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THE EFFECT OF THE TERM OF MULCHING AND HERBICIDES SPRAYING ON 'FOXTROT' TULIP FLOWERING AND BULBS YIELD

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ABSTRACT

The experiment studied the effect of various mulching terms of 'Foxtrot' tulips with wheat straw in combination with spraying of plantations with herbicides using various doses and different amounts of working liquid. The mulch was laid out just after planting and after the soil had frozen. The experiment included combinations, in which the mulch was left until the end of the growing season or removed in spring. Spraying with single (linuron 675 g·ha^{-1} + lenacyl 1000 g·ha^{-1}) or double herbicide dose (linuron 1350 g·ha^{-1} + lenacyl 2000 g·ha^{-1}) was made before covering the soil with mulch and also on mulch – two weeks after planting the bulbs, or in the spring after thawing the soil. Volumes of 300 dm^3 and 600 dm^3 of working liquid were used for spraying. Tulips covered with mulch bloomed 2–3 days later and formed longer shoots as compared to non-mulched ones. The highest yield of marketable bulbs and the first-selection ones was obtained from tulips mulched immediately after planting and sprayed 2 weeks later with herbicides used in a single dose of 600 dm^3 of a working liquid. Mulching of tulips after soil freezing and removal of mulch in spring adversely affects the number and weight of commercial bulbs. The lowest yield was obtained in combinations, in which the mulch was not used. The use of additional nitrogen fertilization before laying out the mulch did not affect the yield of tulips. Herbicides can be used both before mulching and after covering the plantation with mulch. It is not necessary to increase the dose of the agent and the amount of water.

Key words: bulbous plant, organic mulch, cultivation tulips

INTRODUCTION

Tulips are currently the most important group of bulbous plants used for cultivation for cut flower and planting on green areas. Their cultivation in the ground is aimed at obtaining a high quality yield of progeny bulbs. Many natural and agrotechnical factors influence the growth, development and yielding of these plants, but temperature and soil moisture play a crucial role. Tulips belong to geophytes, and their development cycle requires the passage of "warm–cold–warm" sequence [De Hertogh and Le Nard 1993, Van Tuyl and van Creij 2006, Khodorova and Boitel-Conti 2013]. During the summer dormancy, flower induction and differentiation in the tulip bulb is observed. This process occurs best at 17–25°C. In autumn, the planted bulbs require a cool period that induces a number of biochemical processes, activates auxins and gibberellin synthesis. These processes take place at a temperature of 4 to 9°C [Khodorova and Boitel-Conti 2013,

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Leeggangers et al. 2017]. Therefore, tulips in the Central Europe region are planted in autumn, when the soil temperature drops to 10°C. Good rooting of bulbs is necessary for the survival of winter months and for rapid spring growth. As the research shows, the process of respiration and water redistribution, as well as transformation of starch into simple sugars, takes place all the time in autumn. Geophytes have adapted to development at low air and soil temperatures, so that water uptake can occur even at a temperature of 1–2°C [Goryshina 1972]. The course of atmospheric conditions in the growing season cannot be predicted. Rapid fluctuations in soil temperature can be reduced by planting tulip bulbs deeper, but too deeply planted, they create fewer progeny bulbs and are exposed to decay [Marcinek et al. 2013]. In practice, the only effective way to stabilize the soil temperature is to mulch it using various organic materials. For mulching, the straw from cereal cultivation is most often used (*Triticum*, *Secale*, *Hordeum vulgare*, *Zea mays*), but also *Fagopyrum* and *Brassica napus* var. *napus* straw can be applied [Kosterna 2014a]. In the spring after the soil thawing, tulips begin their rapid growth. Photosynthesis processes in geophytes occur the fastest at 20°C [Mamushina and Zubkova 1996]; these plants are not adapted to rapid temperature increase that is now observed at the end of spring. For various spring species of geophytes (*Crocus*, *Erythronium*, *Allium*), growing at a lower temperature remarkably extended the growing season and increased the yield of tubers and bulbs [Lapointe and Lerat 2006, Badri et al. 2007, Ludmark et al. 2009, Gandin et al. 2011, Barnatchez and Lapointe 2012]. For a tulip, the optimal temperature for growth is in the range of 14–20°C [Khodorova and Boitel-Conti 2013]. Research on *Crocus vernus* proved that soil temperature is more important for geophytes than air temperature, and that plants receive the stimulus to enter the dormancy period from the soil [Badri et al. 2007]. Higher temperatures accelerate the growth and transport of carbon to cells, but also cause faster completion of their enlargement and transition to the differentiation phase. Ending of cell differentiation in corms is a signal to complete vegetation and transport of leaf assimilates, even if the leaves have not yet had the aging symptoms [Badri et al. 2007]. The soil temperature is closely related to the air temperature. The rate of soil warming depends on its type and degree of humidity. However, irrigation of plants only slightly stabilizes the soil temperature, while mulching is much more effective [Galavi et al. 2008]. Mulch fulfills a number of positive functions: it protects the soil from erosion, delays its cooling and heating, which means that the soil gets frozen in winter and warmed up in the spring slowly. It reduces daily temperature fluctuations. In addition, mulches reduce the evaporation of water from the soil and its encrustation, improve its structure, and limit the growth of weeds. In cultivation of bulbous plants, the mulching beneficially influenced on the yield of *Tulipa gesneriana* [Marcinek and Laskowska 2014], *Crocus sativus* [Galavi et al. 2008], *Allium aflatunense* [Pogroszewska et al. 2010] and *Allium ursinum* [Błażewicz-Woźniak et al. 2011, Kęsik et al. 2011].

