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Rasa Staniulienė

THE IMPACT OF HIGH-TEMPERATURE ENVIRONMENT ON WEEDS HIGHLY RESISTANT TO THERMAL KILLING

Summary of the doctoral dissertation

Technological Sciences, Environmental Engineering and Landscape
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Rasa Staniulienė

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INTRODUCTION

The agriculture of today is oriented to organic farming in which the use of chemicals has to be reduced or is not allowed at all. One of the most burning issues in organic farms is ecological weed control. Improvement of the technology of thermal weed control has received an increasing attention worldwide.

As studies and practice show, not all weeds equally respond to the thermal effect when wet water vapour is applied for thermal weed control. After thermal destruction of the above-ground part some varieties of weeds spring up again. Analysis of the morphological structure of weeds and their responsiveness to wet water vapour allows weed classification into three groups: weeds of low resistance to thermal killing, those of high resistance to thermal killing (meadow-grass and rosette weeds) and of very high resistance to thermal killing. If the thermal control of these weeds is carried out too late, weeds overgrow cultivated plants, which results in harvest losses.

In order to improve the technology of thermal weed control it was necessary evaluate the parameters of a high-temperature environment, the morphological structure of weeds highly resistant to thermal killing, stages of weed growth and development, the influence of air inter-layers in weed leaves on the spread of a high-temperature field to deeper tissues, and the influence of the angle of tilt of weed leaves on thermal control. This paper analyses the influence of the aforementioned factors on the control of weeds highly resistant to thermal destruction and proposes measures for the formation of a high-temperature environment intended for a more efficient thermal control of weeds using wet water vapour.

The aim and tasks

In order to improve the technology of thermal weed killing the dissertation has set the aim to determine the influence of a high-temperature environment on highly resistant to thermal killing.

In pursuing this aim, the following tasks had to be dealt with:

- to perform an analysis of the factors having an influence of thermal control of weeds highly resistant to thermal killing in the environment of wet water vapour;
- to design a mathematical model of a temperature change in weed tissues and to determine the influence of air inter-layers on thermal destruction of weeds;
- To study the biological peculiarities of weeds highly resistant to thermal killing which have an influence on the efficiency of thermal weed control.

Scientific novelty and practical value

The doctoral dissertation analyses the peculiarities of formation of a high-temperature environment for weeds highly resistant to thermal killing. Modelling of the spread of a high-temperature field in the tissues of weeds highly resistant to thermal killing was performed for the first-ever time and it was determined that a temperature change in the tissues of weeds was suppressed by air inter-layers between leaves. It was determined that an extended duration of exposure to the thermal effect of a high-temperature environment was necessary to destroy weeds highly resistant to thermal killing. The influence of the growth stages of weeds, the angle of tilt of leaves and duration of exposure to the thermal effect of a high-temperature environment on the efficiency of thermal weed control was determined.

Scope of the paper

The dissertation consists of 80 pages and comprises an introduction, four chapters with 52 figures, conclusions and a list of 112 quoted references.

Defended propositions of the dissertation:

- the technology of thermal weed control needs to be adjusted according to the pollution of crops with weeds highly resistant to thermal killing;
- air inter-layers between leaves in weeds highly resistant to thermal killing suppress temperature increase in the central tissues;
- the efficiency of thermal control of weeds highly resistant to thermal killing depends on the compatibility of biological peculiarities of plants and thermal environment;
- an extended duration of exposure to the thermal effect of a high-temperature environment is required for a more efficient thermal control of weeds highly resistant to thermal killing.

1. RESEARCH REVIEW

Weed control in organic farms is determined by the distribution of weed varieties. Different varieties of weeds produce different degrees of damage to agricultural crops. The degree of weed damage to crops is determined not only by the amount of weeds but also by the uniformity of their distribution within a crop area. Weed control in an organic farm is aimed at preventing weed density to reach such a level which would have a negative impact on the productivity of agricultural crops (Krogere *et al*., 2004; Žekonienė ir kt., 2006).

Mechanical weed control is recommended only as a secondary means of weed-fighting however machines of worldwide application undergo regular improvement and are being automated in order to achieve the most efficient effect of weed killing and obtain a richer harvest (Motuzas ir kt., 2006; Rask, Kristoffersen 2007). Mechanical weed control is especially difficult in the crops of carrots, onions from seed and other long-germinating agricultural plants, requiring much manual labour, which results in a high cost of the produce. Many recent research works allow a conclusion that mechanical weed control can be replaced be thermal weed control. This is a promising weed control technique allowing weed killing in the cotyledon stage and discouraging germination of new weeds (Ascard, 1998; Vincent *et al.*, 2001; Leroux *et al.*, 2001; Lichtenhahn, *et al.*, 2005; Čekanauskas ir kt., 2006).

Water vapour-operated devices of thermal weed control were widely discussed in the doctoral dissertations of the department's scientists, which emphasised the fact that the same water vapour technology of thermal weed control may not be applied for all agricultural plants. Each agricultural plant variety requires an individual technology or growth and crop maintenance. The Lithuanian University of Agriculture has carried out research on thermal weed control since 1997. Five doctoral dissertations (Čėsna, 2000; Kerpauskas, 2003; Vasinauskienė, 2004; Čekanauskas, 2007; Čingienė, 2009) were defended and three inventions were recorded in the Republic of Lithuanian Register of Patients on this issue.

