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EFFECTS OF PLASTIC AND BIODEGRADABLE MULCH FILMS IN FIELD TOMATO CULTIVATION

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ABSTRACT

The yield quantity and quality depend on genetic factors, cultivation system and environmental conditions. Growth conditions can be improved by mulching the soil with plastic and biodegradable materials. A 2-factor experiment was conducted in 2011–2013 in the Wroclaw University of Environmental and Life Sciences. The method of random blocks in 3 repetitions was applied. The aim of the study was to compare the yielding of tomato cultivars: Awizo F_1, Brixol F_1 and Polonaise F_1 on synthetic mulches: transparent, black and white polyethylene film (0.05 mm thick), on black polypropylene nonwoven of the mass of 60 $g \cdot m^{-2}$, and on biodegradable film BioAgri, 0.025 mm thick. Significant differences were observed in the quantity of marketable tomato yield in particular years of the experiment. In most favorable year 2012, the yield was by 26% and 56% larger, as compared to other years. The marketable yield of Awizo F_1 cultivar was higher, on average by 33.1% and 64.7%, than in the case of Brixol F_1 and Polonaise F_1. The plants mulched with polyethylene and biodegradable film revealed a tendency to a higher yields as compared to those cultivated on nonwoven or without any mulches.

Key words: biodegradable film, polyethylene film, polypropylene nonwoven, *Solanum lycopersicum* L.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is economically one of the most important vegetables cultivated in Poland. In 2016, its field production in our country covered the area of about 9 000 ha, and the annual production amounted to 2 603 863 t [stat.gov.pl]. Tomato fruits from field production are designed for a direct consumption, but first of all, for processing industry. Both fresh fruit and tomato preserves are of great biological value, including their antioxidant activity [Toor et al. 2005]. They are a valuable source of minerals, as well as carotenoids, lycopene, vitamins E and C, and phenolic compounds, which play a crucial role in human nutrition and prevent from some cancerous and circulatory system diseases [Adalid et al. 2004, Zawiska and Siwek 2014, Pavlović et al. 2017]. Biological value of vegetables depends mainly on the genetic factor, still it is influenced by the environment, e.g. temperature, light, humidity, soil type, content of minerals in the soil, and agrotechnical factors, such as cultivation system, fertilization, irrigation [Lester 2006, Zawiska and Siwek 2014, Pavlović et al. 2017]. Most vegetables accumulate more vitamin C at lower temperatures [Lester 2006, Mozafar 1994], whereas synthesis of carotenoids is specific for particular species and depends on their thermal requirements. Carrot accumulates the most β-carotene at a temperature of 15–20°C, and melon at 30°C. In the case of tomato, the maximal synthesis of lycopene takes place at the temperature of 25–30°C.

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One of basic agrotechnical treatment in industrial tomato production is weeding, usually using herbicides. Unfortunately, according to the literature, the use of herbicides decreases the fruit yield [Bangarwa et al. 2009, Anzalone et al. 2010]. Growth conditions for tomato can be improved, i.a. by mulching the soil with polyethylene film or polypropylene nonwoven of different coloration. Mulches made of opaque film eliminate the need for mechanical weeding and reduce the use of herbicides. While using transparent polyethylene film, herbicides have to be applied before the foil is spread. Combination of these two treatments positively affects the cultivation with no toxic herbicide residue to be accumulated in the crop [Waterer 2000]. Simms et al. [2005] cultivated cucumber and bell pepper on the transparent film mulch and achieved a fruit yield larger respectively by 63.4% and 71.4% in comparison to the plants not mulched. Mulches create soil microclimate, which is favorable for the roots of plants [Gordon et al. 2008], and according to Rohwer and Fritz [2016], they intensify the root growth in young tomato plants immediately after planting. As mulches eliminate weeds, they also limit the number of pathogens [Hutton and Handley 2007]. Mulching decreases the fruit damage and soiling [Simms et al. 2005]. Fruits are more resistant to bursting and they ripen more evenly. The application of polyethylene film or polypropylene nonwoven increases the yield of many vegetable species [Robledo Torres et al. 2010, Adamczewska-Sowińska et al. 2016].