Mulching the tulip plantations is a commonly used treatment both in the Netherlands and in Poland, however, the date when the soil needs to be covered and combining the mulching treatment with the date of herbicide application is controversial. Mulching makes the post–crop application difficult in spring. Sometimes, for this reason, it was recommended to remove it from the plantation in early spring. In order to determine the optimal date for mulching tulips in connection with the use of soil herbicides, the field studies have been carried out covering various variants and dates of these treatments.

MATERIAL AND METHODS

The field experiments were carried out in 2010–2013. Tulip bulbs (*Tulipa gesneriana* L. family *Liliaceae*) of 'Foxtrot' variety from the Double Early group, bought each year from a specialized plantation, were used in the experiments. Bulbs with a circumference of 11–12 cm were planted 12 cm deep in amount of 45 pieces per plot with an area of 1 m^2 at the beginning of October in an experimental farm of the University of Life Sciences in Lublin, Central Eastern Poland (51°23'N, 22°56'E). The experiment was established in a random block pattern in 5 replicates (one replication included 45 bulbs in one plot). Before planting the bulbs, soil analyses were performed (Tab. 1). In autumn, fertilization using Azofoska was applied in a dose of 60 g·m^{-2}, in spring, post-crop fertilization was

Table 1. Characteristic of soil conditions before experiment placing

Years	pH (in H_2O)	Humus (%)	Salinity (NaCl g·dm^{-3})	The content of microelements (mg·dm^{-3})				
				$N\text{-}NO_3$	P	K	Ca	Mg
2010	6.2	1.8	0.24	31.3	71	129	619	43
2011	6.3	1.4	0.30	45.1	137	184	713	69
2012	6.5	1.6	0.48	92.8	133	179	713	65
Optimum content *	6.5–7.2	–	1.0	50–100	50–80	150–200	1000–2000	60–120

* Michałojć and Nurzyński [2006]

applied using Azofoska in a dose of 30 g·m^{-2}, and calcium nitrate in a dose of 10 g·m^{-2}.

The aim of the experiment was to evaluate the effect of plantation mulching date on the growth and yielding of tulips. Therefore, the following terms of covering the plots with wheat straw have been planned: just after planting and after the soil has frozen. The mulch was left until the end of the growing season or in other variants, it was removed in the spring. Since herbicides for weed control are commonly used on tulip plantations, the mulching treatment was combined with spraying of herbicides in various combinations: in autumn before mulching, or after mulching and in spring (spraying on mulch). Due to the fact that the mulch forms a protective barrier on the surface of the soil and may impede the infiltration of herbicide solution – the herbicides were applied at the dose recommended by the manufacturer (single dose) as well as twice increased. For spraying, 300 dm^3 of liquid was used as standard, as well as double quantity (600 dm^3) – so that the solution had the possibility of good penetration to the soil surface. As the organic mulches decompose, as a result of which nitrogen is drawn from the soil, a combination with additional fertilization using ammonium nitrate before mulching the plots was considered.

Two herbicides applied in soil were used for testing: Afalon 450 SC (active substance linuron 450 g·dm^{-3}) and Buracyl 80 WP (active substance lenacyl 80%). Some of the plots according to the scheme were covered with a 10 cm layer of mulch made of wheat straw. The experiment included 11 combinations.

