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The effects of water steam on weeds and fungal diseases in the stands of onion

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Abstract

The experiment was conducted in the fields of farmers in Kaunas (in 2012), Vilkaviškis (in 2013) and Rietavas (in 2014) districts, Lithuania. The aim of the study was to ascertain the effects of water steam as a weed and fungal disease control method in the common onion (*Allium cepa* L.) stand. The trials were carried out according to the following design: 1) weeds were hand-weeded three times: the first hand-weeding was performed after mass emergence of weeds, 9–11 days after planting of onions; the second and third hand-weeding operations were carried out after emergence of weeds at a 2–3 leaf growth stage of weeds; 2) thermal weed control using water steam was carried out twice per growing season with the duration of weeds and onions exposure to steam of 2 seconds; thermal weed control was applied on the entire experimental plot, i.e. all over the plot, without protection of onion plants against exposure to steam; 3) thermal weed control using water steam was carried out twice per growing season with the duration of weed exposure to steam of 2 seconds. Thermal weed control was applied only in the inter-rows at a seedling stage of weeds. The impact of water steam on the onion bulbs was partial.

The findings of the current study suggest that the application of water steam all over the trial plots, twice per growing season gave the most effective control of weeds in the stands of onion. Water steam treatment was found to reduce the occurrence of fungal diseases in the onion stand. The severity of downy mildew in the plots treated with water steam decreased by 52.5–739%, compared with the control plots. The steam treatment all over the trial plots reduced the severity of white rot of onion by 43.5–46.9%. Steaming all over the plots diminished the onion neck rot infection level on onion plants by 68.0–86.1%, while inter-row steaming reduced the disease pressure by 33.3–83.7%. The yield of common onion bulbs in our study ranged from 4.06 to 5.41 kg m^{-2}. A statistically significantly higher yield of onion bulbs was produced in the treatment where steaming had been applied all over the plots compared with the hand-weeded plots.

Key words: *Allium cepa*, mildew, neck rot, onion yield, water steam, weeds, white rot.

Introduction

A major problem that organic farmers face is weed management (Edesi et al., 2012). In most organic farms, weeds are controlled mechanically (Jodaugienė et al., 2008; Van der Weide et al., 2008; Fontanelli et al., 2009; Pannacci, Tei, 2014). Another increasingly used weed control method is thermal weed control. Thermal weed control can be used in various crops (Shrestha et al., 2013; Velička et al., 2016) In different countries, diverse methods of thermal weed control are used in organic farms: flaming (Sivesind et al., 2012), combustion gases (Ulloa et al., 2010; 2012; Datta, Knezevic, 2013), hot foam (Cederlund, Börjesson, 2016), hot water (De Cauwer et al., 2014) and water steam (Melander, Kristensen, 2011; Shrestha et al., 2012; Vidotto et al., 2013). Researchers have indicated that thermal weed control is more effective than mechanical weed control (Virbickaitė et al., 2006; Ascard et al., 2007). However, other researches came up with opposite conclusions (Velička et al., 2016).

Onions are sensitive to weeds. It has been found that 90% of changes in bulb yield depend on the weed infestation level. The literature data suggest that thermal weed control in the onion crop destroys weeds and increases onion yield (Kerpauskas et al., 2009; Sivesind et al., 2012). Yield increase is influenced by the two factors: non-disturbance of onion root system in the vegetative season and thermal stress, which causes partial injury to the onion neck. In our study we noticed

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a third factor, which is a decrease of fungal diseases in the onion stand.

Fungal diseases in onion are a relevant problem. One of the most devastating diseases of onions is downy mildew (*Peronospora destructor* (Berk.) Casp. ex Berk.), which occurs annually in the onion production areas. The outbreaks of downy mildew can result in up to 20–30% yield losses in the field during the onions growing season. Downy mildew also infects bulb tissue, resulting in bulbs that become soft and shrivelled in storage. It is important to identify factors influencing the occurrence of this disease in order to protect crops and obtain the highest possible onion yield. The inoculum of the downy mildew overwinters in onion bulbs and in the residues of the diseased plants, or as mycelium in the planting material. If the weather is humid, 1% of infected plants are sufficient to infect the entire crop (Abkhoo, 2012).

