Currently, the flame weeding method is used most often as an alternative to chemical herbicides (Ascard, 1995). Wet water vapour is a real alternative for the thermal flame weeding method (Vasinauskiene, 2004). Flame weeding and wet water vapour media (Storeheier, 1996) differ substantially by their thermodynamic properties (Sirvydas et al., 2004). For this reason devices and agro–technologies of thermal extermination of weeds also differ considerably.

In the flame weeding technology heat (obtained at 400–800°C with 400 to 800 kJ produced) from 1 kg of combustion products can be transferred to the environment (plants, soil and devices increasing their temperature) in a quantity not exceeding 250 to 600 kJ. Gas transfers its heat energy to plants very slowly. In a high temperature medium, which does not cause saturation with water vapour, plants intensively transpire and, in the process, resist overheating. This technology excludes a sudden rise in the temperature of plant tissues over 58°C, as it requires thermal exposure lasting several seconds (Sirvydas et al., 2006).

1 kg of wet water vapour releases 2250 kJ of thermal energy to the environment, which is 3.7 to 11 times more than 1 kg of gas in flame weeding technology. The wet medium prevents transpiration by the plant, which delays temperature rise in its tissues. Wet water heats the environment with about 2000 times greater efficiency than gaseous medium. Another very useful feature of water vapour medium is its ability to flow in the direction of colder plant and soil surfaces. The vapour condensation process on the surface of the plant causes this flow. Water vapour condensation reduces its volume 1700 times. All this allows a sudden increase in the temperature of plant tissues, and

lasts only 1 to 2 seconds, completely destroying the weed plant. These beneficial features of wet water vapour present great opportunities for the utilization of wet water vapour devices for ecological weed control.

The aim of this work is to present primary data of thermal weed control and to specify possibilities of applications of the method for ecological weed extermination.

MATERIALS AND METHODS

The main index for evaluation of technological processes during the weed control procedures is temperature variation of plant tissues of the plant to be destroyed. Plant temperature variation reflects the total influence of all (biological, thermo-physical and environmental) factors and their compatibility with agricultural technology used.

We measured the temperature of the medium and of the plant, using the ALMEMO 2590–9 device having the microprocessor data gathering, accumulating and processing system. The thermocouple wires are connected through ALMEMO with the programmable memory circuit. High temperature medium flow and plant tissue temperatures were measured according to the preset tasks and needs carrying out up to 100 measurements within one second. The AMR programmes were used to connect the computer with the data–accumulating device. Data were transferred to the computer for their agronomical and thermo-physical analysis using STAT and ANOVA programs. As measurements of local plant tissue temperatures are very complicated, it is necessary to adhere strictly to the methodical temperature measurement requirements. The special experimental rig to investigate plant sensitivity to thermal exposure was used allowing adjustments of the exterminating medium temperature and the duration of the plant surface exposure to it.

For field experiments in 2005 we used the fourth version of our experimental tractor device as a mobile weed control machine using wet water vapour medium (Fig. 1). This machine was built in 2004 to facilitate investigation of the weed thermal extermination process and experience previously gathered. Investigations under laboratory and field conditions were carried out in 1997–2005 in barley, maize and onion crop fields. We carried out field experiments in the experimental station of the Lithuanian Agricultural University. Laboratory experiments were carried out in laboratories of the Agricultural, Thermal and Biotechnological Engineering departments of the University.

Fig. 1. Thermal weed extermination by the wet water vapour device.

RESULTS AND DISCUSSION

The plant tissue temperature variation observed during the thermal weed extermination process reveals further possibilities of weed control using wet water vapour. Based on the results of our investigation, we may deduce that the plant tissue heating process can be divided into three periods (Fig. 2): A–heating up of plant tissues, B–exposure to the constant temperature period, C–tissue cooling period. Duration of period A depends on perfection of the weed extermination device and high temperature medium used. It shows the efficiency of the thermal weed extermination process.Since period C - tissue cooling - is a natural process, the machine operator does not influence it.. Thus, the main evaluation index for the thermal weed extermination process is the local plant tissue temperature. The tissue temperature variation allows evaluation of the following**:** efficiency of the weed extermination process; thermal exposure duration of the plant; velocity of the whole aggregate in field, and the energy feasibility of the process.