1. Control combination without herbicides and mulch.
2. Herbicides applied in a single dose (linuron 675 g·ha^{-1} + lenacyl 1000 g·ha^{-1}) using 300 dm^3 of working liquid. Spraying was carried out 10 days after planting the bulbs, the soil not mulched.
3. Herbicides applied in a single dose (linuron 675 g·ha^{-1} + lenacyl 1000 g·ha^{-1}) using 300 dm^3 of working liquid. Spraying was carried out 2 weeks after planting the bulbs, the soil mulching after freezing.
4. Herbicides applied in a single dose (linuron 675 g·ha^{-1} + lenacyl 1000 g·ha^{-1}) using 300 dm^3 of working liquid. Spraying was carried out 3 days after planting the bulbs, the soil mulching directly after spraying.
5. Soil mulching 3 days after planting the bulbs. Herbicides applied in a single dose (linuron 675 g·ha^{-1} + lenacyl 1000 g·ha^{-1}) using 600 dm^3 of working liquid. Mulch spraying 2 weeks after planting the bulbs.
6. Soil mulching 3 days after planting the bulbs. Herbicides applied in a double dose (linuron 1350 g·ha^{-1} + lenacyl 2000 g·ha^{-1}) using 600 dm^3 of working liquid. Mulch spraying 2 weeks after planting the bulbs.
7. Soil mulching 3 days after planting the bulbs. Herbicides applied in a single dose (linuron 675 g·ha^{-1} + lenacyl 1000 g·ha^{-1}) using 600 dm^3 of working liquid. Mulch spraying in spring (end of March).
8. Soil mulching 3 days after planting the bulbs. Herbicides applied in a double dose (linuron 1350 g·ha^{-1} + lenacyl 2000 g·ha^{-1}) using 600 dm^3 of working liquid. Mulch spaying in spring (end of March).
9. Herbicides applied in a single dose (linuron 675 g·ha^{-1} + lenacyl 1000 g·ha^{-1}) using 300 dm^3 of

working liquid. Spraying carried out 2 weeks after planting, the soil mulching after freezing. In spring (end of March) mulch removed.

10. Herbicides applied in a single dose (linuron 675 g·ha^{-1} + lenacyl 1000 g·ha^{-1}) using 300 dm^3 of working liquid. Spraying carried out 3 days after planting the bulbs, the soil mulching directly after herbicide spraying. In spring (end of March) mulch was removed.

11. Herbicides applied in a single dose (linuron 675 g·ha^{-1} + lenacyl 1000 g·ha^{-1}) using 300 dm^3 of working liquid. Spraying carried out 2 weeks after planting, the soil mulching after freezing (mid of December), prior to mulching, fertilization with ammonium nitrate was applied in a dose of 15 g·m^{-2}.

During the full flowering of tulips, length of the flower shoot (from the ground surface) and the length of tepals (from the petal bottom) were measured. Clones of bulbs were dug out at the end of June. The total yield and marketable yield of bulbs (for which bulbs with a circumference > 11 cm were assumed), as well as the number and weight of first class bulbs with a circumference > 12 cm, were determined. Achieved results were statistically processed using variance analysis for two-factor experiments (years of research and experimental variants). Significance of differences was assessed using multiple Tukey confidence intervals on the significance level α = 0.05.

Metrological characteristic

The system of weather conditions varied in subsequent years of research. In the season 2010/2011, tulips began vegetation in the mid of March. Average monthly temperatures for April, May and June exceeded the long-term average for these months, while the amount of rainfall from March to June was small compared to the long-term average for those months (Tab. 2). The soil temperature at a depth of 10 cm (surrounding the bulbs) in these seasons remained at the level of 7.6°C in the mid of November, which ensured good conditions for development of the tulip root system (Fig. 1). Soil froze in early December and only in the mid of January temperatures above 0°C were recorded, but without sudden changes. In the mid of May, the soil temperature was 16.6°C on average, and at the beginning of June it was 23.6°C on average (Fig. 1).

In the 2011/2012 season, the spring vegetation began in the first days of March, and the average air temperature in the following months exceeded the long-term average. Rainfall was comparable to the multiannual averages for those months. Temperature of the soil in autumn fell sharply since the beginning of the mid November, but the soil froze at the end of January and thawed in early March. After flowering of tulips, the soil temperature remained at 14.0–17.8°C, and at the beginning of June, it was 16.9°C (Fig. 1).