Synthetic mulches need to be removed from the field after the cultivation period is completed, which is an additional expenditure of labor. Then, they have to be professionally reprocessed. It can be avoided in the case of biodegradable mulch films, which are neutral to the environment and decompose into CO_2 and H_2O under the influence of temperature, water, light and microorganisms. They protect the soil against weeds and increase the yield [Anzalone et al. 2010]. However, this type of foil is still 3–4 times more expensive than PE film. Moreno and Moreno [2008] recommend the use of biodegradable films in the cultivation of tomato because of their beneficial effect on the yield, and the fact that, unlike polypropylene, they do not pollute the environment. The yield and crops of tomato, as well as its consumption in Poland, are constantly rising. Weather conditions in some regions of the country favor the cultivation of this species, and produced fruits have a distinctive flavor and are useful for processing. Thus, it is worth trying to undertake tomato production in such a way so as to obtain high-quality fruit without contaminating the environment. The use of mulches makes it possible. The aim of the conducted research was to compare the influence of synthetic and biodegradable mulches applied in tomato production on the yield and nutritional value of fruits meant for processing.

MATERIAL AND METHODS

The research was conducted in 2011–2013 in the Research Station in Psary belonging to the Department of Horticulture at Wroclaw University of Environmental and Life Sciences (51°19'N, 17°03'E), on chernozems with calcic level (FAO-WRB Gleyic Calcic Chernozems) on medium clay, belonging to class III, of pH = 7.25 and salinity 103.1 $\mu S \cdot cm^{-1}$ and the content of 130 mg $K \cdot dm^{-3}$ and 200 mg $P \cdot dm^{-3}$. It was a 2-factor experiment based on the method of random blocks in 3 repetitions. Factor I involved the comparison of the yield of 3 low-growing tomato cultivars meant for processing: Awizo F_1 (PlantiCo Zielonki), Brixol F_1 (United Genetics Italia) and Polonaise F_1 (Bejo Zaden Poland). Factor II regarded the usefulness of different mulches in tomato cultivation: plastic ones – transparent, black and white polyethylene film (PE), 0.05 mm thick, and black polypropylene nonwoven (PP) of the mass of 60 $g \cdot m^{-2}$ – and biodegradable film BioAgri, 0.025 mm thick. BioAgri produced of Mater-Bi®, as a complex bioplastic raw material produced from starch with polyesters. BioAgri certified this product as biodegradable and compostable (Certified Compostable according to the European Standard EN 13432 and the US Standard ASTM D6400). Plots without mulches constituted the control. The experiment comprised 18 combinations. Before the transparent film was spread on the plots, napropamide in the amount of 450 $g \cdot l^{-1}$ was applied. The area of 1 plot was 2.88 m^2 (2.4 × 1.2 m). The tomato seedlings were produced in a greenhouse. The seeds were sown on March 30 in rows into seed boxes. The seedlings in the phase of developed cotyledons were planted out into pots of the diameter of 10 cm. In order to produce seedlings, the peat substrate was used.

The field was plowed before winter, and then cultivated in spring. The applied fertilizer was ammonium nitrate in the dose of 150 kg $N \cdot ha^{-1}$. It was mixed with the soil with rotary tiller. Three days before tomato planting, the mulches were spread on the well-leveled surface of the soil and fixed with metal pins. Holes were made by cutting crosses in mulches. Seedlings were planted on May 16–18, at spacing 60 × 40 cm (12 plants per plot). In the growth period, the plants were protected against diseases by regular fungicide spraying, in accordance with the recommendations of Vegetable Plants Protection Program. The fully ripe fruits were picked in the following periods: July 26 – August 22, 2011, August 9–27, 2012, and July 22 – September 18, 2013, every 10 days. Both the marketable yield (fruits of the diameter >3.5 cm) and early marketable yield (fruits from the first pick) were estimated. The percentage of these yields in the total yield and in the marketable yield respectively, was calculated.

On the experiment site, constant measurements of the air temperature were made by means of an electronic recorder TempLogger AZ 8828, whereas the amount of rainfall was measured with the Hellmann's rain gauge. The obtained data were compared with those for the many years' period 1971–2000, received from the Institute of Meteorology and Water Management. When the plants were in full fruiting (2nd decade of August), chemical analyses examining the biological value of the tomato fruits were carried out. From each plot, 10 fruits were harvested. In those fruits, following items were determined: content of dry mass – using the weighing method [PN-90/A-75101/03], vitamin C – using the titration method [PN-90/A-75101/11], reducing sugars – using the Lane-Eynon method [PN-90/A-75101/07], and carotenoids – using the colorimetric method. In the dry mass of the plant material, the universal method by Nowosielski [1988] was applied to colorimetrically determine the content of P and Mg in 2% acetic acid, whilst the content of K and Ca was measured by means of the flame photometry method. Results regarding the fruit yield, as well as those coming from chemical tests, were submitted to a statistical analysis with the use of the Tukey's test for significance level $\alpha = 0.05$.

