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Influence of thermal effect duration on onion yield

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Abstract. Organic Agriculture development is directly linked to ecologically pure weed removal. One of the ecological weed control processes is thermal weed control using wet water vapour. The analysis of different thermal weed control technologies is presented in the article while using wet water vapour for weed removal in the onion crop. The influence of thermal exposure duration on fertility of the onion crop is presented. It was established, while approximating dependence of onion crop yield on the thermal exposure to wet water vapour duration that the maximal fertility increase was caused by the thermal exposure time of 2.2 s. Two factors influence yield increase, which reached in our experiment 137 to 146%, using weed control technology: the onion root system was left intact during the vegetative season and some thermal stress, caused by partial injury of onion neck tissues.

Key words: Organic Agriculture, thermal effect, onion, plant temperature, high temperature medium.

INTRODUCTION

In Lithuania, in most cases, onions are grown from seedlings. Roots of onions are thread-like and weak. Roots are 1.5 mm thick, slightly branchy, tangled mainly in the 15–20 cm thick arable soil layer (Brewster, 1994). During their development, onions require warmth, moisture and nutrition. Onion yield greatly depends on moisture particularly in the period of intense growth. This influences good rooting of onion seedlings and good yield (Kmitas et al., 2005).

Mechanical weed removal is repeated 3 to 4 times during vegetation, each time sprouting weeds being exterminated, while seeds of other weeds from deeper soil layers are lifted up to the surface with better conditions to sprout.

Ecological thermal weed control uses technologies of flaming by gas (Tei et al., 2003), of hot water (Hanson & Ascard, 2002; Kurfess, 2000) and of wet water vapour (Virbickaite et al., 2006). Thermal weed control technologies have good prospects and are used for weed removal in crops of onions (Sirvydas et al., 2004), barley (Lazauskas & Sirvydas, 2002), maize (Kerpauskas et al., 2006) and other crops.

The aim of this investigation is to establish duration of the thermal exposure by wet water vapour in the thermal weed control process and to reveal factors influencing the maximal onion yield.

METHODS OF INVESTIGATIONS

Experimental field tests of onions being grown from seedlings in crop were carried out in the Testing station (54°53′N, 23°50′E) of the Lithuanian Agriculture University in 2004–2005. The test field chosen for experiments is 66 m long and 3.5 m wide. The field is divided into 6 variant parts. There were 8 reiterations for each variant. The area of elementary registration plot was 1.37 m², the number of such plots was 48. Seedlings were planted distributing into rows with distances between rows 25 cm, while distances between seedlings in a row were 7 cm. One row contained 50 onion seedlings of "Centurion F1" brand. Elementary plots were arranged in the randomised way.

Field tests included simultaneous weed extermination in all variants with different weed control technologies used for the same purpose.

For field experiments, we used already the fourth version of our experimental tractor device as a mobile weed control machine using wet water vapour medium (Kerpauskas et al., 2006). This machine was built in 2004 on the grounds of investigation of the weed thermal extermination process and experience gathered.

Weed removal was repeated three times within the onion vegetative season. When leaves had lodged, onions were harvested completely 100% and weighed several times with accuracy of ± 0.1 g.

At present statistical and agronomical analysis is carried out using codes STAT and ANOVA.

DISCUSSION OF RESULTS

Two technologies of conventional mechanical weed extermination were used in investigations. The first technology (control variant) included soil loosening and extracting out roots, the second technology included extracting weeds out of soil without changing soil structure. Being ecological these technologies require much manual labour.

Data from field experiments are presented in Table 1: Influence by different weed extermination technologies on onion harvest.

While weeds are exterminated by wet water vapour, onions received thermal impact all over the crop area. Roots of onions were not injured (as in the second technology process) and metabolic processes in soil were undisturbed.

Thermal weed control using wet water vapour technology enables the predetermined dose of thermal energy to be transferred to the onion neck. Tissues of the onion neck for different thermal exposure by wet water vapour having temperature of 100°C durations (1, 2, 3, 4 s.) attain different temperatures. Irreversible processes take place in the plant when its tissues reach the temperature of 58°C (Stašauskaitė, 1999). Onion leaves as well as weeds injured thermally in this way are destroyed. After one second of the thermal exposure the first onion leaf reaches for a moment the temperature of 82°C.

Investigation results show that, in field experiments, after one second exposure, the first onion leaf not always killed. Observations in field conditions indicate that with 2 s thermal vapour impact the first onion leaf in the neck part is completely overheated.

Table 1. Influence by different weed extermination technologies on onion harvest.