In thermal weed control it is appropriate to classify weeds according to their responsiveness to wet water vapour under three groups: weeds of low, high and very high resistance to thermal killing. Weeds of high resistance to thermal killing may be divided into two sub-groups: meadow-grass (annual meadow-grass (*Poa annua* L.), barnyard grass (*Echinochloa crus-galli L.)* etc.) and rosette (shepherd's-purse (*Capsella bursa-pastoris* L. Medik), broad-leaved plantain (*Plantago major* L.), dandelion (*Taraxacum officinale* L.), etc.

The specificity of thermal killing of these weeds lies in the fact that the destruction of their under-ground part alone is not enough.

In thermal weed control most questions are related to the group of weeds of high resistance to thermal killing (mead-grass and rosette) and, the dissertation, therefore, further widely analyses the peculiarities of these weeds having an influence on thermal weed control with wet water vapour.

The author's contribution to research on improving thermal weed control technologies can be described as follows:

1. A mathematical model intended for modelling temperature changes in the tissues of weeds highly resistant to thermal killing has been designed.
2. The influence of the air inter-layer of weeds highly resistant to thermal killing on the process of thermal weed killing has been investigated.
3. It has been determined that the efficiency of thermal weed control with regard to weeds highly resistant to thermal killing can be enhanced in two ways:
    - by extending the duration of exposure to the thermal effect;

- by considering the angle of tilt of weed leaves during thermal weed control.

4. Temperature change in the environment and tissues of weeds highly resistant to thermal killing depending on the stages of weed growth, the angle of tilt of leaves and duration of exposure to the thermal effect of a high-temperature environment was investigated.

2. THE METHODOLOGY OF EXPERIMENTAL RESEARCH

The object of research: weeds of high resistance to thermal killing (meadow-grass and rosette). Responsiveness of meadow-grass weeds (barnyard grass *Echinochloa crus-galli L.)* to the effect of wet water vapour was determined by performing research in seven established stages of growth depending on the number of leaves.

Responsiveness of rosette weeds (shepherd's-purse (*Capsella bursa pastoris* L. Medik) to wet water vapour was researched by analysing the responsiveness of shepherd's-purse to a high-temperature environment depending on the number of leaves and the angle of tilt of leaves. Depending on the stage of development of shepherd's-purse the plants were divided into four groups. Each group consisted of 10 plants. The first group comprised plants with the number of leaves $n<10$; the second group – $11<n<15$; the third group – $16<n<20$ and the fourth group – $n>21$. Determining the influence of the angle of tilt of shepherd's-purse leaves on its thermal killing with water vapour, the plants were divided into four groups. Each of the groups consisted of 10 plants. Plants in the first group had the angle of tilt of leaves $\beta<20^o$; in the second group – $21^o<\beta<30^o$; in the third group – $31^o<\beta<40^o$ and in the fourth group – $\beta>40^o$. The angle of tilt of shepherd's-purse leaves was measured with the instrument УВ – Хл4. The angles of tilt of leaves were determined with regard to the soil surface. The angle of tilt of plant leaves changes in the course of the day depending on solar irradiance falling on the plant surface. Irradiance falling on a plant surface was measured with the luxmeter MS6610 Mastech displaying a range of 0-50 000 lx with the measurement error of ± 5 %.

In a laboratory, planted plants were watered and grown for 4 to 5 days in order they could acclimatise and to reduce the effect of their transplantation on research to the minimum extent.

Temperature measurement. Temperature sensors, 0.07 mm in diameter, were used for temperature measurements in the tillering node or rosette. The temperature sensors were introduced into plant tissues in line with isotherm at a depth of least 100 diameters of the temperature sensor. The sensor introduced into plant tissues must have a good contact with plant tissues. Wiring from the sensor inlet to the device under measuring must be laid within the plant sprout or rosette at a length of around 200 diameters of the sensor.

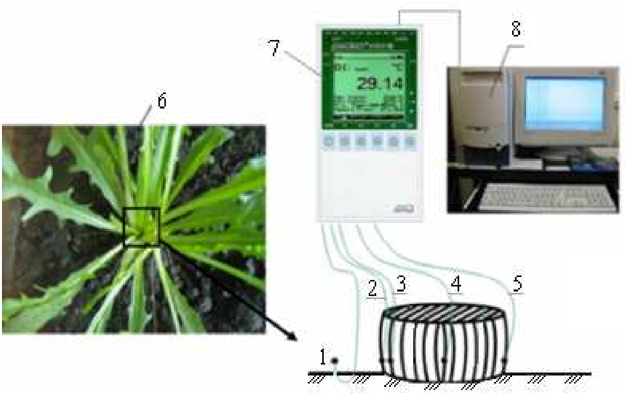

Fig. 1 The principle scheme of temperature measurement in shepherd's-purse (*Capsella bursa-pastoris* L.) during thermal weed killing: 1; 2; 3; 4; 5 – temperature measurement sensors in the plant and its environment; 6 – the plant under research (shepherd's-purse); 7 – ALMEMO 2590-9; 8 – computer.

The effect of water vapour on rosette plants (shepherd's-purse) was studied by measuring temperature in 5 points (Fig. 1). 1 – ambient temperature; 2 and 5 – temperature of the surface tissues of the plant; 3 – temperature under the first leaf; 4 – in the plant centre.

Temperature measurement in the tissues of meadow-grass plants (barnyard grass) was done by introducing six temperature sensors into the tillering node which displayed the temperature of the thermal environment (supplied vapour) of weeds; temperature change on the plant surface and temperature of the tillering node.

Data of temperature measurements were recorded with the data logger ALMEMO 2590-9 having microprocessor data processing and storage systems; ALMEMO measuring inlets (ZA 9000-FSU) were used. The recorded data from the accumulator were loaded on computer using a serial interface with AMR software for further data processing. To evaluate the error of temperature measurement, the arithmetic average $\overline{T}$, the average square deflection S and the error of the measurement data average $\Delta\overline{T}$ were calculated.