Table 2. Average air temperature and rainfall the measurements of Experimental Meteorological Station of University of Life Science in Lublin in cultivation of 'Foxtrot' tulips in the years 2010–2013

Month	Mean air temperature (°C)				Sums of rainfall (mm)			
	2010/ 2011	2011/ 2012	2012/ 2013	Mean for years 1951–2010	2010/ 2011	2011/ 2012	2012/ 2013	Mean for years 1995–2010
October	5.6	7.9	8.0	7.6	11.2	28.5	88.8	40.1
November	6.4	2.4	5.5	2.6	46.8	1.0	29.8	38.2
December	–4.6	1.9	–3.7	–1.6	32.4	34.5	28.8	31.4
January	–0.9	–1.9	–3.8	–3.7	24.8	33.6	57.7	23.4
February	–4.5	–7.4	–1.0	–2.8	25.2	22.1	28.5	25.8
March	2.4	4.4	–2.4	1.0	8.1	28.6	60.8	28.0
April	10.2	9.5	8.1	7.4	29.9	34.0	51.1	39.0
May	14.3	15.0	15.3	13.0	42.2	56.3	101.6	60.7
June	18.9	17.3	18.5	16.3	67.8	62.8	105.9	65.9

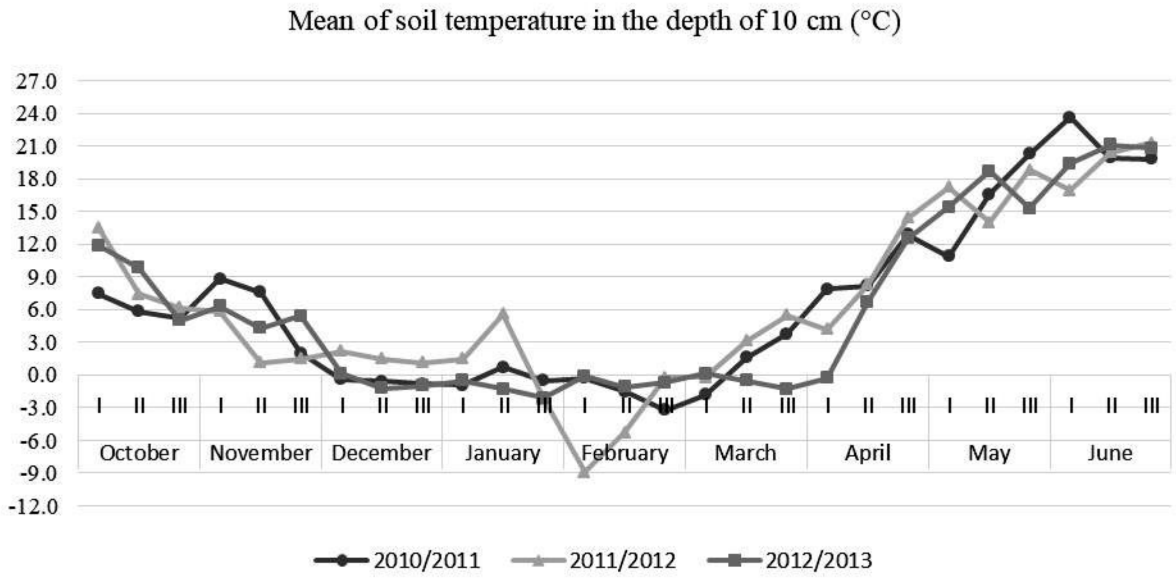

Fig. 1. Average on non-mulching soil temperature of Experimental Meteorological Station of University of Life Science in Lublin in cultivation of 'Foxtrot' tulips in the year 2011–2013

The season 2012/2013 was characterized by a large amount of rainfall in the autumn with soil temperatures of 5.4°C at the end of November. Soil froze in the mid of December and thawed until the mid-April, but at the beginning of March, there were periodic thaws with large amount of rainfall. Soil temperature from the end of April to the mid of June remained at 12.5–19.4°C (Fig. 1).

RESULTS

Tulips cultivated on plots without mulch (combination 1 and 2) and mulched in autumn, but with the mulch removed in spring (combination 9 and 10) bloomed (colored tepals) on average 2–3 days earlier than plants growing on plots covered with mulching left until the end of the growing season.

In combinations where the mulch was laid out immediately after planting the bulbs (variants 5–7), regardless of the date of spraying, dose of herbicides, and the spray liquid, longer flower shoots were obtained in reference to non-mulched combinations (1 and 2), and variants mulched after the soil freezing (combinations 3, 9 and 11) (Tab. 3). The longest tepals were produced by tulips, which were covered with mulch just after planting the bulbs, and spraying the herbicides in a single dose with the use of 600 dm^3 of working liquid was done in spring (combination 7). The shortest tepals were found on tulips in a control combination not mulched, to which no herbicides were used (combination 1), mulched after freezing the soil and sprayed with herbicides in a single dose using 300 dm^3 of working liquid two weeks after planting the bulbs, regardless of whether the straw was left (combination 3) or removed in spring (combination 9) and regardless of additional fertilization (combination 11). The length of the flower shoot and tepals varied in subsequent growing seasons. The longest shoots were formed by tulips in 2012, and the shortest in 2011 (Tab. 3).