RESULTS AND DISCUSSION

During the experiment, the most advantageous weather conditions for the development of tomato were observed in 2011 (Tab. 1). The average temperatures in particular decades of July and August, which is the period of intensive blooming and fruit formation, were between 17.3°C and 22.4°C. The rainfall was evenly distributed, and its amount was only slightly different from the monthly total means for the many years' period. The statistical analysis of the research results revealed significant differences in the tomato fruit yield quantity in the cultivation years 2011–2013. The year 2012 featured the greatest marketable yield; in 2011 and 2013, it was smaller by 20.6% and 35.8%, respectively (Tab. 2). What can be regarded as a disadvantageous phenomenon, probably resulting in a smaller tomato fruit yield in 2011, was heavy rain in July and a rain deficit in August, and in 2013 – no rain after the plants had been planted and scarce rain in July and August. The weather conditions at the beginning of the growth period of tomato in 2011 and 2012 caused faster fruiting and, consequently, high early yield. In 2013, the early yield was significantly lower by 48.7%, on average.

It was noticed that the marketable yield of Awizo F_1 cultivar was higher, on average by 33.1% and 64.7%, than in the case of cultivars Brixol F_1 and Polonaise F_1. It also had the greatest share in the total yield (Tab. 2). Statistically significant differences between the cultivars were reported in 2011 and 2012, whereas in 2013, the marketable yield of all cultivars maintained on the same level. In the conducted research, the tomato fruit yield was similar or greater in comparison to other industrial cultivars examined in the climatic conditions of Poland [Kosterna 2014, Jędrszczyk and Ambroszczyk 2016]. In the most favorable year 2012, the mean marketable fruit yield of Awizo F_1 amounted to 95.64 $t \cdot ha^{-1}$ and it constituted 89% of the total yield. The early marketable yield remained on the average level between

Table 1. Mean air temperature and sum of rainfall during the growing period of tomato in 2011–2013

Month	Temperature (°C)					Rainfall (mm)				
	decade			mean monthly temperature	deviation from mean monthly temperature for many years	decade			sums of rainfall	deviation from monthly sums of rainfall for many years
	I	II	III			I	II	III		
					2011					
May	10.5	16.0	17.9	14.9	1.4	6.7	13.9	20.8	41.4	–15.6
June	20.4	18.7	18.3	19.1	2.8	3.9	4.5	13.5	21.9	–57.1
July	18.2	20.5	16.3	18.2	0.1	65.5	40.0	47.7	153.2	62.2
August	19.3	19.4	19.5	19.4	1.6	1.6	11.6	9.5	22.7	–41.3
September	17.3	16.1	14.5	15.9	2.3	20.9	0.9	–	21.8	–29.2
					2012					
May	16.4	13.3	17.8	15.9	1.7	10.5	2.5	7.5	20.5	–32.2
June	14.1	18.6	18.8	17.2	0.3	26.9	40.5	9.7	77.1	0.5
July	22.4	17.3	20.6	20.1	1.2	31.8	19.0	20.0	70.8	–8.7
August	20.7	18.9	19.6	19.7	1.7	13.0	21.5	13.9	48.4	–17.3
September	16.8	14.3	13.5	14.8	1.2	13.2	31.8	–	45.0	–1.0
					2013					
May	14.9	15.4	12.7	14.3	0.2	57.5	–	–	57.5	–0.4
June	14.9	20.4	16.0	17.1	0.3	26.5	–	61.0	87.5	18.7
July	20.0	18.1	21.9	20.0	1.0	–	12.0	16.3	28.3	–52.7
August	24.1	20.3	18.7	21.0	2.5	25.2	11.8	–	37.0	–29.6
September	17.4	13.1	10.7	13.8	–0.2	6.8	56.6	19.7	98.4	53.3

5.25 $t \cdot ha^{-1}$ (Brixol F_1) and 6.69 $t \cdot ha^{-1}$ (Awizo F_1) (Tab. 3). Only in 2013, the influence of the cultivar on the yield quantity was statistically confirmed. At that time, the Brixol F_1 cultivar gave a yield that was on average 3.4 times smaller than in the case of remaining cultivars. It was observed that during all those years, the early yield of the cultivar Polonaise F_1 had the greatest share in the total marketable yield (on average 14.4%). In the case of Brixol F_1 and Awizo F_1, the percentage was approximately 9%.