3. MODELLING OF THE EFFECT OF A HIGH-TEMPERATURE ENVIRONMENT ON WEEDS

In the process of weed killing with wet water vapour, the composition of a water vapour and air mixture changes. With the content of water vapour in the mixture decreasing the temperature of vapour condensation is also decreasing. This is clearly seen (Fig. 2) when temperature was measured on different sides of the plant leaf (leaf thickness was 1.65 mm). As the result shows, the difference of temperature on different sides of the leaf reaches up to 29.5±1.3 ^{o}C. This shows that during thermal weed control weed leaves bend down and protect sleeping weed buds or a weed stem from a higher temperature of vapour condensation. When sleeping buds or a stem appear in the local zone of an air and water vapour mixture they are protected against the effect of a high-temperature environment.

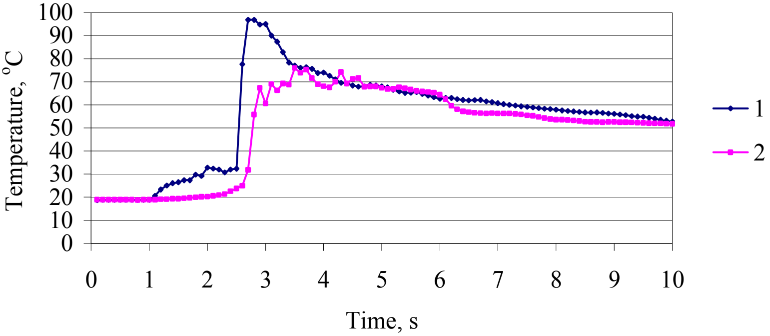

Fig. 2 The change of vapour condensation temperature on different sides of the plant leaf: 1 – temperature above the plant leaf; 2 – under the leaf.

Assessment of a high-temperature environment and biological factors of the plant. According to the morphological structure and heat spread in weed tissues, weeds exposed to thermal destruction can be divided into three groups: 1 – weeds of low resistance to thermal killing – these are weeds with a continuous stem (white goosefoot, chickweed, speedwell, dwarf snapdragon, gallant soldier, etc.); 2 – meadow-grass weeds of high resistance to thermal killing; the sprout of these weeds consists of twisted leaves (barnyard grass, annual mead-grass and others); 3 – rosette weeds of high resistance to thermal killing; these weeds are of a complicated geometrical form (shepherd's-purse, broad-leaved plantain, dandelion, etc.). The process of heat spread in plant tissues differs in different groups of plants. Therefore, it is important to evaluate differences in a temperature change process in weed tissues by considering their morphological features.

Modelling of temperature change in weed tissues. In order to model heat spread in the tissues of weeds exposed to thermal effect it is necessary to develop a plant model and set the initial and boundary conditions for the model in question. For the theoretical calculations of temperature of the thermal effect on weed tissues the following weed models were used:

Weeds of low resistance to thermal killing. In thermal weed control with wet water vapour the part affected thermally is a cylindrical continuous plant stem suffering from thermal effect perpendicularly (according to the normal) to the surface.

Meadow-grass weeds of high resistance to thermal killing. Weed has an infinite cylindrical shape and air spaces of a certain thickness, i.e. to thermal killing is responsive the cylindrical non-continuous sprout of the plant, which suffers from the thermal effect perpendicularly (according to the normal) to the surface (Fig. 3).

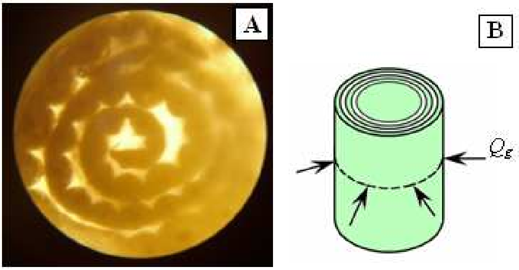

Fig. 3 Meadow-grass weed of high resistance to thermal killing: A – a microscopic section (increased by 20 times) of barnyard grass (*Echinochloa crus-galli L.*) sprout; B – model of the sprout.

Rosette weeds of high resistance to thermal killing. Weed is a body of a complicated geometrical form, which suffers from the thermal effect perpendicularly to the surface. Form of the body is determined by the number of weed leaves, thickness of leaves, the angle of tilt and the diameter of rosette (Fig. 4).

Modelling of temperature changes in the tissues of different varieties of weeds offers the possibility of identifying the impact of thermal control process on weeds and the opportunities of killing them thermally depending on their morphological structure.

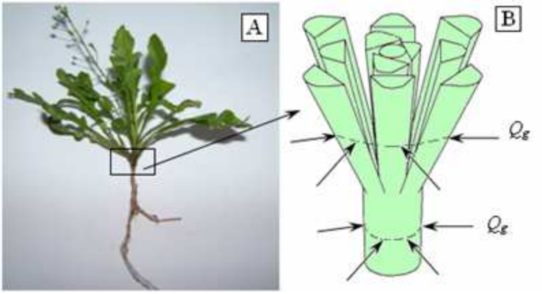

Fig. 4 Rosette weed of high resistance to thermal killing: A – shepherd’s-purse (*Capsella bursa-pastoris* L. Medik); B – rosette model.