The largest number of progeny bulbs was obtained from tulips mulched immediately after planting the bulbs and spraying with herbicides 2 weeks later in a single dose using 600 dm^3 of working liquid (combination 5) (Tab. 4). The least progeny bulbs were produced by tulips in a control combination, in which mulching and herbicides were not used (combination 1). In the other variants of experiment, the number of

Table 3. The effect of the weed control method on the flower shoot and tepal length of 'Foxtrot' tulips

Combination	Herbicides	Mulching	Flower shoots	
			shoot length (cm)	tepals length (cm)
1	Control – without herbicides	I	35.9 cd*	5.4 b
2	A + C + F	I	35.9 cd	5.5 ab
3	A + C + G	J	36.1 bcd	5.4 b
4	A + C + E	K	36.5 abc	5.5 ab
5	A + D + G	K	37.5 a	5.6 ab
6	B + D + G	K	37.3 a	5.6 ab
7	A + D + H	K	37.4 a	5.7 a
8	B + D + H	K	37.1 ab	5.5 ab
9	A + C + G	J + L	35.7 d	5.4 b
10	A + C + E	K + L	36.8 abc	5.6 ab
11	A + C + G	J + M	36.0 c	5.4 b
Mean for the year		2011	3.8 C	5.0 C
		2012	38.6 A	6.0 A
		2013	37.3 B	5.6 B

* Means followed by the same letter do not differ significantly
A – herbicides used in a single application: linuron 675g·ha $^{-1}$ + lenacyl 1000 g·ha $^{-1}$
B – herbicides used in a double application: linuron 1350g·ha $^{-1}$ + lenacyl 2000 g·ha $^{-1}$
C – dose of working fluid 300 $dm^3 \cdot ha^{-1}$
D – dose of working fluid 600 $dm^3 \cdot ha^{-1}$
E – spraying 3 days after planting, before mulching
F – spraying 10 days after planting
G – application 2 weeks after planting
H – applications in spring
I – no mulching
J – mulching after soil frezing
K – mulching after planting
L – mulch removed in spring
M – additional fertilization with 15 gm^{-2} ammonium nitrate before mulching

progeny bulbs was statistically comparable. The largest weight of the total yield bulbs was obtained by laying out the mulch immediately after planting the bulbs, and spraying with single dose of herbicides, using 600 dm^3 of working liquid was done 2 weeks after planting the bulbs (combination 5). Significantly smaller mass of bulbs was produced by non-mulched tulips (combination 1 and 2), and mulching after soil freezing (combination 3), as well as those, from which the mulch was removed in spring (combination 9 and 10) regardless of whether they were covered immediately after planting or after freezing in autumn. In these combinations, herbicides were applied in autumn in a single dose using 300 dm^3 of working liquid, and the spraying was carried out after 3 or 14 days from planting the bulbs (Tab. 4).

The largest number of bulbs included in the marketable yield have been formed by tulips in straw-mulched combinations immediately after planting the bulbs and left till the end of the growing season (combinations 4, 5, 6, 7) or removed in spring (combination 10), regardless of the date of herbicide application and their dose, as well as amount of working liquid used. The lowest number of marketable bulbs was obtained in a control combination, in which mulching and herbicides were not used, and mulched after freezing the soil, from which the mulch was removed in spring, and herbicides were applied 2 weeks after planting the

Table 4. Total and marketable yield (psc.·m^{-2}) and (g·m^{-2}) of 'Foxtrot' tulips

Combination	Herbicides	Mulching	Total yield		Marketable yield	
			(psc.·m^{-2})	(g·m^{-2})	(psc.·m^{-2})	(g·m^{-2})
1	Control – without herbicides	I	167.9d	1884.9f	38.3b	1232.3f
2	A + C + F	I	183.3a–d	2007.8def	40.9 ab	1308.7def
3	A + C + G	J	174.6a–d	2078.3cde	41.2ab	1385.8c–f
4	A + C + E	K	176.3a–d	2178.1a–d	42.9a	1478.7abc
5	A + D + G	K	188.2a	2319.7a	43.8a	1564.6a
6	B + D + G	K	182.3a–d	2310.5ab	42.6a	1560.4ab
7	A + D + H	K	186.5ab	2256.4abc	42.3a	1515.7abc
8	B + D + H	K	171.1bcd	2137.6a–d	42.0ab	1457.9a–d
9	A + C + G	J + L	169.0cd	1940.7ef	37.8b	1280.2ef
10	A + C + E	K + L	175.7a–d	2085.3cde	43.8a	1406.5b–e
11	A + C + G	J + M	183.6abc	2171.1ab	41.9ab	1443.7a–d
Mean for the year		2011	217.2A	2571.7A	48.8A	1851.9 A
		2012	175.3B	2114.0B	44.2B	1370.6B
		2013	141.7C	1688.1C	31.8C	1041.5C