White rot of onion (*Stromatinia cepivora* (Berk.) Whetzel.) also infects onion bulbs. The disease infects whole plants and the yield is lost. Sclerotia remain viable in the soil for several years and can infect healthy plants (Southwood et al., 2015).

Onion neck rot (*Botrytis allii* Munn., *Botrytis cinerea* Pers., *Botrytis* spp.) affects leaves and bulbs of onion (Rasiukevičiūtė et al., 2016). The rots caused by the *Botrytis* spp. fungi in Lithuania and in the rest of the world result in yield losses ranging from 15–20% to 50%. The optimal weather conditions for the spread of rots and no use of fungicides cause severe epiphytotics of the disease (Valiuškaitė et al., 2010).

The use of thermal weed control affects not only weeds but also pests, pathogenic microorganisms, as well as disease causal agents of crops. There is very little data about the effect of the thermal control on fungal diseases of plants. The literature data indicate that water steam reduced verticillium and dark leaf and pod spot incidence in winter oilseed rape crop (Marcinkevičienė et al., 2018) and flaming reduced blossom end rot incidence in tomato (Wszelaki et al., 2007).

The current study aimed to determine the effects of water steam used as a thermal control method on weeds and fungal diseases in onions.

Materials and methods

The sites of field trials. In 2012, field trials were conducted in Kaunas district, Cinkiškiai village on an *Epicalcari Endogleyic Cambisol* (*CM-gln.cap*) with a texture of light loam on moderately heavy loam. In 2013, field trials were carried out in Vilkaviškis district, Klausučiai village on a *Haplic Epigleyic Luvisol* (*LV-glp. ha*) with a texture of sandy loam on light sandy loam. In 2014, field trials were done in Rietavas district, Sauslaukio village on an *Endogleyic Eutric Planasol* (*PL-eu.gln*) with a texture of light sandy loam on moderately heavy loam. The soils are classified according to WRB (2014). A common onion (*Allium cepa* L.) cultivar 'Centurion' F_1 was grown in the field trials. The onions were planted in rows with a 25 cm distance between rows and a 7 cm distance between plants. The experiment was laid out in four replications. The plots were arranged in a random order. The size of experimental plot was 21 m^2.

The following experimental design was used: 1) manual weed control: weeds were hand-weeded three times; the first hand-weeding was performed after the mass emergence of weeds, 9–11 days after planting of onions; the second and third hand-weeding operations were carried out after emergence of weeds at a 2–3 leaf growth stage of weeds; 2) water steam on entire plots: thermal weed control using water steam was performed twice per growing season with the duration of weed exposure to steam of 2 seconds; thermal weed control was applied on the entire experimental plot, i.e. all over the plots, without the protection of onion plants against the effects of exposure to steam; 3) water steam on inter-rows: thermal weed control using water steam was carried out twice per growing season with the duration of weed exposure to steam of 2 seconds. Thermal weed control was applied only in the inter-rows at a seedling stage of weeds. The impact of water steam on the onion bulbs was partial.

Weeds were counted before each steaming and 5 days after each steaming in four 0.25 m^2 spots of each plot. Within the first ten-day period of July, weeds were counted in all treatments, and their air-dry mass was determined.

The following fungal diseases were assessed in the onion stand: downy mildew, white rot and neck rot. The fungal diseases were assessed only in 2013 and 2014.

Disease assessment before harvesting was conducted in 4 spots of each trial plot on 10 plants per row. The infected plants were counted and the disease incidence, expressed in percent, was calculated as follows (Žemės ūkio augalų kenkėjai…, 2002): $P = n \times 100 / N$, where P is disease incidence, %, n – the number of diseased plants, N – the total number of inspected plants.

Disease severity was calculated according to the following formula: $R = [\Sigma (n \times b)] / N$, where $\Sigma (n \times b)$ is the number of leaves with the same infection score or percentage and the sum of products of severity value, N – the total number of leaves scored.

The onions crop was harvested on 10–15 August from four spots of each trial plot from one square meter.

In 2012, the average daily temperature of May and the amount of rainfall were close to the standard climate normal (SCN). June was cool and rainy. The amount of rainfall was 34% higher than the SCN. July was warmer than usual, and the amount of rainfall exceeded the SCN by 1.5 times. The average daily temperature and the amount of rainfall of the first ten-day period of August were close to the SCN.