A sharp change in the ambient temperature during exposure to the thermal effect conditions an unsettled temperature regime depending on the heat transfer coefficient and the contact of the plant and wet water vapour on the surface. Taking account of the fact that the length of weed stems is by 10-30 times bigger than their diameter, generally the regularities of an infinite cylinder can be applied for temperature changes in the plant and the temperature field in the inner layers of the plant can be expressed by the Fourier differential equation of heat conduction:

$$\frac{\partial t(r,\tau)}{\partial \tau} = \frac{\lambda}{c\rho}\left(\frac{\partial^2 t(r,\tau)}{\partial r^2} + \frac{1}{r}\frac{\partial t(r,\tau)}{\partial r}\right) = a\left(\frac{\partial^2 t(r,\tau)}{\partial r^2} + \frac{1}{r}\frac{\partial t(r,\tau)}{\partial r}\right), \qquad (1)$$

where: t – temperature °C of the plant of a cylindrical form;

r – range from the plant’s longitudinal centre-line outwards m;

τ – time s;

λ – heat conduction coefficient of the plant W/(m·K);

c – specific heat of the plant kJ/(kg·K);

ρ – density of the plant kg/m^3;

a – temperature conduction coefficient of the plant m^2/s.

To solve the differential heat conduction equation (1), setting of the boundary conditions is necessary. The temperature $t(r, \tau)$ of any point of plant’s inner layers at the initial moment of time ($\tau = 0$) is marked by t_{pr} and it is assumed to be steady. Therefore, the initial condition of the problem is described by the equation:

$$t(x,0) = t_{pr} = const\ . \qquad (2)$$

From the initial condition (2) it follows that at the initial moment of time ($\tau = 0$) temperature in plant layers thicknesses x_i does not depend on time.

The parameters of the ambient temperature, i.e. the temperature of wet water vapour and its changes, depending on the average heat transfer coefficient α /(m^2·K) being in the range of 50 000-100 000 W/(m^2·K), are assumed to be known. Considering the fact that the interest is directed to a short-term effect (1-3 s) of the temperature impulse, a steady temperature of contact of the plant's external surface and wet water vapour environment in points (when $\tau \neq 0$) is assumed, i.e. the first boundary conditions is as follows:

$$t\left(r_{iškor},\tau\right)=t_{iškor}=const\,. \qquad (3)$$

The second boundary condition is described on the assumption that the temperature of the plant's central axis within the entire heat exchange process is finite:

$$\frac{\partial t(0,\tau)}{\partial r}=0\,,\ t(0,\tau)\neq\infty\,. \qquad (4)$$

When a plant has a complex geometrical form a temperature change was analysed in the longitudinal section of stem-rosette. In this case the differential equation of heat conduction is as follows:

$$\frac{\partial t}{\partial \tau}=\frac{\lambda}{c\rho}\left(\frac{\partial^2 t}{\partial x^2}+\frac{\partial^2 t}{\partial y^2}\right), \qquad (5)$$

where $t(x, y,)$ – temperature of the point $^{\circ}$C;

To solve the differential equation of heat conduction (5), the equation (2) is assumed as the initial condition. To write down the boundary condition it is assumed that the temperature of plant's external surface contact with the environment of water vapour in points (when $\tau \neq 0$) is stable:

$$t\left(x_{iškor},\tau\right)=t_{iškor}=const\,. \qquad (6)$$

The second boundary condition is applied on the assumption that the temperature of plant’s central axes is finite within the entire process of heat exchange:

$$\frac{\partial t(0,\tau)}{\partial x}=0\,,\quad t(0,\tau)\neq\infty\,. \qquad (7)$$

An additional condition is introduced and it is assumed that plant’s stem-root is of infinite length and temperature in it remains stable irrespective of changes in the ambient temperature and time. Therefore, the additional condition is applied for a stem of infinite length:

$$t(\infty,\tau)=f(y)=const \text{ or } \frac{\partial t(\infty,\tau)}{\partial y} \qquad (8)$$

Taking account of the fact that a plant may consist of several layers and its geometrical form is complex, to solve the Fourier equation and to determine the temperature in the inner layers of the field plant the finite difference method was used. In modelling the differential equation of process's heat conduction was replaced with the equation of finite differences.

Calculation schemes on the plane xy. In all these cases temperature changes in weeds were modelled by attributing a certain typical section of the weed and considering the diameter of the weed, thicknesses of its leaves layers, the thickness of air inter-layers on the plane of the weed being destructed, and a complicated geometrical form (Fig. 5).

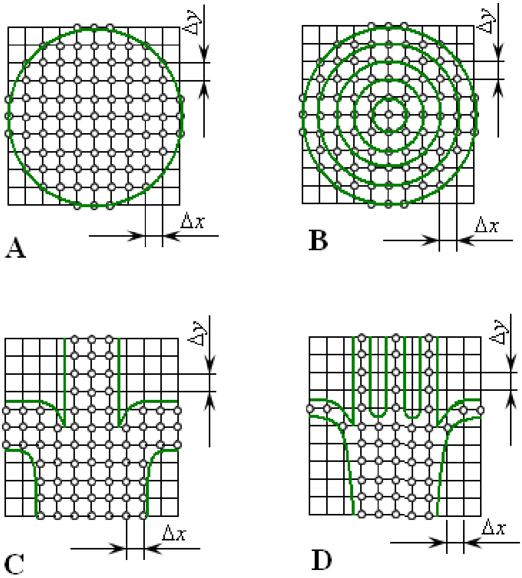

Fig. 5 Calculation schemes of lattices on the plane *xy* by the finite difference model. A – weed of low resistance to thermal killing; B – meadow-grass weed of high resistance to thermal killing; C, D – rosette weed of high resistance to thermal killing.