Wet water vapour medium, if properly applied at the soil surface, causes the ring–shaped damage to the plant tissues (Fig. 3). The plant stem ring damage is lethal and the dying process continues.Duration of the plant decay process depends on microclimate conditions.

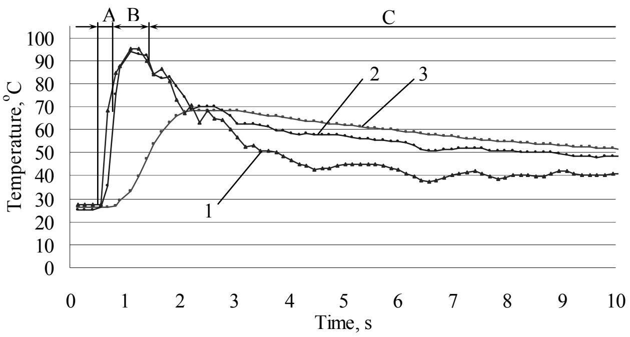

Fig. 2. Temperature variation in the barnyard grass plant and its medium: 1–in medium surrounding the plant, 2–on the plant surface, 3–in the branching nod of the plant. High temperature field is kept up for the period of 1.2 s. Barnyard grass (*Echinochloa crus–galli L.*) in the growth stage of two leaves. A, B and C–periods of the process of weed thermal extermination (see explanation in text).

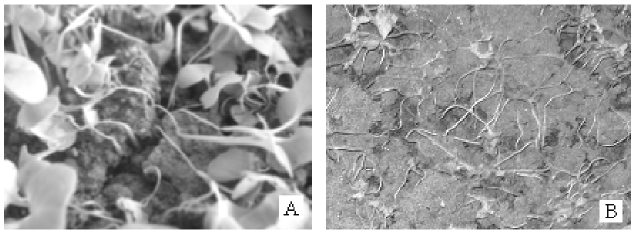

Fig. 3. The lethal process in plant tissues after the thermal damage: A–plants two days after exposure to wet water vapour, B–the same plants five days after exposure.

Thermal weed control by damp water steam was carried out in onion, barley and maize culture crops. Data of these investigations are in the Table 1.

Table 1. Influence of thermal weed control by damp water steam on onion, maize and barley yield and weed overgrow.

Culture	Yield	Differences with control		Dry weed mass	
	t ha^{-1}	t ha^{-1}	%	g m^{-2}	%
Onions (2000–2002)					
Manual weeding three times	4.766		100	19.29	100
Steaming two times	5.168	+0.402	108	10.93	57
LSD_{05}		0.387			
Barley					
Control	3.110		100	118.4	100
Steaming	3.780	+0.670	122	65.9	56
LSD_{05}		0.667			
Maize					
Control	30.75		100	320	100
Steaming	33.73	+2.98	110	128	40
LSD_{05}		12.6			

The best way to evaluate water steam effect on weeds is to exterminate germinated (up to 2 leaf) weeds. Extermination of later stage weeds is ineffective. To achieve good results for every culture, the growing technology should be coordinated with weed control technology and biological features of prevailing weeds.

The energetic balance of weed control by damp water steam equipment shows that only 2% of produced heat is used for weed control. 98% is heat waste. Fuel expenditures for 1 ha weed control are 25–40 l ha^{-1} (Sirvydas et al., 2003).

CONCLUSIONS

1. Thermal weed control by water steam offers an efficient, reliable, ecological and economical means of weed extermination.
2. Reducing the mass of weeds using damp water steam produces an inversely proportional increase of cultured plant yields.
3. Data of investigations and preliminary calculations show that in practice, energy input in weed control by water steam would be half that of flaming by gas technology.
4. Damp water steam effectively destroys short-life weeds; perennials can re-sprout.

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