In 2013, May was warm; the average daily temperature was 2.7°C higher than the SCN. The amount of rainfall was close to the normal. June was warm and dry with an average daily temperature exceeding the SCN by 2.8°C, whereas the amount of rainfall was 1.6 times lower than the normal. The average daily temperature of July was close to the SCN, and the amount of rainfall was 1.5 times higher than the SCN. The first ten-day period of August was warm with a sufficient amount of rainfall. In 2014, May was moderately warm and rainy. In June, the weather became cooler, with ununusually cool third ten-day period when the average daily temperature was by 3 degrees lower than the SCN, while the amount of rainfall was close to the SCN. The average daily temperature of July was 2.5°C higher than the SCN, whereas the amount of rainfall was close to the standard climate normal. The first ten-day period of August was warm and dry.

The trial data were statistically processed using the analysis of variance (*ANOVA*) (Raudonius, 2017). The experimental data that did not fit the normal distribution law were transformed using the function y = lnx + 1 prior to the statistical evaluation.

Results and discussion

The predominant broadleaf annual weed species in the onion stand during the trial period were as follows: white goosefoot (*Chenopodium album* L.), common chickweed (*Stellaria media* (L.) Vill.), shepherd's purse (*Capsella bursa-pastoris* (L.) Medik.) and field pennycress (*Thlaspi arvense* L.). The broadleaf perennial weeds found in the trial plots were as follows: corn thistle (*Cirsium arvense* L. Scop.) and field sowthistle (*Sonchus arvensis* L.). The monocot weed species found in the trial plots were as follows: couch grass (*Elytrigia repens* (L.) Nevski) in 2012–2014 and barnyard grass (*Echinochloa crus-galli* (L.) P. Beauv.) in 2013–2014.

The number of weeds estimated before the first application of steam was similar in all trial treatments (Table 1). There were found differences in weed counts only between experimental years. Five days after application, steam treatments were shown to reduce the weed counts by 84.9–97.6%.

Table 1. Number of weeds m^{-2} in the stands of onion

Treatment	2012	2013	2014
Before 1st weed control			
Manual weed control	21.3	31.7	35.2
Water steam on entire plots	20.8	32.8	36.9
Water steam on inter-rows	18.0	25.5	40.1
LSD_{05}	2,32	3.41	4.15
After 1st weed control			
Manual weed control	2.0	3.5	2.8
Water steam on entire plots	0.5	1.0	0.9
Water steam on inter-rows	2.1	2.8	3.4
LSD_{05}	1.37	0.89	1.02
Before 2nd weed control			
Manual weed control	46.5	37.8	25.2
Water steam on entire plots	26.5	17.0	18.4
Water steam on inter-rows	37.2	29.8	21.7
LSD_{05}	4.13	5.26	3.85
After 2nd weed control			
Manual weed control	3.5	2.2	2.1
Water steam entire	1.8	1.2	0.9
Water steam inter-rows	4.8	5.0	6.2
LSD_{05}	0.83	0.95	0.77

The steam treatment was applied for the second time on 20–25 June. During the second steaming, it was noticed that in 2012 the emergence of weeds was more intensive, while in 2014 it was less intensive compared with the first emergence of weeds. The intensity of weed emergence was found to be associated with the weather conditions. In 2012, the whole month of June was rainy, whereas in 2014 the first half of June was dry. The amount of rainfall during the second and third ten-day periods of this month was close to the standard climate normal; however, the amount of rainfall was unevenly distributed: there were two days with heavy rain and the rest of the period was without rain. Before the second application of steam, the weed counts were significantly lower in the plots treated with water steam, compared with hand-weeded plots. Steam treatment affected not only already emerged weeds but also emerging weeds. Five days after the second application of steam, the weed counts in the steam-treated plots had decreased by 71.4–95.1%.

During both steam treatments, higher weed counts were identified in the plots where steam treatment had been applied only on inter-rows. The weeds that grew in the rows between the onion plants were either not affected by steaming at all or affected only partially.