The following parameters were selected for calculations: the initial plant temperature – 25 °C; plant surface temperature in the environment of wet water vapour – 97 °C; heat conduction coefficient of the plant λ – 0.57 W/(m·K); heat conduction coefficient of the air inter-layer λ –0.0267 W/(m·K), no impurities of non-condensing gas are present, vapour is homogeneous, heat transfer coefficient of the water vapour α – 100000 W/(m^2·K).

After making calculations, temperatures in all weed section nodes at certain time moments of the impact of wet water vapour were obtained and the change of temperature field in weed tissues was determined.

The results of modelling temperature change in weed tissues and their assessment. As the data of modelling show, temperature change in the central tissues of weeds of low resistance to thermal killing depends on a plant diameter (Fig. 6).

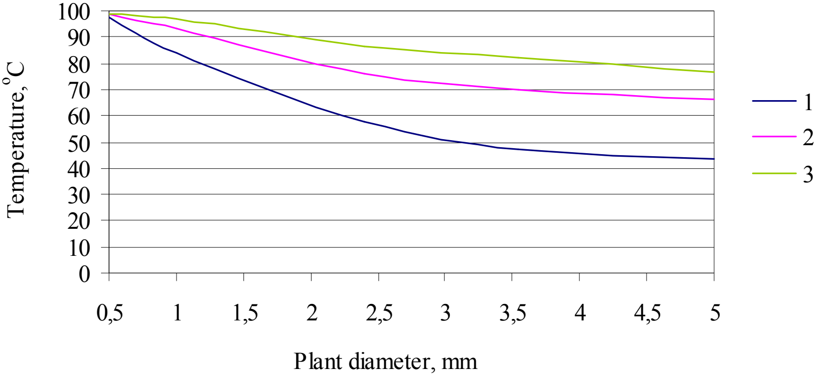

Fig. 6 Temperature change in the central tissues of weeds of low resistance to thermal killing depending on the diameter during thermal weed control: 1, 2, 3 – durations of the thermal effect is 1 s, 2 s, 3 s.

According to data analysis, with weed diameter increasing temperature in the central tissues of weeds of low resistance to thermal killing is decreasing during thermal weed control. A time of exposure to the impact of a high-temperature environment of 1 s is not enough to thermally destroy weeds of low resistance to thermal killing having a stem over 2.4 mm in diameter.

As regards weeds of high resistance to thermal destruction, with weed diameter and the thickness of air inter-layer between leaves increasing temperature in the central tissues of weeds is decreasing. Fig. 7 shows the impact of air inter-layer temperature in the central tissues of 2.4-diameter weed.

As determined by theoretical studies of temperature change in weed tissues, temperature changes are impacted by the morphological structure of weeds, the duration of exposure to a high-temperature environment and weed diameter. According to data analysis, with weed diameter increasing temperature in the central tissues of weeds of low resistance to thermal killing is decreasing during thermal weed control. As regards weeds of high resistance to thermal destruction, with weed diameter and the thickness of air inter-layer between leaves increasing temperature in the central tissues of weeds is decreasing.

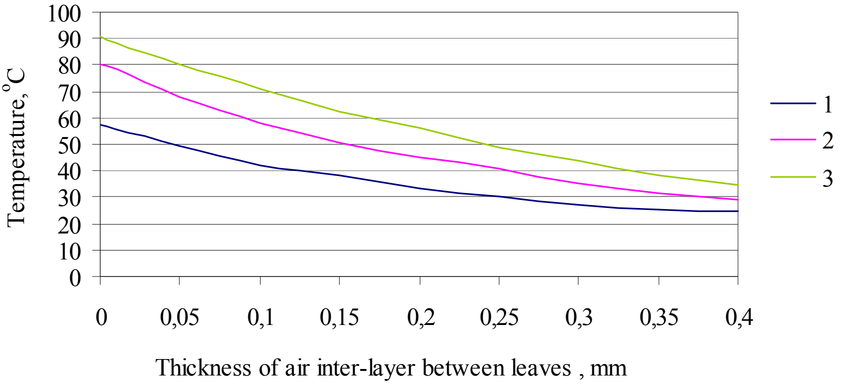

Fig. 7. The impact of an air inter-layer on a temperature change in the central tissues of weed, 2.4 mm in diameter, during thermal weed control: 1, 2, 3 – durations of the thermal effect is 1 s, 2 s, 3 s.

The performed modelling of temperature change in weed tissues allows an assessment of the impact of the morphological structure of plants, air inter-layers and duration of exposure to a high-temperature environment on the thermal weed control with wet water vapour.

4. THE RESULTS AND ASSESSMENT OF EXPERIMENTAL RESEARCH

Temperature change in the tissues of meadow-grass weeds. As determined by experimental research on temperature measurement in barnyard grass and its environment, this weed has the lowest resistance to thermal destruction in the growth stage of one-two leaves. The tillering stage of barnyard grass begins when the weed has 3-5 leaves. When the weed is in the growth stage of 3 leaves, the plant forms sleeping buds. Owing to intensive root development and the start of the tillering stage, the tillering node of barnyard grass is drawn into soil. Thus, the plant protects the tillering node against unfavourable environmental factors and the thermal effect. Already in the growth stage of 3 leaves of barnyard grass an extended duration of exposure to the thermal effect of a high-temperature environment is necessary to destroy it thermally. When canvas is additionally used by water vapour spreaders, the period of cooling and at the same time the duration of thermal effect are extended. When the duration of thermal effect is extended in the aforementioned way, the thermal killing of meadow-grass weeds before the stage of tillering becomes more efficient.