It was reported in many studies that soil mulching increased the yield of many thermophilic vegetables – pumpkin [Gordon et al. 2008], bell pepper [Brown and Channell-Butcher 2001, Simms et al. 2005], eggplant [Adamczewska-Sowińska et al. 2016]. Robledo Torres et al. [2010] proved that cultivation on photoselective film mulches of different colors, especially the green one, positively affected the morphological features of zucchini plants and fruits, and increased the seed yield of this species. Soil mulching is beneficial also in the cultivation of tomato [Rajablariani et al. 2012]. In the present research, in comparison to the plots not mulched, the mean rise in the marketable yield was 7.8%, and in the early yield 25.6%. Yield increasing effect was not statistically confirmed in any of the years of experiment. However, it must be noted that in the least favorable vegetation season (year 2013), in mulched objects, the highest early yield increasing (an average of 69%) in comparison with the control was recorded. Synthetic mulch most often used in vegetable cultivation is black PE film, with its very good properties and relatively low price. Rohwer and Fritz [2016] report that in the cultivation on black PE film, the early yield of

Table 2. Marketable yield of tomato fruits depending on cultivar and type of mulch, in 2011–2013

Type of mulch	Marketable yield ($t \cdot ha^{-1}$)				Percentage in the total yield (%)			
	Awizo	Polonaise	Brixol	mean	Awizo	Polonaise	Brixol	mean
2011								
Black PE film	67.59	54.05	61.00	60.88	64.6	51.3	61.2	59.0
White PE film	75.17	41.90	53.18	56.75	68.5	51.2	62.5	60.7
Transparent PE film	89.53	47.72	52.60	63.28	71.1	52.8	55.2	59.7
Black PP nonwoven	65.57	47.16	55.84	56.19	66.9	48.3	54.9	56.7
Biodegradable film	77.43	43.06	52.66	57.72	70.8	49.8	57.0	59.2
Without mulches	59.90	45.02	45.37	50.10	56.5	51.9	55.5	54.6
Mean	72.53	46.49	53.44	57.49	66.6	50.9	57.7	58.4
$NIR_{\alpha = 0.05}$ for:								
Cultivar (I)	18.20							
Type of mulch (II)	n.s.							
Interaction (I × II)	n.s.							
2012								
Black PE film	90.63	57.81	77.43	75.29	85.1	75.8	84.6	82.3
White PE film	102.03	63.02	68.29	77.78	91.2	74.1	84.5	84.0
Transparent PE film	85.42	55.27	59.55	66.74	89.5	68.8	74.5	78.3
Black PP nonwoven	101.16	57.70	59.55	72.80	92.0	70.2	79.3	81.7
Biodegradable film	100.52	53.41	64.18	72.70	90.9	71.9	81.1	82.7
Without mulches	94.10	54.46	59.09	69.21	85.4	72.4	70.8	77.2
Mean	95.64	56.94	64.68	72.42	89.0	72.2	79.2	80.1
$NIR_{\alpha = 0.05}$ for:								
Cultivar (I)	27.18							
Type of mulch (II)	n.s.							
Interaction (I × II)	n.s.							
2013								
Black PE film	55.24	22.07	57.58	44.97	74.1	33.5	60.5	57.2
White PE film	61.46	33.41	53.10	49.32	74.7	46.6	66.5	63.2
Transparent PE film	68.68	28.91	54.50	50.70	80.4	30.3	55.2	54.4
Black PP nonwoven	50.44	31.37	34.40	38.73	71.7	38.7	64.1	56.6
Biodegradable film	53.28	50.02	41.92	48.41	73.8	50.8	68.9	62.7
Without mulches	48.03	31.08	61.01	46.71	76.6	46.8	68.7	64.3
Mean	56.19	32.81	50.42	46.47	76.1	41.7	62.2	60.0
$NIR_{\alpha = 0.05}$ for:								
Cultivar (I)	n.s.							
Type of mulch (II)	n.s.							
Interaction (I × II)	n.s.							
mean for 2011–2013								
Black PE film	71.15	44.65	65.34	60.38	74.7	54.1	68.4	66.2
White PE film	79.55	46.11	58.19	61.28	78.6	57.9	71.0	69.2
Transparent PE film	81.21	43.97	55.55	60.24	79.4	49.6	60.8	63.3
Black PP nonwoven	72.39	45.41	49.93	55.91	78.0	52.2	65.0	65.1
Biodegradable film	77.08	48.83	52.92	59.61	79.2	56.5	68.4	68.2
Without mulches	67.34	43.52	55.15	55.34	72.4	57.2	65.1	64.9
Mean	74.79	45.41	56.18	58.79	77.1	54.5	66.4	66.2
$NIR_{\alpha = 0.05}$ for:								
Cultivar (I)	10.14							
Type of mulch (II)	10.14							
Interaction (I × II)	n.s.							