In order to estimate the efficacy of steaming, weed counts were made and weed air-dry mass was determined one month after the last application of steam (Table 2). In 2012 and 2013, in the trial plots where steam had been applied only in the inter-rows, weed counts were higher than in the plots in which steaming had been applied all over the plots; however, the differences were not significant. The air-dry mass of weeds from the plots where steaming was applied in the inter-rows was statistically significantly higher than in the plots of treatments 1 and 2 in all experimental years.

Table 2. Number of weeds and air-dry mass one month after the last weed control

Treatment	2012	2013	2014
Number of weeds m^{-2}			
Manual weed control	10.5	10.5	8.3
Water steam on entire plots	10.2	12.8	10.8
Water steam on inter-rows	12.3	14.3	7.6
LSD_{05}	2.18	1.96	1.83
Air-dry mass g m^{-2}			
Manual weed control	13.10	11.77	12.90
Water steam on entire plots	10.38	16.00	9.95
Water steam on inter-rows	22.15	18.34	15.27
LSD_{05}	1.82	1.73	2.18

Steam application as a weed control method in the onions was shown to reduce disease incidence as well. In order to accurately estimate the effects of steaming on onion diseases, we carried out assessments of fungal diseases at the beginning of August, before harvesting in 2013 and 2014. In both experimental years, onion leaves were most severely affected by downy mildew (agent *Peronospora destructor* Berk. Fr.) (Table 3). The disease affected 15.2–39.9% of onion leaves and the disease severity ranged from 1.52% to 10.49%. Onions

Table 3. Downy mildew incidence and severity in the stands of onion, %

Treatment	Incidence		Severity	
	2013	2014	2013	2014
Manual weed control	39.9 a	25.1 a	10.49 a	5.83 a
Water steam on entire plots	26.0 b	15.2 a	3.79 b	1.52 b
Water steam on inter-rows	29.2 ab	18.3 a	4.98 b	2.16 b

Note. The differences between the averages of treatments marked by not the same letter (a, b) are significant ($P < 0.05$).

were more severely affected by downy mildew in 2013 when the weather before harvesting was relatively warm, and the amount of rainfall was high. In both trial years, steam application in the onions significantly reduced the severity of downy mildew. Similar research findings were obtained in the sugar beet stand where steaming was found to significantly reduce the severity of foliar diseases in sugar beet stand (Brazienė, Vasinauskienė, 2016).

Water steam treatment was also found to impact on the severity of fungal diseases on onion bulbs (Table 4). In the hand-weeded plots, the white rot of onion affected 45.6–57.5% of the total bulbs assessed, whereas where weed control was conducted by applying steam all over the plots, white rot-affected bulbs accounted for 24.2–32.5% (depending on the trial year). In the treatments where steaming was applied only on the inter-rows, a reduction in the number of white rot-affected bulbs was identified only in 2013. Steaming was also found to affect the spread of onion neck rot. In the plots where steaming had not been applied, onion neck rot-affected bulbs accounted for 7.2–15.3% (depending on the trial year). Steaming applied all over the plots reduced the neck rot incidence on onions by 68.0–86.1%, the reduction in the neck rot incidence in the inter-row steamed plots amounted to 33.3–83.7%.

Table 4. Severity of fungal diseases on onion bulbs, %

Treatment	White rot		Neck rot	
	2013	2014	2013	2014
Manual weed control	57.5 a	45.6 a	15.3 a	7.2 a
Water steam on entire plots	32.5 b	24.2 b	4.9 a	1.0 b
Water steam on inter-rows	42.5 ab	46.3 a	2.5 a	4.8 a

Note. The differences between the averages of treatments marked by not the same letter (a, b) are significant ($P < 0.05$).

The yield of onion bulbs in our trials ranged from 4.06 to 5.41 kg m^{-2} (Table 5). A statistically significantly higher bulb yield was obtained in the treatment, where steaming had been performed all over plots compared with the hand-weeded plots. This resulted from the fact that soil had not been disturbed and onion roots had not been damaged. Moreover, the documented research findings suggest that steaming applied in the onion stand and the resulting thermal stress activate plant growth and, in turn, increase the yield (Sirvydas, Kerpauskas, 2012).