Data on the responsiveness of barnyard grass to the environment of wet water vapour in different growth stages of the plants and at different durations of the thermal effect of a high-temperature environment as well as the extended duration of the thermal effect of a high-temperature environment are presented in Fig. 8.

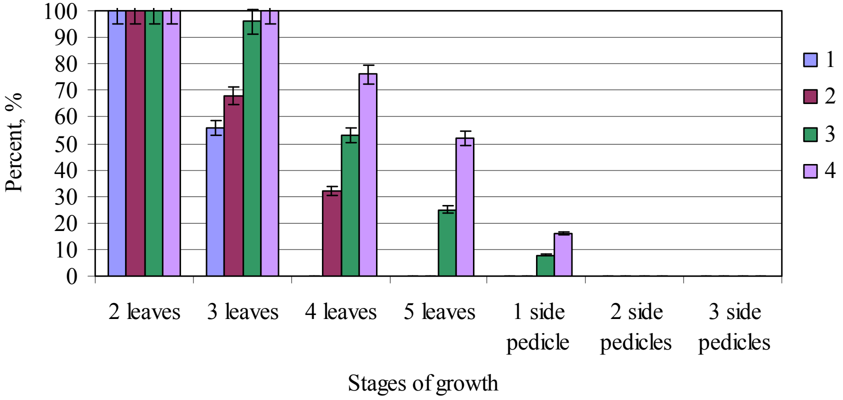

Fig. 8 The impact of growth stages of barnyard grass (*Echinochloa crus-galli* L.) on its thermal destruction: 1, 2, 3 – durations of the thermal effect is 0.8 s, 1.2 s, 2.4 s; 4 – extended duration of the thermal effect of a high-temperature

The performed studies on the peculiarities of thermal control of meadow-grass weeds show that the major impact on thermal control is done the weed growth stage-plant diameter. The barnyard grass is the most responsive to thermal effect in the growth stage of 2 leaves when it is destroyed 100 per cent at different durations of exposure to thermal effect. An extended duration of the thermal effect of a high-temperature environment has to be applied in other stages of growth. When the stage of tillering starts, thermal killing of barnyard grass becomes complicated.

Temperature change in the tissues of rosette weeds. Temperature measurements done in the tissues of shepherd's-purse and its environment during thermal weed control displayed the regularities of temperature changes depending on the number of leaves.

As the data given in Fig. 9 show, the dependence of shepherd's-purse destruction on the number of its leaves can be divided into three groups: Group I – the shepherd's-purse with less than ten leaves is killed 100 % during thermal weed control; Group II – when the number of leaves is 11-19 the shepherd's-purse is destroyed 50 %, which depends of the angle of tilt of shepherd's-purse leaves; Group III – the shepherd's-purse is very heavy with 20 leaves and more and the plants are not killed. Therefore, it can be stated that the destruction of shepherd's-purse directly depends on the number of leaves. With the number of leaves of shepherd's purse increasing temperature in the rosette is decreasing and the degree of the thermal destruction of this weed, therefore, is also decreasing (Fig. 9).

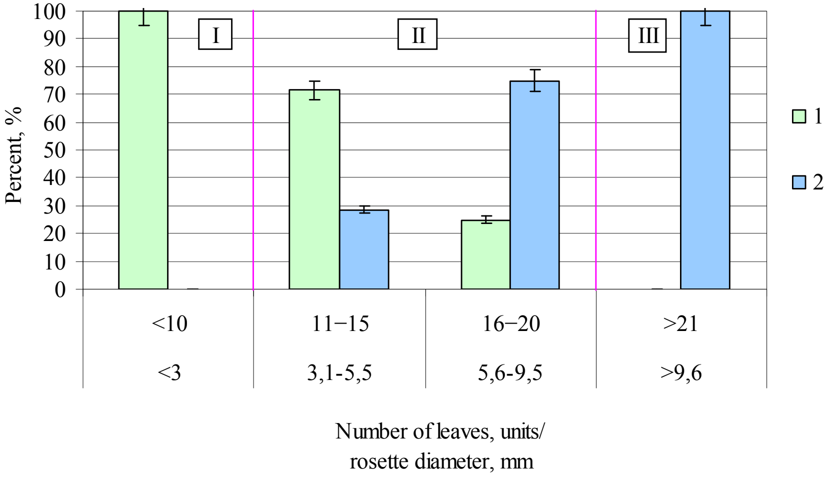

Fig. 9 The impact of the number of leaves and the rosette diameter of shepherd's-purse (*Capsella bursa-pastoris* (L.) Medik) on thermal destruction of the weeds. 1 – Destroyed plants after thermal control; 2 – non-destroyed plants after thermal control

Results of the performed research show that the destruction of shepherd's-purse is impacted not only by the number of its leaves but and also by the angles of tilt of shepherd's-purse leaves from the soil surface. During research on shepherd's-purse it has developed that the angle of tilt of leaves has a major importance for its destruction in the growth stage of 11-15 leaves. As the performed studies on the peculiarities of destruction of shepherd's-purse in the environment of wet water vapour show, the weed's responsiveness to the environment of wet water vapour differs depending on the angles of tilt of leaves: the plant destruction rate is around 70 % when the angle of tilt of shepherd's-purse leaves from the soil surface is up to 20°; the best rate of plant destruction, up to 80 %, is achieved when the angle of tilt is 21-30°. With the angle of tilt further increasing the rate of shepherd-s-purse destruction is decreasing (Fig. 10).