Table 3. Early marketable yield of tomato fruits depending on cultivar and type of mulch, in 2011–2013 ($t \cdot ha^{-1}$)

Type of mulch	2011				2012				2013				Mean for 2011–2013			
	Awizo F_1	Polonaise F_1	Brixol F_1	mean	Awizo F_1	Polonaise F_1	Brixol F_1	mean	Awizo F_1	Polonaise F_1	Brixol F_1	mean	Awizo F_1	Polonaise F_1	Brixol F_1	mean
Black PE film	6.71	7.23	10.01	7.99	9.66	5.90	8.04	7.87	3.51	4.39	2.13	3.34	6.63	5.84	6.73	6.40
White PE film	12.91	6.19	7.12	8.74	6.25	6.08	4.17	5.50	5.49	8.53	1.63	5.22	8.21	6.93	4.31	6.48
Transparent PE film	9.20	5.21	8.04	7.48	6.08	7.00	9.09	7.39	6.48	6.35	0.51	4.45	7.25	6.19	5.88	6.44
Black PP nonwoven	10.94	6.25	7.29	8.16	4.75	7.75	6.66	6.39	3.09	4.76	1.67	3.17	6.26	6.25	5.20	5.91
Biodegradable film	10.47	5.61	6.31	7.47	6.60	10.13	8.39	8.37	3.00	7.27	1.88	4.05	6.69	7.67	5.52	6.63
Without mulches	8.16	8.39	5.38	7.31	5.27	5.96	5.27	5.50	1.86	4.46	0.88	2.40	5.10	6.27	3.84	5.07
Mean	9.73	6.48	7.36	7.86	6.44	7.14	6.94	6.84	4.17	5.79	1.45	3.77	6.69	6.53	5.25	6.16
$NIR_{\alpha = 0.05}$ for:																
Cultivar (I)	n.s.				n.s.				0.05				2.03			
Type of mulch (II)	n.s.				n.s.				n.s.				n.s.			
Interaction (I × II)	n.s.				n.s.				n.s.				n.s.			

Table 4. Dry matter and selected organic compounds in tomato fruits depending on cultivar and type of mulch (mean for 2011–2013)

Type of mulch	Dry matter (%)				Reducing sugars (%)				Vitamin C (mg · 100 g^{-1} f.m.)				Carotenoids (mg · 100 g^{-1} d.m.)			
	Awizo F_1	Polonaise F_1	Brixol F_1	mean	Awizo F_1	Polonaise F_1	Brixol F_1	mean	Awizo F_1	Polonaise F_1	Brixol F_1	mean	Awizo F_1	Polonaise F_1	Brixol F_1	mean
Black PE film	5.12	4.77	4.97	4.95	2.95	2.83	2.46	2.75	17.88	19.32	14.53	17.24	5.87	4.30	4.87	5.02
White PE film	5.04	5.37	5.02	5.14	2.49	2.79	2.12	2.47	21.27	21.22	13.26	18.57	3.90	4.20	5.42	4.51
Transparent PE film	5.22	5.10	5.33	5.22	2.74	3.31	2.52	2.86	19.46	18.70	15.08	17.75	3.37	3.92	6.50	4.60
Black PP nonwoven	5.29	5.37	4.55	5.07	3.09	2.71	2.42	2.74	23.19	17.64	16.48	19.10	4.60	4.20	5.47	4.76
Biodegradable film	4.85	4.93	4.77	4.85	2.77	3.63	2.09	2.83	16.82	20.76	15.24	17.61	5.47	5.40	5.07	5.31
Without mulches	5.07	4.37	5.10	4.85	2.26	3.04	2.63	2.64	19.78	19.11	16.49	18.46	4.57	4.37	5.60	4.85
Mean	5.10	4.98	4.96	5.01	2.72	3.05	2.37	2.71	19.73	19.46	15.17	18.12	4.63	4.40	5.49	4.84
$NIR_{\alpha = 0.05}$ for:																
Cultivar (I)	n.s.				0.35				n.s.				n.s.			
Type of mulch (II)	n.s.				n.s.				n.s.				n.s.			
Interaction (I × II)	n.s.				n.s.				n.s.				n.s.			