No.	Variants	Yield, kg m^{-2}	Difference when compared with reference variant	
			kg m^{-2}	%
	Year 2004			
1.	Soil was loosened and weeds gathered	3.52	0	100.00
2.	Weeds were extracted and soil not loosened	3.93	0.40	111.43
3.	Exposure by wet water vapour, duration 1 s	4.41	0.89	125.20
4.	Exposure by wet water vapour, duration 2 s	5.15	1.63	146.20
5.	Exposure by wet water vapour, duration 3 s	4.78	1.25	135.56
6.	Exposure by wet water vapour, duration 4 s	3.56	0.03	100.92
	R_{05}		0.102	
	Year 2005			
1.	Soil was loosened and weeds gathered	3.31	0	100.00
2.	Weeds were extracted and soil not loosened	3.60	0.30	108.92
3.	Exposure by wet water vapour, duration 1 s	3.78	0.48	114.36
4.	Exposure by wet water vapour, duration 2 s	4.55	1.24	137.57
5.	Exposure by wet water vapour, duration 3 s	4.10	0.60	124.00
6.	Exposure by wet water vapour, duration 4 s	3.40	0.09	102.80
	R_{05}		0.39	

The second leaf after 2 s of exposure to wet water vapour is not affected as it is known from field experiments by lethal process, however, the partial injury and the thermal stress is unquestionable.

Consideration of the onion yield increase (Table 1) suggests that influence by wet water vapour on onions during the thermal weed control process is substantial and completely reliable. The aim of field experiments in 2004 and 2005 was to determine the optimal duration of thermal exposure to obtain the maximal yield of onions. Yield data are presented in diagram form in Fig. 1.

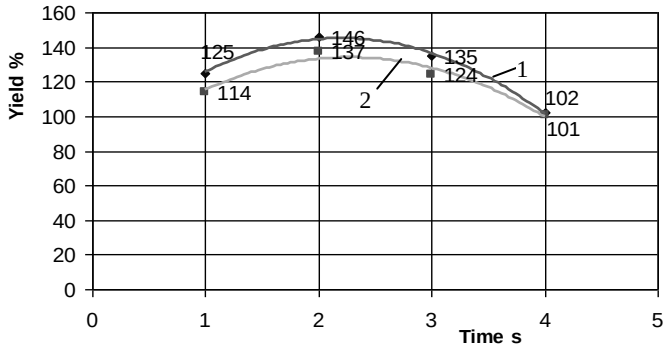

Fig. 1. Onion yield as a function of thermal exposure duration 1 – data of experiments carried out in 2004 and 2 – 2005.

The analysis of field experiments carried out in 2004 and 2005, while seeking to establish how yield depends on thermal exposure duration, led to the conclusion that fully consistent parabolic dependence exists with great enough determination factor R^2, which can be expressed by the equations:

$$2004 \text{ m.} \quad y = -13.75x^2 + 60.45x + 78.75; R^2 = 0{,}99 \quad (1)$$

$$2005 \text{ m.} \quad y = -11.25x^2 + 51.35x + 75.25; R^2 = 0{,}945 \quad (2)$$

These yield dependences on thermal exposure duration, expressed by equations (1), (2), allow approximation and obtaining the reliable conclusion that the maximal onion yield in 2004 could be caused by thermal effect lasting 2.2 s, while, in 2005, it was caused by exposure to vapour lasting 2.15 s. This supports our statement that to obtain the maximal yield possible of onions, while carrying out weed control procedures with wet water vapour, the thermal exposure of 2.2 s should be used.

Only two factors can influence onion yield grown with the application of wet water vapour process for thermal weed control: non-disturbing root treatment in the vegetative season (usually unavoidable in mechanical weed removal technology) and the thermal stress, which cause partial thermal injury of the plant. The summary (complex) influence of both factors on yield was discussed earlier. On the basis of investigation data of 2004 it is valid to say that, essential, completely reliable onion yield increase of 0.40 kg m^{-2} using mechanical weed extraction without injuring roots was obtained. Investigation data of 2005 show increase of onion yield by 0.30 kg m^{-2}, however having $R_{05} = 0.39$ we cannot confirm this onion yield to be essential and reliable. However, it can be said with assurance, that mechanical onion root injury during weed control processes negatively influences yield.

CONCLUSIONS

Thermal weed control technology using wet water vapour in the onion crop is an ecological one and provides essential and reliable yield increase. Yield increase of onion crop is influenced by the two factors: non-disturbance of onion root system in the vegetative season and thermal stress dosed to cause the partial injury of the onion neck. The maximal onion yield could be obtained by exposure of thermal effect lasting 2.15–2.20 s. The thermal stress of the cultural plant created by thermal weed control is one of new scientific and economic problems for ecological agricultural development.

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