Explanations, see Table 3

Table 5. The effect of the weeds control method on the yield of the Ist sort bulbs of 'Foxtrot' tulip

Combination	Herbicides	Mulching	Yield of bulbs of the circumference >12cm		Mean weight of bulbs >12cm in circumference (g)
			(psc.·m^{-2})	(g·m^{-2})	
1	Control – without herbicides	I	30.4bc	1047.4cd	34.3e
2	A + C + F	I	29.8c	1032.7d	34.7de
3	A + C + G	J	31.3abc	1136.4bcd	35.8cde
4	A + C + E	K	32.3abc	1221.6ab	37.5abc
5	A + D + G	K	34.5a	1331.4a	38.2ab
6	B + D + G	K	32.9abc	1302.6a	39.1a
7	A + D + H	K	34.1a	1317.2a	38.2ab
8	B + D + H	K	31.4abc	1184.3abc	36.8a–d
9	A + C + G	J + L	29.4c	1053.0cd	35.6cde
10	A + C + E	K + L	33.5abc	1191.0abc	34.5de
11	A + C + G	J + M	33.9ab	1264.3ab	36.3b–e
Mean for the years		2011	44.2A	1763.4A	39.9A
		2012	34.5B	1167.5B	33.9C
		2013	17.6C	636.9C	35.6B

Explanations, see Table 3

bulbs in a single dose using 300 dm^3 of spray liquid (combination 9). The largest weight of marketable bulbs was obtained by mulching the tulips immediately after planting the bulbs, and spraying the herbicides in a single dose was performed two weeks later with the use of 600 dm^3 of the working liquid (combination 5). The smallest weight of these bulbs was produced by non-mulched tulips (combination 1 and 2) and mulched after freezing the soil, from which the mulch was removed in spring, and herbicides were applied 2 weeks after planting the bulbs in a single dose using 300 dm^3 of spray liquid (combination 9) (Tab. 4).

The largest number of the first sort bulbs were produced by tulips mulched immediately after planting the bulbs and sprayed with herbicides in a single dose 2 weeks after planting, or in the spring using 600 dm^3 of working liquid (combination 5 and 7) (Tab. 5). The least bulbs with a circumference >12 cm were obtained from non-mulched plants (combination 1 and 2), and when the mulch was laid out after the soil freezing and removed in spring and herbicides were applied in a single dose using 300 dm^3 of working liquid 2 weeks after planting the bulbs (combination 9). The largest mass of these bulbs was produced by tulips mulched immediately after planting bulbs and sprayed with herbicides in a single or double dose with the use of 600 dm^3 of working liquid, when spraying was carried out 2 weeks after planting (combination 5 and 6) or in spring (combination 7). The yield of marketable bulbs differed in individual growing seasons. The highest yields were obtained in 2011, and more than twice lower in 2013 (Tab. 5).

The largest average mass calculated for a single bulb with circumference >12 cm was obtained by mulching tulips after planting and leaving the mulch until the end of vegetation, spraying with herbicides 2 weeks after planting bulbs applying a double dose of herbicides using 600 dm^3 working liquid (combination 6). The smallest weight of the first–selection bulbs characterized tulips that were not mulched (combination 1 and 2), as well as when the mulch was laid out after planting the bulbs and removed in spring and herbicides were applied in a single dose using 300 dm^3 of spray liquid, and spraying was done 3 days after planting of bulbs (combination 10) (Tab. 5).

DISCUSSION

The main function of mulches is to protect the soil from adverse weather conditions and limit temperature fluctuations [Abdul–Baki et al. 1996, Kumar and Dey 2011, Bajoriene et al. 2013, Kosterna 2014a, b]. Due to this, mulching improves the plant growth conditions. The obtained results indicate clearly beneficial effect of early mulching of tulips – just after planting the bulbs (regardless of the dose and date of herbicide application) – on the length of the flower shoot and length of tepals. Tulips growing on mulched plots bloomed a little bit later as compared to plants not covered with mulch. This clearly shows that the soil is warming more slowly in the spring under the mulch cover, as demonstrated by Siczek et al. [2015] and confirms previous studies conducted on tulips [Rasmussen and Henriksen 1990].