Table 5. Macroelements in tomato fruits depending on cultivar and type of mulch, mean for 2011–2013 (mg · 100 g^{-1} d.m.)

Type of mulch	P				K				Mg				Ca			
	Awizo F_1	Polonaise F_1	Brixol F_1	mean	Awizo F_1	Polonaise F_1	Brixol F_1	mean	Awizo F_1	Polonaise F_1	Brixol F_1	mean	Awizo F_1	Polonaise F_1	Brixol F_1	mean
Black PE film	334.0	369.3	437.3	380.2	5167	4783	5100	5016	398.3	263.3	396.7	352.8	350.0	337.7	270.7	319.4
White PE film	298.7	410.3	387.7	365.6	4575	4567	5233	4792	373.3	236.7	230.0	280.0	320.7	366.7	300.0	329.1
Transparent PE film	371.3	327.3	421.7	373.4	5325	4283	4975	4861	420.0	195.0	368.3	327.8	391.7	316.7	321.0	343.1
Black PP nonwoven	284.3	305.7	357.7	315.9	4717	4842	4992	4850	371.7	241.7	238.3	283.9	308.3	346.0	350.0	334.8
Biodegradable film	316.3	440.7	435.7	397.6	4717	4908	5350	4992	378.3	190.0	356.7	309.3	341.7	379.3	287.7	336.2
Without mulches	160.0	404.7	311.7	358.8	5083	5125	5092	5100	431.7	245.0	345.0	340.6	287.3	379.3	329.3	332.0
Mean	327.4	376.3	391.9	365.2	4932	4751	5124	4936	395.6	228.6	322.5	315.6	333.3	354.3	309.8	332.5
$NIR_{\alpha = 0.05}$ for:																
Cultivar (I)	n.s.				n.s.				n.s.				n.s.			
Type of mulch (II)	n.s.				n.s.				n.s.				n.s.			
Interaction (I × II)	n.s.				n.s.				n.s.				n.s.			

tomato fruits was by 24% larger than that from not mulched objects. In the research by Thomas et al. [2009], the marketable yield of tomato fruits obtained on black film mulch was higher, as compared to that from the objects mulched with the materials of a different color. Rajablariani et al. [2012] quotes that in comparison to the yield from not mulched plots, the fruit yield of tomato cultivated on black or silver-black PE film increased by 50% and 65%, respectively.

On the other hand, massive usage of PE film and problems with its reprocessing pose a threat to the environment. An alternative solution could be non-polluting biodegradable materials, slowly decomposing under the influence of environmental conditions [Shogren 2000]. The rate of decay of such foils depends, among others, on the temperature, cultivated species, as well as type of polymer. According to Greer and Dole [2003], in regions with a moderate climate where solar radiation is less intensive, the process of decomposition is slower. Similarly, if the cultivated species are fast-growing and thoroughly covering the soil surface, i.e. tomato or pumpkin, the degradation of film slows down. Kijchavengkul et al. [2008] emphasize that the color of film also matters – white biodegradable film decomposes faster than the black one. Moreno et al. [2009], as well as Ngouajio et al. [2008] reported that soil under black biodegradable film was less heated than in the case of black PE film, still the yield of plants mulched with those materials was comparable. The effect was confirmed in the research by Kijchavengkul et al. [2008] and Anzalone et al. [2010]. Also in the present experiment, the marketable yield obtained in the cultivation on black biodegradable film (59.61 $t \cdot ha^{-1}$) was comparable to that achieved on PE film mulches (on average 60.63 $t \cdot ha^{-1}$). The early marketable yield from all objects mulched with film was similar. Moreover, the percentage share of the marketable yield in the total yield (68.2%) confirmed also the good quality of the fruit yield obtained from objects where biodegradable film was applied. Moreno and Moreno [2008] and Anzalone et al. [2010] also proved that in the case of tomato, the quality of fruits from both biodegradable film and PE film was equally high.