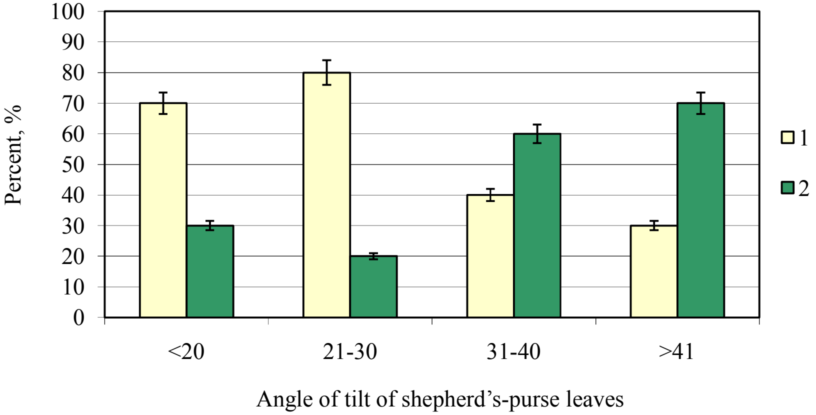

Fig. 10 The influence of the angle of tilt of shepherd's-purse leaves on thermal weed control. 1 – Destroyed plants after thermal control; 2 – non-destroyed plants after thermal control

The angle of tilt of weed leaves changes in the course of the day. Data of this research allows a conclusion that where the shepherd's-purse is dominated by horizontal leaves thermal weed control with wet water vapour has to be applied before 12:00; where the shepherd's-purse is dominated by vertical leaves thermal weed control with wet water vapour has be applied from 12:00 to 18:00. If thermal weed control is applied at unsuitable time the shepherd's-purse will spring up again.

CONCLUSIONS

1. The efficiency of a high-temperature water vapour environment for weeds highly resistant to thermal killing depends not only on a stage of growth, duration of thermal effect, pollution of crops with weeds but also on biological peculiarities.
2. An air inter-layer between the leaves of the multi-layer weeds highly resistant to thermal killing suppresses a temperature increase in the central tissues, which has an influence on the resistance of the weeds to thermal control.

3. The efficiency of thermal weed control with wet water vapour depends on the biological peculiarities of weeds highly resistant to thermal killing (meadow-grass and rosette):

- Meadow-grass weeds (barnyard grass (*Echinochloa crus-galli* L.)) are the most sensitive to a high-temperature environment in the growth stage of one-two leaves. An extended duration of the thermal effect of a high-temperature environment has to be applied in other stages of growth.
- Rosette weeds (shepherd's-purse (*Capsella bursa-pastoris* L. Medik)) are the most sensitive to a high-temperature environment in the growth stage of up to 10 leaves. The rate of thermal destruction depends on the angle of tilt of leaves when the number of leaves is 11-15.

4. The angle of tilt of leaves of rosette weeds highly resistant to thermal killing changes in the course of the day and thermal weed control, therefore, has to be carried out taking account of the dominating angle of tilt of rosette weed leaves. In case of predominance of vertical leaves thermal weed control has to be carried out between 12:00 and 18:00, and in the event of horizontal leaf predominance, thermal weed control has to be applied before 12:00.

5. It has been determined experimentally that upon extending the duration of the thermal effect of a high-temperature environment, the barnyard grass (*Echinochloa crus-galli L.*) is thermally destroyed in 52 % of the cases in the 5-leaves growth stage. When the stage of tillering starts, the barnyard grass is not destroyed thermally.

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ABOUT THE DISSERTATION AUTHOR

Rasa Staniulienė was born on 2 October 1980 in Raguva Town (Panevėžys district). In 1999 – graduated from Raguva Secondary School. In 2003 – was awarded Bachelor’s of Mechanical Engineering (specialisation – engineering of agricultural production technologies) and in 2005 – Master’s qualification degrees at the Department of Agricultural Machinery, the Lithuanian University of Agriculture (LŽŪU) Faculty of Agricultural Engineering. From 2005 until 2010 – doctoral student in the area of environment and landscape sciences of the study field of technological sciences at LŽŪU.

REZIUMĖ

Šiandieninis žemės ūkis orientuojamas į ekologinį žemės ūkį, kuriame cheminių medžiagų naudojimas yra sumažintas ar net negalimas. Vienas iš sunkiausiai sprendžiamų klausimų ekologiniuose ūkiuose yra ekologiška piktžolių kontrolė. Pasaulyje didelis dėmesys skiriamas terminės piktžolių kontrolės technologijos tobulinimui.

Tyrimai ir patirtis rodo, kad naudojant terminei piktžolių kontrolei drėgną vandens garą, ne visos piktžolės vienodai reaguoja į terminį poveikį. Termiškai sunaikinus antžeminę dalį, atskiros piktžolių rūšys po kurio laiko atželia. Išnagrinėjus piktžolių morfologinę sandarą ir piktžolių jautrumą drėgnam vandens garui, galima piktžoles suskirstyti į tris grupes: lengvai termiškai sunaikinamos, sunkiai termiškai sunaikinamos (miglinės ir skrotelinės piktžolės) ir labai sunkiai termiškai sunaikinamos piktžolės. Terminėje piktžolių kontrolėje didelę problemą kelia sunkiai termiškai sunaikinamos piktžolės. Suvėlinus šių piktžolių terminę kontrolę, piktžolės stelbia žemės ūkio augalus, patiriami derliaus nuostoliai.