Mainly soil herbicides are used in the cultivation of tulips, which inhibits the germination of weed seeds and development of young seedlings. It is important to evenly distribute the working liquid and its penetration into the topsoil. Herbicide spraying is usually done immediately after planting the bulbs before covering the plantation with straw. From the research conducted by Marcinek and Laskowska [2014] on 'Double Dazzle' tulips, it follows that it is equally effective to apply herbicides in the autumn as well as in the spring after thawing the soil. In the conducted experiment, no differences were observed in the number and weight of weeds at different doses of herbicides and different amounts of working liquid (data not published). There was also no negative effect of herbicides applied in the higher dose with the use of 300 dm^3 of the working liquid (higher solution concentration) on the growth of the flowering shoot and the yield of progeny bulbs. Previous experiments have shown that non-use of mulching as well as its removal in spring increases weed infestation in relation to combinations, in which herbicides and straw mulching were applied immediately after planting or after freezing of the soil and was left until the end of the growing season [Marcinek and Laskowska 2014].

Tulips are characterized by a very short vegetation period, which can be divided into three separate stages. In autumn months (October – November), the plants root themselves, forming the bundle of the root system. Winter is the time of dormancy and biochemical transformations in bulbs, while in spring the plants bloom and form progeny bulbs. In autumn, development of the shoot, which grows partly above the bulb, is also observed, but remains below the surface of the ground. If, at this time, the soil temperature drops too quickly below 4°C, or it is very dry, the bulbs root weakly, and the rooting process continues in the spring after thawing the soil. This does not delay the flowering of plants, but adversely affects the bulbs yield (data not published). In the experiment carried out, significantly higher yields of progeny bulbs and marketable bulbs, including the first class ones, were obtained in all combinations, in which mulch was laid out in October, 2–3 days after planting the bulbs regardless of the dose of herbicides and working liquid, as well as the date of the procedure. This proves the important role of mulching in stabilizing the soil temperature and humidity in autumn months during rooting of tulips. It also confirms the results of previous research carried out in Denmark, where it has been shown that the yield of tulip bulbs is positively affected by covering them with a mulch as early as in September (with early planting of bulbs) [Rasmussen 1975]. The only contraindication to early mulching is damage caused by feeding of voles, which among the most species of bulbous plants, eagerly eat tulip and hyacinth bulbs, as well as crocus corms [Curtis et al. 2009]. Higher yields of vegetables mulched directly after planting with different types of straw have been also obtained by Jamil et al. [2005], Kar and Kumar [2007], Olfati et al. [2008] and Kosterna [2014a, b, c]. In winter months, periods of thaw are the most dangerous for tulips grown on soils with high water capacity. Soil under the influence of snow melts and rainfall is excessively moistened and does not dry out, air shortage can cause plants to suffocate, and re-freezing leads to serious damage to the root system. Mulching can reduce the effects of rapid temperature changes during this time. In spring, cover made of mulch sometimes seems unnecessary, it hinders fertilization of tulips and does not protect against frosts, because the soil in the morning is warming up more slowly [Kosterna 2014d]. However, the research shows that the tulips yielded better in the combinations, in which the mulch was left until the end of the growing season. The scheme of the experiment included two variants, in which the mulch was removed in spring. Significantly lower yield was obtained by covering the plots with mulch after freezing the soil and removing it in March as compared with the combination, in which the tulips were covered immediately after planting and the mulch was removed after thawing the soil in spring. This clearly indicates the important role of mulching in the soil surface isolation in autumn. During the research, the weather conditions were very diverse. In the season 2010/2011, despite of much lower rainfall in March, April and May, as well as a significant warming of the soil at the end of May and the beginning of June to 20 and 23°C (non-mulched soil), tulips of the studied variety released extremely high yields of progeny bulbs. Straw mulch can suppress soil temperature in summer due to the interactive effect of high solar reflectance and low thermal conductivity [Kosterna 2014d, Awe et al. 2015]. Siczek et al. [2015] reported that straw mulch used in soybean cultivation in Haplic Luvisol generally improved the soil water status, reduced the hydraulic gradients and soil temperature in winter and summer. Tulips come from steppe regions and show average water requirements [De Hertogh and Le Nard 1993]; however, dry autumn worsens the rooting of bulbs. Spring drought limits the growth of progeny bulbs and adversely affects the yield. The research carried out shows that on soils with high water capacity, high yields can be obtained even with a small amount of rainfall, provided that they are evenly distributed. Mulching prevents from water losses that arise due to evaporation, thus