Conducted chemical analyses showed that tomato fruits contained on average 5.01% of dry mass, 2.72% of reducing sugars, 18.12 $mg \cdot 100\ g^{-1}$ f.m. of vitamin C, and 4.84 $mg \cdot 100\ g^{-1}$ d.m. of carotenoids (Tab. 4). The influence of the research factors on the above-mentioned chemical composition was not proved to be statistically significant. Only fruit of Brixol F_1 cultivar contained significantly less reducing sugars, as compared to the fruits of remaining cultivars. It was also observed that fruits of this cultivar tend to accumulate smaller amounts of vitamin C (on average by 22.6%) and calcium (approx. by 10%), but at the same time, more carotenoids (on average by 21.5%), phosphorus (by 11.4%) and potassium (by 5.8%) (Tab. 5). In the research conducted by Jędrszczyk and Ambroszczyk [2016], in the fruits of an industrial tomato cultivar, the mean percent content of dry mass amounted to 5.79%, reducing sugars in total – 2.27%, and vitamin C – 19.83 $mg \cdot 100\ g^{-1}$ f.m. George et al. [2004] report the content of vitamin C in various examined tomato cultivars between 8.4 and 30.4 $mg \cdot 100\ g^{-1}$ f.m., whereas Pavlović et al. [2017] determined much lower values: 1.86–8.05 $mg \cdot 100\ g^{-1}$ f.m. Zalewska-Korona and Jabłońska-Ryś [2012] estimated the amount of this component at the level of 7.80–15.60 $mg \cdot 100\ g^{-1}$ f.m., with the highest content in the case of Awizo F_1 cultivar. The present experiment showed that Awizo F_1 accumulated 19.73 $mg \cdot 100\ g^{-1}$ f.m. of vitamin C. Numerous studies comparing the cultivars of tomato indicate significant differences as far as the content of carotenoids in the fruits is concerned. Guil-Guerrero and Rebolloso-Fuentes [2009] report the amount of 133–517 $\mu g \cdot g^{-1}$ d.m. The present research revealed that the content of these components fluctuated between 3.37 and 6.50 $mg \cdot 100\ g^{-1}$ d.m., depending on the treatment. However, the differences were not statistically significant. The average amount of macroelements in 100 g of dry mass was assessed as: 365.2 mg P, 4936 mg K, 315.6 mg Mg and 332.5 mg Ca. Just as in the case of the study by Guil-Guerrero an Rebolloso-Fuentes [2009], no significant differences between the cultivars were noticed. On the other hand, Nour et al. [2013] proved that the content of mineral components in fruit depended on the tomato cultivar. The type of applied mulch had no significant effect on the content of any particular component in the tomato fruits. The amount of dry mass, reducing sugars and calcium was slightly larger in fruits obtained from the plots with transparent PE film, more carotenoids and phosphorus was observed when black biodegradable film was applied, and the use of PP nonwoven resulted in a greater content of vitamin C. Zawiska and Siwek [2014] report the increase in the amount of ascorbic acid, soluble sugars and dry mass in tomato fruits, when tomato was cultivated on polypropylene and biodegradable nonwoven.

CONCLUSIONS

1. Weather conditions significantly modified the marketable fruit yield and the early marketable fruit yield of tested tomato cultivars. In the years with favorable temperature and rainfall, the above-mentioned values increased on average by 39.3% and 95%, respectively.

2. The greatest marketable fruit yield, as well as its highest percentage share in the total yield was observed for Awizo F_1 cultivar. The early yield of all cultivars taken into consideration remained on the same statistical level.

3. Soil mulching did not significantly increase the marketable or the early yield of tomato fruits. However, in comparison to the yield from not mulched plots, the marketable yield achieved on the PE film and biodegradable film mulches was higher by 9.6% and 7.7%, respectively, whereas the early yield was larger by 28%, on average.

4. Neither the cultivar nor the type of applied mulch statistically differentiated the chemical composition of tomato fruits.

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