Table 5. The yield of onion bulbs, kg m^{-2}

Treatment	2012	2013	2014	Average
Manual weed control	4.30	4.49	4.13	4.42
Water steam on entire plots	5.41	5.21	4.40	5.01
Water steam on inter-rows	4.20	5.02	4.06	4.43
LSD_{05}	0.470	0.415	0.572	0.565

In the plots where steaming had been applied only on the inter-rows, the yield increase was obtained only in 2013. This is likely to be associated with the more abundant mass of weeds in these plots. Statistical analysis showed negative, weak and statistically not significant correlation between these indicators.

Conclusions

1. Water steam treatment applied in the onion stand was shown to provide effective control of weeds. The data of the assessments carried out 30 days after the last steam treatment suggest that the best weed control was achieved when steam treatment had been applied twice on the entire trial plots. This method proved to be also most effective in reducing air-dry mass of weeds.

2. Steaming treatment against weeds was found to reduce the occurrence of foliar diseases in the onion stand. The severity of downy mildew in the steam-treated plots decreased by 52.5–73.9% compared with the control treatment.

3. Steaming all over the plots resulted in 43.5–46.9% reduction in onion white rot severity.

4. Steam treatment on the entire plots decreased the incidence of onion neck rot by 68.0–86.1% and steaming of inter-rows gave 33.3–83.7% reduction in the disease incidence.

5. Steaming all over the trial plots enhanced the onion bulb yield by 6.5–16.8%.

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Vandens garų poveikis piktžolėms ir grybinėms ligoms svogūnų pasėlyje

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[2]Lietuvos agrarinių ir miškų mokslų centro Rumokų bandymų stotis

Santrauka

2012 m. Kauno rajono, 2013 m. Vilkaviškio rajono ir 2014 m. Rietavo savivaldybės ūkininkų laukuose buvo atlikti tikslieji lauko bandymai, siekiant nustatyti vandens garų kaip terminės kontrolės įtaką piktžolėms ir grybinėms ligoms valgomojo svogūno (*Allium cepa* L.) pasėlyje. Tyrimas buvo atliktas pagal schemą: 1) piktžolės ravėtos rankomis tris kartus; pirmą kartą ravėta piktžolėms masiškai sudygus, 9–11 d. po sodinimo; pakartotiniai antras ir trečias ravėjimai buvo atlikti piktžolėms sudygus, 2–3 lapelių augimo tarpsniu; 2) piktžolės naikintos drėgnuoju vandens garu du kartus per vegetacijos periodą, drėgno vandens garo aplinkos išlaikymo trukmė – 2 sekundės; piktžolių terminis naikinimas buvo vykdytas ištisai visame laukelyje, svogūnų neapsaugant nuo drėgno vandens garo poveikio; 3) piktžolės naikintos drėgnu vandens garu du kartus per vegetacijos periodą, drėgno vandens garo aplinkos išlaikymo trukmė – 2 sekundės; piktžolių terminis naikinimas vykdytas tik tarpueiliuose, joms esant daigo tarpsnio, o svogūnų ropelėms drėgno vandens garo poveikis buvo dalinis.
Tyrimo duomenimis, svogūnų pasėlyje piktžoles efektyviausiai naikino vandens garai, panaudoti du kartus ištisinio plikymo būdu. Vandens garai mažino svogūnų sergamumą grybinėmis ligomis. Netikrosios miltligės intensyvumas laukeliuose, kuriuose buvo panaudoti vandens garai, sumažėjo 52,5–73,9 %, lyginant su kontroliniais laukeliais. Vandens garus panaudojus ištisiniu būdu, sklerotinio puvinio pažeidimų sumažėjo 43,5–46,9 %. Vandens garai, panaudoti pasėlyje ištisiniu būdu, svogūnų sergamumą kekeriniu puviniu sumažino 68,0–86,1 %, panaudoti tarpueiliuose – 33,3–83,7 %. Tyrimo duomenimis, svogūnų ropelių derlius svyravo nuo 4,06 iki 5,41 kg m^{-2}. Laukeliuose, kurie buvo ištisai purkšti vandens garais, gautas esmingai didesnis svogūnų derlius nei ravėtuose.

Reikšminiai žodžiai: *Allium cepa*, miltligė, piktžolės, pilkasis puvinys, svogūnų derlius, vandens garai.