Norint tobulinti piktžolių terminės kontrolės technologiją teko įvertinti aukštatemperatūrės aplinkos parametrus, sunkiai termiškai sunaikinamų piktžolių morfologinę sandarą, piktžolių augimo ir vystymosi tarpsnius, piktžolių lapų oro tarpsluoksnių įtaką aukštatemperatūrio lauko plitimui į gilesnius audinius, piktžolių lapų posvyrio kampo įtaką terminei kontrolei. Šiame darbe yra nagrinėjama minėtų veiksnių įtaka sunkiai termiškai sunaikinamų piktžolių kontrolei, bei siūlomos

sprendimo priemonės formuojant aukštatemperatūrę aplinką efektyvesnei terminei piktžolių kontrolei drėgnuoju vandens garu.

Tikslas ir uždaviniai

Darbo tikslas – nustatyti aukštatemperatūrės aplinkos poveikį sunkiai termiškai sunaikinamoms piktžolėms.

Siekiant įgyvendinti tikslą reikėjo išspręsti šiuos uždavinius:

- atlikti veiksnių, turinčių įtakos sunkiai termiškai sunaikinamų piktžolių terminei kontrolei drėgno vandens garo aplinkoje, analizę.
- sudaryti matematinį modelį temperatūros kitimui piktžolių audiniuose ir nustatyti oro tarpsluoksnio įtaką piktžolių terminiam sunaikinimui;
- ištirti sunkiai termiškai sunaikinamų piktžolių biologinius ypatumus, turinčius įtakos terminės piktžolių kontrolės efektyvumui.

Mokslinis naujumas ir praktinė reikšmė

Disertacijoje sprendžiami iki šiol netyrinėti aukštatemperatūrės aplinkos formavimo ypatumai sunkiai termiškai sunaikinamoms piktžolėms. Pirmą kartą atliktas aukštatemperatūrio lauko plitimo sunkiai termiškai sunaikinamų piktžolių audiniuose modeliavimas ir nustatyta, kad temperatūros kitimą piktžolių audiniuose slopina oro tarpsluoksniai tarp lapų. Nustatyta, kad sunkiai termiškai sunaikinamoms piktžolėms sunaikinti reikalinga prailginta aukštatemperatūrės aplinkos terminio poveikio trukmė. Ištirta piktžolių augimo tarpsnių, lapų posvyrio kampo ir aukštatemperatūrės aplinkos terminio poveikio trukmės įtaka terminės piktžolių kontrolės efektyvumui.

Darbo apimtis

Disertacijos apimtis 80 puslapių, ją sudaro įvadas, keturi skyriai su 52 paveikslais, išvados, cituotų 112 literatūros šaltinių sąrašas.

Ginamieji disertacijos teiginiai:

- terminę piktžolių kontrolę reikia derinti prie pasėlio užterštumo sunkiai termiškai sunaikinamoms piktžolėmis.
- sunkiai termiškai sunaikinamose piktžolėse, esantys oro tarpsluoksniai tarp lapų, slopina temperatūros didėjimą centriniuose audiniuose;
- terminės piktžolių kontrolės efektyvumas priklauso nuo sunkiai termiškai sunaikinamų piktžolių biologinių ypatumų;
- sunkiai termiškai sunaikinamų piktžolių efektyvesnei terminei kontrolei reikalinga prailginta aukštatemperatūrės aplinkos terminio poveikio trukmė.

IŠVADOS

1. Aukštatemperatūrės drėgno vandens garo aplinkos efektyvumas sunkiai termiškai sunaikinamoms piktžolėms priklauso ne tik nuo augimo tarpsnio, terminio poveikio trukmės, pasėlio užterštumo piktžolėmis, bet ir biologinių ypatumų.
2. Daugiasluoksnėse sunkiai termiškai sunaikinamose piktžolėse esantis oro tarpsluoksnis tarp lapų slopina temperatūros didėjimą centriniuose audiniuose, tai turi įtakos piktžolių atsparumui terminei kontrolei.
3. Terminės piktžolių kontrolės drėgnu vandens garu efektyvumą įtakoja sunkiai termiškai sunaikinamų (miglinių ir skrotelinių) piktžolių biologiniai ypatumai:
   - Miglinės piktžolės (paprastoji rietmenė (*Echinochloa crus-galli* L.)) jautriausios aukštatemperatūrei aplinkai vieno-dviejų lapelių augimo tarpsnyje. Kituose augimo tarpsniuose reikalinga prailginta aukštatemperatūrės aplinkos terminio poveikio trukmė.
   - Skrotelinės piktžolės (trikertė žvagine (*Capsella bursa-pastoris* L. Medik)) jautriausios aukštatemperatūrei aplinkai iki 10 lapelių augimo tarpsnio. Kai lapelių skaičius yra 11-15, terminį sunaikinimą įtakoja lapų posvyrio kampas.
4. Sunkiai termiškai sunaikinamų skrotelinių piktžolių lapų posvyrio kampas kinta dienos metu, todėl terminę piktžolių kontrolę reikia vykdyti įvertinus skrotelinių piktžolių dominuojantį lapų posvyrio kampą. Kai dominuoja vertikalūs lapai, terminę piktžolių kontrolę vykdyti tarp 12-18 h, kai dominuoja horizontalūs lapai – terminė piktžolių kontrolė turi būti atlikta iki 12 h.
5. Eksperimentiniais tyrimais nustatyta, kad prailginus aukštatemperatūrės aplinkos terminio poveikio trukmę, paprastoji rietmenė (*Echinochloa crus-galli* L.) 5 lapelių augimo tarpsniu termiškai sunaikinama 52 %. Prasidėjus krūmijimosi tarpsniui, paprastoji rietmenė termiškai nesunaikinama.

APIE DISERTACIJOS AUTORĘ

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