the mulched soil is always more moist than non-mulched one [Tomar et al. 1992, Olasantan 1999, Siwek 2002, Sinkeviciene et al. 2009, Kosterna 2014d, Biswas et al. 2015, Siczek et al. 2015]. With a strong drought, however, the mulch may deteriorate the plant growth conditions, as it retains water that arises from dew, as well as small rainfall [Siczek et al. 2015]. The biggest problem, however, is the intense rainfall that occurs in spring and early summer as a result of global warming [Rajczak et al. 2013]. The Haplic Luvisol type soil (IUSS Working Group WRB, 2015) is prone to surface crusting under intensive rain, but otherwise very valuable agriculturally worldwide [Fullen and Catt 2014]. Mulching on soils of this type helps maintain the aggregate structure. The yield of tulip bulbs in the 2012/2013 season was drastically low. It resulted from very strong soil moisture during the entire vegetation of tulips. In October, the sum of rainfall more than doubled the average value for this month. The sum of precipitation in April, May and June significantly exceeded the average for these months. It caused excessive moisture level of the soil and deteriorated the access of air to the roots. Research on the impact of precipitation and temperature on the soil structure not covered by mulching, on which the tulips were grown (the same field, where the experiment was carried out) proved that after heavy rains in May and June, the soil had a non-aggregate structure, also the soil pores were transformed. The soil showed a very high available water capacity, but the air availability and permeability fell below the values required for the good condition of plants [Bryk et al. 2017]. In particular, the upper soil layer has been severely degraded. The yielding of tulips is adversely affected by long-lasting intense rainfall, as well as high soil and air temperatures. The role of mulch is important in both cases, because on the one hand, it protects against sealing the top layer of soil, and on the other hand, it lowers its temperature and reduces daily fluctuations even by a few degrees [Charkaborty et al. 2008, Kumar and Bhardwaj 2012, Kosterna 2014a, b]. However, soil mulching is not able to protect plants from excess rainfall and gives better results on lighter than heavy soils [Woods 1975]. In May and June, there often arises the problem of high air temperatures, which leads to a strong heating of the soil, especially in the absence of rainfall [Kosterna 2014 a, b]. Geophytes take the stimulus to enter the dormancy stage and can complete their vegetation early [Badri et al. 2007, Barnatchez and Lapointe 2012]. In tulips, such a fast ending of vegetation in June may very much reduce the yield of bulbs. The largest differences in the temperature of non-mulched and mulched soil were recorded after the use of mulch with light color and made of wheat [Sinkeviciene et al. 2009] and rye straw [Kosterna 2014a, b, d]. In summer, the soil mulched with rye straw was cooler in the morning by 1.8–2.1°C, and in the afternoon hours by 4.8–5.5°C. In summer, the mulch more effectively limits the heating of soil than just irrigation [Galavi 2008]. The effectiveness of mulching also depends on the thickness of its layer [Koster et al. 1997, Kosterna 2014c], which is particularly important for plants with lower heat requirements [Olasantan 1999, Dahiya et al. 2007, Sinkeviciene et al. 2009]. Cover made of mulch increases the number and activity of soil microorganisms [Siczek and Frąc 2012, Patkowska et al. 2016]. Cabilovski at al. [2014] reported that the content of nitrogen and microelements in the soil covered with wheat straw mulch was lower than in soil covered with black polyethylene. Therefore, on weaker soils, poor in nitrogen and phosphorus, it is recommended to apply additional fertilization before covering the plants with organic mulch [Kim et al. 1987]. In own studies, the use of additional nitrogen fertilization before mulching of plants did not affect the yield of tulip bulbs. The main material for mulching the plantation is currently straw of various cereal types [Kosterna 2014a–d]. Its advantage is low price and wide availability. However, the quality of mulching is very important. Fungi may be present in the cereal straw, e.g. *Fusarium avenaceum* (Fr.) Sacc., that can infect tulip leaves [Piwoni 2002]. Straw can also contain cereal seeds that germinate and make the secondary weed of tulip plantation [Koster and Meer 1986]. A big problem may also arise from residues of herbicides used on cereal plantations [Sadowski and Kucharski 2003], which after rinsing into the soil, may be toxic to bulbous plants.

CONCLUSIONS

1. Mulching the tulip plantations in autumn after planting the bulbs and leaving the mulch until the end of the growing season has a positive effect on the length of flowering shoots and yield of marketable bulbs, as well as yield of the first class bulbs.

2. Herbicides in the cultivation of tulips can be used before laying out the mulch or on the mulch in autumn or spring at the recommended dose: linuron 675 $g \cdot ha^{-1}$ + lenacyl 1000 $g \cdot ha^{-1}$ using standard working liquid of 300 dm^3.

3. Cultivation of tulips without cover from mulch, as well as late covering of plantations after freezing the soil and removal of mulch in spring reduces the number and weight of marketable yield of bulbs and bulbs with a circumference >12 cm.

4. There is no need for additional nitrogen fertilization before mulching the tulip plantations on soils abundant in Haplic Luvisol humus.

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